

salivary α -amylase before and after the hypoxia awareness training.

METHODS: This study was a cross-sectional study conducted in October 2022 at the Aviation Physiology Research Laboratory, Taiwan. Flight cadets from the Air Force Academy were recruited to participate in the study when they attended the hypoxia awareness training. Hypobaric chamber Contract 540 (Guardite Inc., Chicago, IL) was used to undertake the hypoxia awareness training. Before and after the training, we collected the saliva from cadets and determined the value of α -amylase with a salivary α -amylase monitor (Nipro CM-21, Japan). During the hypoxia awareness training, we also recorded the time of useful consciousness (TUC) at 25,000 feet. All data were managed and analyzed by the SPSS 24.0 software. **RESULTS:** There were 22 subjects (20 males and 2 females) with an age range from 22 to 24 years old. The mean of TUC was 3.6 ± 0.9 minutes at 25,000 feet. Results showed that the value of α -amylase significantly increased after the hypoxia awareness training (Before vs. after: 14.8 ± 8.6 kIU/L vs. 21.2 ± 14.6 kIU/L, p -value = 0.036). However, the correlation between the value of α -amylase and TUC during the hypoxia awareness training was not established in this study. **DISCUSSION:** Our findings illustrated that hypoxia exposure could increase the value of α -amylase among the flight cadets. It also means that α -amylase could be a potential factor to understand the physiological responses induced by in-flight hypoxia. However, the relationship between the value of α -amylase and TUC was not determined due to the small sample size. In addition, residual confounding effects on the α -amylase such as demographic factors and lifestyle habits were not also eliminated from this study. Next work will continue to collect more data and information to clarify the change level of α -amylase by the TUC and altitude.

Learning Objectives

1. The audience will learn about the change of the salivary α -amylase before and after the hypoxia awareness training.
2. The participant will be able to understand the physiological responses induced by in-flight hypoxia.

Wednesday, 05/24/2023
Grand Ballroom A-B-C-D-E

4:00 PM

[S-66]: PANEL: 13TH ANNUAL RAM BOWL

Sponsored by the American Society of Aerospace Medicine Specialists

Chair: Allen Parmet
Co-Chair: Rebecca Blue

PANEL OVERVIEW: The 13th Annual RAM Bowl features participants from the Air Force, Navy, Army, Mayo Clinic, UTMB and international representatives competing for the Louis H. Bauer Trophy. Aerospace Medicine Residents are required to demonstrate multiple competencies to satisfy the requirements of ACGME and ABPM and serve as specialists in the field.

[371] 13TH ANNUAL RAM BOWL

Allen Parmet¹, Rebecca Blue², Joanna Nelms³, Rahul Suresh⁴, Roy Allen Hoffman⁵, Alex Garbino⁶, Walter III Dalitsch⁷, Mary Cimrmancic⁸, Joseph McKeon⁹

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(Education - Program/Process Review)

The 13th Annual RAM Bowl features participants from the Air Force, Navy, Army, Mayo Clinic, UTMB and international representatives competing for the Louis H. Bauer Trophy. Aerospace Medicine Residents are required to demonstrate multiple competencies to satisfy the requirements of ACGME and ABPM and serve as specialists in the field. Multiple tools

are available for developing appropriate didactic knowledge in aerospace medicine, public health, epidemiology, biostatistics and health care management. Residents participate in a college bowl format that test aerospace medicine competencies including the flight environment (atmosphere, radiation, vibration, acceleration, and microgravity), clinical aerospace medicine, aircraft and space vehicle systems/operations, accident investigation, historical events, aerospace physiology, human factors, ergonomics, medical standards, Federal Aviation Administration regulations, passenger transport, restraint and escape, cockpit resource management and aeromedical transportation. Questions are divided into toss-up and bonus questions. Multiple rounds of competition will lead to the selection of an individual victor and awarding of the Louis H. Bauer Trophy to the top team, sponsored by the American Society of Aerospace Medicine Specialists.

Learning Objectives

1. Participants will understand the positive predictive value of commonly used screening tests in determining public health management decisions.
2. Participants will understand gas laws and how they affect physiology during flight.
3. Participants will understand regulatory requirements for certification of civil aviation pilots in the United States.

THURSDAY, MAY 25, 2023

Thursday, 05/25/2023
Grand Ballroom

8:15 AM

57TH HARRY G. ARMSTRONG LECTURE

Student presentations from the 2023 Greater New Orleans Science and Engineering Fair

Thursday, 05/25/2023
Grand Ballroom A-B-C

10:00 AM

[S-67]: PANEL: COMMERCIAL SPACEFLIGHT APPLICATIONS FOR SPACE MEDICINE: A MULTI-CARRIER AND MISSION AGNOSTIC STANDARDIZED APPROACH

Sponsored by the Aerospace Nursing and Allied Health Professionals Society

Chair: Emmanuel Urquieta
Co-Chair: Jimmy Wu

PANEL OVERVIEW: This panel presents the results from three commercial spaceflight missions: Inspiration4, MS-20, and AX-1. The Translational Research Institute for Space Health (TRISH) has developed a commercial spaceflight research program and a standardized series of high-priority experiments to be collected across spaceflight carries regardless of mission duration or destination. The TRISH Essential Measures encompass sensorimotor and space motion sickness, cognitive performance, physiologic monitoring, biochemical and genetic testing, and spaceflight associated neuro-ocular syndrome (SANS) surveillance. In addition, environmental data and health records are also collected. All of these datasets are coded/de-identified and stored in a database and biobank with the goal of making them accessible to future investigators and spaceflight carriers. The panel will present results from $n=9$ commercial spaceflight participants across the three missions. Each presentation will highlight the value of the data from a research and clinical perspective with a focus on its use for personalized and predictive medicine. As large standardized and diverse datasets such as the one presented here are created, the opportunity to use the data to improve mission safety, selection criteria, mission experience, and personalized medicine approaches will become a possibility.

[372] EXPAND DB: AN OPEN, STANDARDS-BASED DATA REPOSITORY FOR COMMERCIAL SPACEFLIGHT BIOMEDICAL RESEARCH DATA STORAGE, DISSEMINATION AND ANALYSIS

Sharib Khan, Chintan Patel
TrialX, New York, NY, United States

(Original Research)

INTRODUCTION: Recent spate of commercial space flights and orbital missions have created an exciting avenue to understand human health in space. Such missions are being undertaken by civilian astronauts who are also participating in biomedical research, thus providing an opportunity to collect unprecedented data on the impact of space on the average human body. The space health research conducted on the three such commercial missions since September 2021, involved capturing and storing multimodal data from a variety of data sources including hand-held ultrasounds, wearables, surveys, electronic health records, biosamples including genomics and environmental/telemetry data from the space capsule. Furthermore, the data collected from these missions is shared across researchers, missions and flight operators, going beyond the usual siloed study-by-study data models. Towards these goals, we have built the EXPAND DB (Database) with the Translational Research Institute for Space Health (TRISH) that has collected data from 9 civilian astronauts from three commercial missions. **METHODS:** The EXPAND DB has been architected using an Entity-Attribute-Values (EAV) data modeling approach to allow storage of diverse data types, for example, an Entity (Subject-345), Attribute (blood_glucose) has Value (105 mg/dL). The data repository has been designed to allow granular permission-based data access for all stakeholders using a secure token-based architecture. The repository also enables researchers to analyze the data through an analytics and visualization tool. **RESULTS:** The database currently houses 903,301 data points from 9 subjects across the three space missions: Inspiration 4 (688,537, 76.2%), MS-20 (143,824, 15.9%), Axiom-1 (70,940, 7.9%) and 3,159,155 data points from environmental telemetry. In terms of data types, the database is currently storing 446 neuro-cognitive and other surveys, 197 ultrasounds, 442,940 wearables data points and 4TB of genomic sequence data. The database has been accessed 135 times to store/retrieve data by 18 researchers or flight operators since September 2021. **DISCUSSION:** As more commercial missions conduct health research activities, the EXPAND DB can provide a foundational resource for the scientific community to store and collaborate on space health research. We are working further towards adding capabilities to add meta-data, data dictionaries and medical vocabulary based data tagging to facilitate standardization and data reuse.

Learning Objectives

1. The participant will be able to learn new results from high-priority space medicine research in commercial spaceflight participants.
2. The audience will learn about a new approach to collecting and using data from commercial spaceflight missions for space medicine applications.
3. The participant will be able to understand the new opportunities as well as the current limitations of implementing research in commercial spaceflight missions.

[373] THE MULTIMODAL EVALUATION OF SPACEFLIGHT HEALTH AND COMMERCIAL SPACEFLIGHT DATA REPOSITORY: LESSONS FROM MEDICAL RESEARCH IN COMMERCIAL SPACEFLIGHT

Eric Bershad¹, Mohammad Hirzallah¹, Jimmy Wu³, Mathias Basner⁴, Mark Shelhamer⁵, Doug Ebert⁶, Frederic Zenhausern⁷, Jaime Mateus⁸, Sharib Khan⁹, Kathy Johnson-Throop¹⁰, Emmanuel Urquieta Ordonez¹¹

¹Baylor College of Medicine, Houston, TX, United States; ³Translational Research Institute for Space Health, Houston, TX, United States; ⁴University of Pennsylvania Perelman School of Medicine, Philadelphia, PA, United States; ⁵Johns Hopkins University School of Medicine, Baltimore, MD, United States; ⁶KBR, Houston, TX, United States; ⁷University of Arizona, Phoenix, AZ, United States; ⁸SpaceX, Hawthorne, CA, United States; ⁹TrialX, New York City, NY, United States; ¹⁰Throop Data Consulting, LLC, Houston, TX, United States; ¹¹Translational Research Institute for Space Health, Houston, TX, United States

(Original Research)

INTRODUCTION: As the commercial space exploration sector grows, future crews should have a battery of self-performed, multi-modal tests to monitor their health and performance in addition to a database to store valuable biomedical data and biospecimens. **METHODS:** We established the Multimodal Evaluation of Spaceflight Health (MESH) protocol to enable understanding some of major effects of short-duration spaceflight on humans on commercial spaceflight missions. The Commercial Spaceflight Data Repository (CADRE) aimed to incorporate results into a long-term biomedical data and biospecimen repository. We present our experience with integrating and managing the human research experiments performed on during commercial crew flight. Tissue samples are organized using Open Specimen, a system that allows for monitoring of the type of biosamples, quantities, and storage location and environmental parameters. Access to the CADRE data repository can be made by any researchers with an authorized research purpose and IRB approval. A data privacy release board consisting of physicians, scientists, and administrative personnel, will review data requests and help facilitate data release. **RESULTS:** MESH and CADRE have served the medical research and data and biospecimen storage needs of 3 space missions to date: Inspiration4, Space Adventures, and Axiom-1, with n=9 and n=5 subjects respectively. Data collected is diverse and includes cognition, sensorimotor, ultrasound, vision, biospecimens, and biometric data. **DISCUSSION:** Logistical challenges included: time limitations requiring expedited Institutional Review Board (IRB) review, multisite investigators, training without direct crew access, development of data storing and sharing agreements to permit cross-disciplinary analysis, and a mixture of academic and industry sites. During development of CADRE, challenges included: broad diversity of mission and test subject data types, plans for enrollment over multiple mission, standardization of data elements, and privacy challenges. Our efforts allowed us to complete our intended aims within a compressed timeline, including collection and storage of data into CADRE, which will allow future researchers to access these valuable data for the benefit of all humankind. This research is supported by the Translational Research Institute for Space Health (TRISH), funded under NASA Cooperative Agreement NNX16A069A.

Learning Objectives

1. The audience will learn about the logistical challenges and solutions to developing the research infrastructure for commercial spaceflight missions.
2. The audience will learn about the development of the Commercial Astronaut Data Repository (CADRE), a unified platform to collect and preserve data and biospecimens from commercial spaceflight missions to enhance our understanding of the effects of spaceflight on human health and performance.

[374] COGNITIVE PERFORMANCE, SUBJECTIVE RESPONSES AND PHYSIOLOGIC CHANGES IN THE INSPIRATION 4 CREW

Mathias Basner¹, Adrian Ecker¹, Christopher Jones¹, Victoria Schneller¹, Marc Kaizi-Lutu¹, Sierra Park-Chavar¹, Yoni Gilad¹, Alexander Stahn¹, Anil Menon², Jaime Mateus³

¹University of Pennsylvania, Philadelphia, PA, United States; ²NASA JSC, Houston, TX, United States; ³SpaceX, Hawthorne, CA, United States

(Original Research)

INTRODUCTION: SpaceX's first all-commercial crew flight, the 3-day Inspiration4 (I4) mission, launched a four-person crew on 9/15/2021 in the Dragon spacecraft from Kennedy Space Center. The primary objective of this project was to assess feasibility of collecting high-quality low-burden physiologic and behavioral data from commercial crews. **METHODS:** The crew filled out a brief alertness and mood survey prior to performing all 10 tests of NASA's Cognition test battery twice before, 2-3 times during and twice after the mission on an Apple iPad mini with the Joggle Research app. They wore an Apple watch series 6 for 2-3 days pre- and post-flight and continuously in-flight. **RESULTS:** Significant changes across mission phases were observed for crew heart rate (HR; $p<0.0001$) and heart rate variability (HRV; $p=0.0046$). Furthermore, the

crew exhibited substantially lower activity in-flight relative to pre-flight ($p < 0.0001$), with reduced active energy expenditure ($p = 0.0001$). Sound pressure levels were similar in-flight relative to pre-flight and remained below the occupational 8 h exposure limit of 80 dBA. In-flight, three of the four astronauts exhibited a significant and positive association between CO_2 levels and higher heart rate variability ($r = 0.42$ to $r = 0.63$). In general, crew cognitive performance was not affected in- relative to pre-flight. However, one astronaut exhibited a performance decrement early in-flight primarily due to decreased accuracy on the Psychomotor Vigilance Test, Line Orientation Test, and Matrix Reasoning Test. The crew reported a nightly sleep duration of 6.7 ± 0.7 h with relatively poor sleep quality in-flight, and a moderate level of stress that was lower in-flight relative to pre-flight, as well as a moderately high level of workload.

DISCUSSION: Data acquisition rate was close to 100%. The observed in-flight physiologic changes were as expected and, except for one crewmember who struggled during first in-flight bout, cognitive test data were nominal across all mission phases. With few exceptions, the crew showed healthy survey responses across all mission phases. This demonstrates that commercial crews can collect valuable behavioral and physiologic data with relatively little crew burden. These data will help improve health and safety for future crews. **SUPPORT:** TRISH EXP0005 through NASA Cooperative Agreement NNX16AO69A, SpaceX

Learning Objectives

1. The audience will learn about how crew physiology measured with a smartwatch changes in a commercial crew on a 3-day flight.
2. The audience will learn about how crew cognition changes in a commercial crew on a 3-day flight.

[375] INITIAL ANALYSIS OF PRE- AND POST-FLIGHT REFRACTIVE ERROR CHANGES IN COMMERCIAL SPACEFLIGHT PARTICIPANTS

Shivang Dave¹, Carlos Hernández², Andrea Gil-Ruiz², Eric Bershad³, Emmanuel Urquieta³, Mohammad Hirzallah³, Daryl Lim¹, Eduardo Lage⁴

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(Original Research)

INTRODUCTION: The effects of microgravity exposure, and its relation to spaceflight-associated neuro-ocular syndrome (SANS) [1][2], has previously been studied on cohorts of astronauts. Astronauts are selected via a rigorous standards that may be different from the variability present in non-astronauts [3]. Commercial spaceflights provide an opportunity to investigate SANS onset on non-astronaut participants during shorter spaceflights. This study examined the pre- and post-spaceflight refractive error changes on 5 subjects across 2 separate commercial launches (12 & 17 days long, respectively) with a handheld wavefront binocular autorefractor (QuickSee, PlenOptika), that provides objective measurements.

MATERIALS AND METHODS: Five subjects (30-75 years old) participated in an IRB-approved clinical study part of the EXPAND program approved by Baylor College of Medicine. Measurements were taken three times per session across 2 sessions for both pre- and post-flight, ideally within 1 week of flight. Each session involved QuickSee measurements with and without a fogging lens (FL), to relax patient accommodation that could mask hyperopic patients [4]. Wavefront images were analyzed to provide spherical equivalent (M) autorefraction results of the right eye. Repeatability of the autorefraction results was assessed using the repeatability coefficient (RC). Four intrasession RCs were calculated comparing pre- and post-flight measurements with and without FLs, respectively, while the pre- and post-flight variation were plotted using the mean of the normalized measurements. **RESULTS:** We have not observed a significant variation in the refraction for either flight or patient between pre- and post-flight measurement sessions. The repeatability coefficient of the device pre-flight is 0.35 (Table 1). Figure 1 shows the variability of the pre- and post-flight refractive error, with (left) and without (right)

FL normalized by the mean M of the four conditions. **DISCUSSION:**

Although we did not observe hyperopic shift, further studies are needed to strengthen any potential conclusions due to the limitations of this initial study including the small number of research subjects, measurement timepoints not being within 24 hours of the flight which could alter refractive changes, and the variability of different launches, units, and flight surgeons. Future private spaceflights present an opportunity to expand this dataset to overall strengthen the conclusions.

Learning Objectives

1. The participant will be able to learn new results from high-priority space medicine research in commercial spaceflight participants.
2. The audience will learn about a new approach to collecting and using data from commercial spaceflight missions for space medicine applications.
3. The participant will be able to understand the new opportunities as well as the current limitations of implementing research in commercial spaceflight missions.

[376] OTOLITH AND POSTURE EVALUATION IN COMMERCIAL SPACEFLIGHTS

Mark Shelhamer¹, Serena Tang², Nabila Ali¹, Mallika Sarma¹, Michael Schubert¹, Anil Menon³, Jaime Mateus⁴, Jennifer Law⁵, Emmanuel Urquieta⁶

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(Original Research)

INTRODUCTION: Biomedical experiments have been performed on recent commercial orbital flights. One of these experiments is a sensorimotor study on otolith function and posture control, presented here. **METHODS:** This project has two parts. The first is an evaluation of otolith asymmetry, as manifest by vertical and torsional alignment of the eyes, assessed by a perceptual-nulling method. The second part is a posture evaluation: body sway during quiet standing with eyes closed, followed by sit-to-stand testing. This was carried out on the flights of Inspiration4 (I4), Soyuz MS-20, and Axiom-1 (Ax-1). **RESULTS:** In the I4 ocular-alignment study, we find a difference (retrospectively) between subjects who experienced space motion sickness (SMS) and those who did not. In vertical-alignment testing, when preflight and postflight testing both show consistent misalignment, but that alignment is different after flight than before flight, this is associated with SMS. We posit that this is because postflight testing reflects the in-flight adaptive state (compensation for asymmetry in other than 1g), and that 0g compensation should in general be different from the 1g compensation. Postflight posture data during quiet standing were examined with Detrended Fluctuation Analysis (DFA). This examines fluctuations (variance) of body sway around a linear trend, at different time scales. Many biological processes follow a power law, where the magnitude of the fluctuations (F) is related to the duration of the time window (Δt) over which the fluctuations are measured: $F(\Delta t) \sim (\Delta t)^{\alpha}$. Those I4 subjects with SMS show deviation from power-law scaling. Processing of data from MS-20 and Ax-1 is ongoing. The dichotomy of the flights makes direct comparisons difficult. I4 spent 3d in orbit, while Ax-1 spent 17d, and the pre/post testing schedules were also different. SMS data are not yet available for all flights. From Ax-1, 2 subjects show deviation from power-law scaling in posture data. Unfortunately, these subjects do not exhibit the clear pattern in vertical alignment (VAN) that we believe from I4 to indicate SMS. This discrepancy may be because of the longer duration of Ax-1 or the difference in postflight schedules. **CONCLUSIONS:** I4 results hold promise for using ocular alignment to predict SMS susceptibility and alterations in postural control; we hope to verify these findings in the later flights.

Learning Objectives

1. Understand otolith asymmetry and its role in adaptation to space-flight.
2. Understand the analysis of posture data through power-law scaling of body-sway magnitude.

[377] IMAGING EXPERIMENTS ON THE INSPIRATION4 MISSION: A GLIMPSE INTO THE FUTURE

Ashot Sargsyan¹, Douglas Ebert¹, Kadambari Suri¹, Jaime Mateus², Michael Loesche², Steven Uhl¹, Aaron Everson¹

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(Original Research)

INTRODUCTION / BACKGROUND: We pursued ultrasound imaging-based human research objectives during the 3-day private orbital mission Inspiration4 aboard a Crew Dragon spacecraft (SpaceX, CA, USA). Imaging targets included urinary bladder, eyes, and internal jugular veins (IJV) with inspiratory resistance. We also examined data quality in autonomously performed procedures of different levels of complexity. **METHODS:** Four volunteer subjects consented to this IRB-approved investigation. Imaging data were collected preflight and on flight days 1, 2, and 3 with a Butterfly iQ+ ultrasound system (Butterfly Network, USA) interfaced with mobile computing platform. ResQGuard ITD 7.0 impedance threshold devices (Zoll, USA) provided inspiratory resistance. Procedural instruction materials were used for autonomous imaging procedures. Imaging data analyzed in Osirix MD DICOM viewer (Pixmeo, Switzerland). Due to the small number of subjects, statistical analysis options were limited; the team anticipates pooling of the data with future compatible datasets. Procedural compliance and data quality were evaluated in addition to physiological parameters. Data quality was scored on a scale from 0 to 3, with 2.0 or higher considered successful. **RESULTS:** Combined success score averages for bladder (least demanding), IJV, and eyes (most demanding) were 2.3, 2.4, and 0.76, respectively. The IJV data set was the most complete. Preflight, ITD reduced IJV cross-sectional area (CSA) from 0.71 ± 0.26 to 0.45 ± 0.34 cm² (36%). In-flight, ITD intervention reduced CSA from 0.73 ± 0.17 to 0.52 ± 0.31 cm² (29%). These and other trends represent preliminary results from the small sample size in early space flight. **DISCUSSION:** Autonomous performance of complex imaging procedures is feasible with adequate skill management tools. Bladder and IJV exams (low and moderate complexity) were highly successful. However, the most complex exam (eyes) resulted in success scores below the acceptability threshold. Reduction of IJV capacity upon ITD intervention was the most consistent observation in this small dataset. In conclusion, we report reassuring results of a new paradigm of autonomous imaging-based human research. We also report unique physiological data from early microgravity exposure, which may be pooled with compatible data sets for robust analysis and conclusions. This research is supported by the Translational Research Institute for Space Health (TRISH), NASA Cooperative Agreement NNX16AO69A.

Learning Objectives

1. The audience will be able to understand the feasibility, value, and limitations of imaging-based human research in highly constrained autonomous space missions.
2. The audience will learn about physiological effects of resistance breathing in microgravity.
3. The audience will learn about the significance and approaches to procedural compliance and data quality assessments in imaging-based research.

Thursday, 05/25/2023
Grand Ballroom D-E

10:00 AM

[S-68]: SLIDES: TAKING SENSORIMOTOR STUDIES FOR A SPIN

Chair: Pierre Denise
Co-Chair: Jeffrey Hovis

[378] EVALUATION OF SPATIAL DISORIENTATION TRAINING: END USER SURVEYS FOR THE WILDCAT HELICOPTER SIMULATOR

Alaistair Bushby¹, Steven Gaydos²

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(Original Research)

INTRODUCTION: Spatial disorientation (SD) remains a significant operator threat and safety issue among military rotary wing (RW) aircrews, particularly during times of high workload and deceptive visual cues. With endorsement from the tri-Service Consultant Advisors in Aviation Medicine, British RW Forces employ a layered training approach that includes simulator-based immersive scenarios. The training was developed by a multi-disciplinary team and embedded within advanced training packages that were not solely focused on SD. **METHODS:** Ten separate RW SD training scenarios were developed for the AW159 Wildcat helicopter simulator. A post-sortie survey instrument was distributed to assess 1) hazard awareness, 2) training effectiveness, 3) role and mission relevance, and 4) perceived ability to respond to future SD threat. Aircrew participation and responses were voluntary and anonymous. A corresponding assessment from the simulator instructor was used for independent determination if the crew became disoriented during the training. **RESULTS:** The six-month training cycle yielded 69 completed surveys with elevated seven-point Likert-scale assessments across all four categories (6.0 median scores, respectively). Results suggest favorable aircrew perceptions of training objective success with illustrative free-form feedback comments. Of all sorties flown, the majority of aircrew (68%) became disoriented at some point during the sortie. **DISCUSSION:** Results support a high level of operator satisfaction with training objectives within a RW simulator environment. SD simulator-based training can serve as an important component of a layered, multimodal approach. Advantages include a safe, interactive, environment for immersive crew training, ability to address root causes of provenance, and compatibility with role-specific mission sets.

Learning Objectives

1. Participants will broadly recognize most common causes of operator threat and flight safety risks associated with RW SD.
2. Participants will appreciate unique capabilities presented by SD training through immersive simulation.

[379] FIELD ASSESSMENT OF SENSORIMOTOR FUNCTION FOLLOWING LONG-DURATION SPACEFLIGHT

Scott Wood¹, Sarah Moudy², Timothy Macaulay³, Michael Bishop³, Gilles Clément³

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(Original Research)

INTRODUCTION: Field assessments of functional task performance following long duration spaceflight are critical to characterize the risk associated with sensorimotor adaptation. A portable test battery involving sit-to-stand, prone-to-stand, walk and turn with obstacle, and tandem walking has been implemented during pre- and postflight testing to provide Sensorimotor Standard Measures that could be implemented in remote test locations. **METHODS:** To date, 19 astronauts (12 males, 7 females) participated in this study before and after 6–8-month expeditions to the International Space Station (198 ± 70 days, mean \pm std). Ethics approvals were obtained, and all subjects provided informed consent. Tests were conducted preflight, within a few hours after landing, and then 1 day and 6–11 days later. Time to stability was the outcome measure for both standing tasks, time to completion and turn rate for the walk and turn task, and percent complete steps for the tandem walking (eyes open and closed). Statistical analyses included mixed effects (multi-level) generalized linear models. **RESULTS:** Consistent with previous Field Tests, significant effects of spaceflight were observed during the initial testing including longer times to stabilize posture when standing, longer times to complete the short obstacle walk, and fewer correct steps during tandem

walking. The recovery timeline varied with task complexity, generally taking longer when either the basis of support was limited (e.g., tandem walk) and/or visual cues were deprived (eyes closed). **DISCUSSION:** These data suggest that additional sensorimotor-based countermeasures may be necessary to maintain functional performance during long-duration spaceflight. Maintaining core measures as new countermeasures are implemented during future missions will be instrumental in assessing their efficacy. This test battery will also serve as the basis for developing sensorimotor assessments during future space exploration.

Learning Objectives

1. Understand the purpose of obtaining a core set of field measures to characterize the risk of sensorimotor adaptation following spaceflight.
2. Understand the initial decrements observed during the early post-flight testing and the timeline of recovery.

[380] PILOT-VEHICLE CLOSED-LOOP COMPUTATIONAL MODELS

Tara Nibhanupudy¹, Moein Nazifi¹, Elena López-Contreras Gonzalez¹, Kassia Love¹, Megan Reissman², Timothy Reissman², Torin Clark³, Yoon Chan Rah¹, Faisal Karmali¹

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(Original Research)

INTRODUCTION: Spatial disorientation is a leading cause of aviation fatalities. These incidents often arise from interactions between vehicle dynamics and neural processes underlying pilot behavior. Increasing our ability to predict/prevent incipient adverse events during human-aircraft interactions could substantially mitigate risk. To address this problem, we aimed to 1) develop a closed-loop cybernetic model including state-of-the-art spatial orientation and motor-control components, and 2) validate and refine the model using human experiments.

METHODS: Closed-loop “comprehensive models” were developed for rotation control with and without changing orientation relative to gravity. These (Matlab/Simulink) incorporated validated spatial orientation, motor control, and vehicle models. Subjects (n=9) ages 21-38 sat in a motorized rotary chair (Neurokinetics) and used a joystick to control chair motion, with instructions to minimize chair velocity while experiencing a pseudo-random sum-of-sines “disturbance” (0.004-1.7 Hz). Model predictions included gain and phase values averaged across subjects as a function of disturbance frequency. Experimental data was used to enhance and tune the model. **RESULTS:** The closed-loop model predicted wide variations in task performance by frequency. In particular, the models predicted that human performance was mediocre for rotation control about an Earth-vertical axis in the dark (gravitational cues did not provide useful information about task performance). Human experimental data closely followed the frequency response predicted by the model. The most effective nullification was seen to occur in a small band of medium-range frequencies (0.01-0.1 Hz), due to combined dynamics of high-pass filter vestibular perception low-pass filter motor control. Innovations that improved model predictions were 1) addition of a decision-making element reflecting the corruption of sensory feedback by neural noise 2) tuning of parameters of pilot effort (Kp) and the central nervous system (CNS) delay. **CONCLUSIONS:** The model accurately predicts the human experimental frequency response. These novel models of human-vehicle systems increase understanding of the dynamic interaction between vehicle states and human sensorimotor systems. With this, performance decrements in vehicle control, e.g., during spatial disorientation or weightlessness, can be more accurately predicted/mitigated. Multi-axis rotational tasks remain to be characterized.

Learning Objectives

1. The audience will learn about how, within a human-vehicle system, the dynamics of spatial orientation, motor control, and the vehicle combine to contribute to active control of motion tasks.
2. The audience will gain an understanding of the applications of human-vehicle closed-loop models toward increasing safety of airplane and spacecraft operation.

[381] VESTIBULAR FUNCTION ASSESSMENT IN AIRCREW

Oded Ben-Ari

Israeli Air Force, Ramat Gan, Israel

(Original Research)

INTRODUCTION: Spatial Disorientation is a significant cause of fatal aviation accidents, hence the importance of an intact vestibular system. The Video Head Impulse Test (V-HIT) uses the Vestibulo-Ocular Reflex (VOR) to evaluate the function of the semi-circular canals. The V-HIT measures the Gain (the ratio of the eye velocity to the head velocity), which normally ranges from 0.8 to 1.2 in the general population. The objective of the current study was to define V-HIT Gain norms for healthy Israeli Air Force (IAF) aviators. **METHODS:** This was a retrospective study that included 174 V-HIT Gains of aviators (of them 165 healthy and 9 dizzy) that were examined in the IAF Aeromedical Center between March 2020 to March 2022. Only Gains of horizontal canals were included in the study. **RESULTS:** The mean age was 28.1 (range: 17-60). Gain values were 0.85-1.05 and 0.88-1.12 in the right and left ear, respectively. A significant negative correlation was found between Gain and age. A significant difference between the Gain of the healthy ear and that of the impaired ear was found in the dizzy group. **DISCUSSION:** Vestibular screening of aviators is important and feasible. The normal range of Gains for IAF aviators differs from that of the normal population. V-HIT Gains can be used to detect both impairment and aging of the vestibular system.

Learning Objectives

1. Considering implementation of a vestibular assessment as part of the yearly medical checkup.
2. Defining a of normal range for Gain values in aircrew.

[382] VIBROTACTILE FEEDBACK AS A COUNTERMEASURE FOR SPATIAL DISORIENTATION

Vivekanand Vimal, Alexander Panic, James Lackner, Paul DiZio
Brandeis University, Waltham, MA, United States

(Original Research)

INTRODUCTION: Spatial disorientation (SD) is a major contributor to fatal aircraft accidents. Vibrotactile feedback has been shown to be useful, however it is unknown whether it will be immediately beneficial or whether training will be needed to ensure pilots and astronauts can rely on vibrotactile feedback when disoriented. **METHODS:** Blindfolded participants (n=30) were secured into a Multi-Axis Rotation System device that was programmed to behave like an inverted pendulum and they used a joystick to stabilize around a balance point. In the horizontal roll plane, they did not tilt relative to the gravitational vertical and therefore did not have gravitational cues to determine their ongoing position. In our prior work, 90% of participants reported SD, and collectively, they showed minimal learning, poor performance and significant loss of control. Here, Group C (Control) balanced in the vertical roll plane on Day 1 where they could use gravitational cues and they subsequently balanced in the horizontal roll plane on Day 2. Group V did the same but had 4 vibrotactors on each arm that signified the extent and direction of tilt from the balance point on both days. Group VT had training on Day 1 using the vibrotactors to find and orient at non-zero balance points in the vertical roll plane. On Day 2 they used the vibrotactors in the horizontal roll plane. **RESULTS:** Group V performed significantly better than Group C on Day 2, but had minimal improvement across trials and still had elevated levels of losing control. 90% of Group V participants reported a conflict where their perceived orientation differed from what the vibrotactors were indicating. Group VT performed statistically better than Groups V and C, and they showed continued learning and improvements on Day 2. On the final 5 trials of Day 2 we deactivated the vibrotactors for both Group V and VT. While performance worsened it was not statistically worse than the Control group, suggesting that the vibrotactors did not create a negative dependence. **DISCUSSION:** Vibrotactile feedback is a valuable countermeasure to SD, however it may cause a conflict between perceived and cued orientation. Exposure to vibrotactors in ground-based conditions may not be enough to overcome the conflict that will arise in aerospace conditions. We show

that an effective training program has a component where participants need to rely on vibrotactile feedback to complete the task.

Learning Objectives

1. The audience will learn about how vibrotactile feedback may cause a conflict between perceived and cued sense of self orientation when spatially disoriented.
2. The audience will learn how the conflict caused by vibrotactile feedback during disorientation can be reduced by using a specialized training program.

[383] IDENTIFICATION OF INDIVIDUAL DIFFERENCES FOR INCORPORATION IN OPERATOR STATE MONITORING

Amanda Kelley, Aaron McAtee, Katie Feltman, Michelle Duffy
U.S. Army Aeromedical Research Lab, Fort Rucker, AL, United States

(Original Research)

INTRODUCTION: Ongoing work within the military continues to pursue the goal of operator state monitoring (OSM) through psychophysiological metrics. This approach would allow for a mostly non-invasive, objective assessment of the operator's cognitive state. While much of the work completed to-date has yielded promising results, a key obstacle remains: accounting for individual variability. This study used archived datasets from four studies of physiological measures and workload.

METHODS: De-identified datasets from four studies completed at the U.S. Army Aeromedical Research Laboratory were included within this study. Study 1 consisted of discrete computerized cognitive tasks, whereas Study 2 and 3 were completed within the UH-60 simulator. Study 4 used an unmanned aerial system (UAS) simulator. Participants included rated aviators; and cognitive-normal Soldiers. Physiological measures included electrocardiogram (heart rate, heart rate variability [HRV]); respiration rate; electroencephalogram (frontal alpha, theta, beta); and electrooculogram (blink rate, number of blinks, blink velocity). Individual differences included intelligence, sleepiness, anxiety, and depression symptoms. Workload was measured using the NASA task load index (NASA-TLX). **RESULTS:** Workload scores and effect sizes for the physiological measures were inconsistent across studies, discouraging aggregate analysis. Correlational analyses of individual studies did not yield consistent patterns across studies, with the exception of a moderate to strong positive relationship seen between depression and blink measures in Studies 1 and 4. Six machine learning algorithms were run predicting subjective workload and another six predicting workload conditions. Age and number of blinks were the most consistent predictors (age 4/6, number of blinks 5/6) of subjective workload whereas NASA-TLX scores and total frontal beta and alpha electroencephalogram activity consistently predicted workload condition (6/6 algorithms).

DISCUSSION: The findings from this study support continued evaluation of physiological measures to predict workload levels with emphasis on electrooculogram and electroencephalogram measures, but do not suggest a large influence of the individual factors explored, with the exception of age's influence on workload. Next steps include evaluating individual participant's data to quantify the variability of each physiological response under high and low workload manipulations.

Learning Objectives

1. Participants will learn about physiological measures and how they relate to cognitive workload and performance.
2. Participants will learn whether, and if so, to what extent, individual differences correlate with physiological measures under varied levels of workload.

Thursday, 05/25/2023

Grand Chenier

10:00 AM

[S-69]: PANEL: AEROMEDICAL ETHICS PANEL

*Sponsored by the American Society of
Aerospace Medicine Specialists*

Chair: Mark Mavity

PANEL OVERVIEW: Aerospace medicine may present an array of potential ethical dilemmas to aviation medicine physicians and other aeromedical professionals that may arise out of conflicts between the interests, rights, and responsibilities of those within our profession, individual patients/aircrew, private employers, and governmental certifying agencies. Case studies will be presented for open audience discussion that address a variety of relevant ethical and/or legal value conflicts in the current practice of aerospace medicine.

Learning Objectives

1. The audience will explore the process of ethical decision-making and its impact upon the practice of aerospace medicine.
2. The audience will learn about the current foundational resources which form the framework of current medical ethical guidance, particularly the ASAMS Ethical Guidelines as they relate specifically to the practice of aerospace medicine.
3. The audience will be encouraged to provide thought and attention to the ethical issues impacting the practice of aerospace medicine.

[384] AEROMEDICAL ETHICS

Mark Mavity

The American Society of Aerospace Medicine Specialists, McLean, VA, United States

(See Overview)

Thursday, 05/25/2023

Napoleon Ballroom C1-C2

10:00 AM

[S-70]: SLIDES: COLLISION STRESS AND VISION

Chair: Harriet Lester

Co-Chair: Kevin Gildea

[385] COMPARISON OF SCHEDULES, STRESS, SLEEP PROBLEMS, FATIGUE, MENTAL HEALTH AND WELL-BEING OF LOW COST AND NETWORK CARRIER PILOTS

Marion Venus

Venus Aviation Research, Training & Pilot Support, Universität Bern Institut für Psychologie, Zurich, Switzerland

(Original Research)

OBJECTIVE: This research investigates and compares working-conditions, duty rosters, stress, sleep problems, fatigue levels, mental health, and well-being of pilots working for network (NWCs), and low-cost carriers (LCCs). This study extends previous research by investigating working conditions, pilots' actual rosters, fatigue and mental health of two groups of pilots flying for LCC or NWC. **METHOD:** A comprehensive cross-sectional online survey was completed by N=338 pilots (185 NWC, 153 LCC pilots). All pilots reported their roster data of the last 2 months during peak flight season, psychosocial and work-related stress (e.g., high job insecurity, less total flight-experience, lower income, more time pressure, more early starts), sleep difficulties, levels of fatigue, well-being, symptoms of depression, anxiety, and common mental disorders (CMD). **RESULTS:** LCC pilots reported significantly more work-related stressors like lower income, younger age, less total flight experience, more demanding rosters (more sectors, more early starts, more duty and flight hours), significantly more sleep difficulties, and very high levels of fatigue. Moreover, LCC pilots' well-being was significantly more impaired: 24.2% of the LCC vs. 14.8% of NWC pilots reported positive depression screening results, and 7.1% of LCC and NWC pilots reported significant symptoms of anxiety. **CONCLUSIONS:** This study confirms that different airline business models and management strategies result in more stressful working conditions for LCC pilots, whose health is more impaired by high fatigue and mental health issues. Although LCC pilots did not report significantly higher duty and flight hours, the work-related stressors like more bogus self-employment, high job, and income insecurity, more time

pressure, were associated with even higher levels of fatigue, significantly more sleep problems, and more impaired mental health and well-being. In line with previous research, LCC pilots reported more safety issues and more fatigue-related incidents compared with NWC pilots.

Learning Objectives

1. The audience will learn about the differences in fatigue and mental health issues of pilots flying for network or low-cost carriers.
2. The audience will learn about general and pilot-specific stressors, and which stressors specifically apply to low-cost carrier pilots.

[386] PILOTS' STRESS, FATIGUE, DEPRESSION, ANXIETY, COMMON MENTAL DISORDERS AND WELLBEING - "SLIDING DOWN A DANGEROUS PATH"

Marion Venus

Venus Aviation Research, Training & Pilot Support, Universität Bern Institut für Psychologie, Zurich, Switzerland

(Education - Program/Process Review)

OBJECTIVE: This study investigated international pilots' rosters (duty, flight hours, early starts, night flights, standby days, ...), work-related and psychosocial stress, sleep difficulties, fatigue levels, wellbeing, symptoms of depression, anxiety, and common mental disorders (CMD), and how they are interrelated. **BACKGROUND:** Several scientific studies have confirmed that fatigue can pose a significant risk to flight safety. Other studies reported high accumulated fatigue, sleep problems, positive depression screening results for more pilots, compared with the general population - despite fatigue risk management, flight time limitations and sophisticated safety management systems. **METHOD:** A cross-sectional online survey was completed by 406 international pilots, who reported their duty rosters of the last two months. Pilots also self-assessed their stress-levels, sleep problems, fatigue, wellbeing, and mental health. **RESULTS:** Although pilots were on average rostered for only 60% of maximum legal duty and flight hours, three out of four pilots (76%) reported severe or high fatigue. Every fourth pilot reported considerable sleep difficulties (24%). 18.7% pilots reported positive depression screening results, 8.5% positive anxiety screenings, 7.2% reported significant symptoms of depression and anxiety. Highly significant to high correlations between stress, sleep problems, fatigue, symptoms of depression, anxiety, CMD and well-being were found. Pilots reported negative experiences with fatigue risk management and failures of safety management systems. **CONCLUSIONS:** Chronic stress appears to be linked to psychophysiological wear and tear, and was associated with higher levels of fatigue, more sleep disturbances and more impaired mental health. Future research should not only consider fatigue as an immediate threat to aviation safety, but also as a significant threat to pilots' safety-relevant fitness to fly.

Learning Objectives

1. Participants will learn, how widespread fatigue and sleep problems are among professional pilots.
2. Participants will learn, how many pilots may suffer from significant symptoms of depression and anxiety, and reasons why.
3. Participants will learn which cases of confidential reporting of flight safety issues led to repression, harassment, dismissal and eventually to court.

[387] MAKING SENSE OF SPECIAL SENSES: TWO FATAL ACCIDENTS, CATARACTS AND MACULAR DEGENERATION

Harriet Lester¹, Kevin Gildea², Benisse Lester³

¹FAA, Jamaica, NY, United States; ²FAA, Oklahoma City, OK, United States;

³Consultant, Washington, DC, United States

(Education - Case Study)

INTRODUCTION: Two vision related fatal aircraft accidents are presented. The first involved symptomatic cataracts, with a failed landing at night in a Cessna 172K. The second involved under-reported macular degeneration, with a stall in a Cessna U206C. **BACKGROUND:** Vision is a critical and vulnerable special sense for the aviator. Cataracts and macular

degeneration are common conditions that can compromise visual perception and contribute to aviation accidents, especially in the aging pilot. Visual challenges abound in aviation under the best of circumstances.

The normal aviator perceives a three dimensional world with a two dimensional retina, scans to overcome the limitations of our visual field and photoreceptor array, and adapts to atmospheric changes that alter contrast, color perception, and acuity. The aviator with cataracts may experience symptoms related to the optical properties of light as both particle and wave, interacting with the changing chemical substance of an aging lens. Symptoms may range from early dysfunctional lens syndrome to decreased acuity, overt glare, halos, contrast loss, color distortion, and other phenomena. Symptomatic cataracts are treated with surgery. The aviator with macular degeneration may experience defects and distortions in the central visual field. Macular degeneration degrades the best seeing portion of the eye, diminishing acuity and color perception with dry and wet varieties. Anti-vegf intravitreal injections treat wet macular degeneration. **CASE PRESENTATION:** NTSB Report WPR14FA078 is the cataract case. 12/26/13, a Cessna 172K crashed into a tree in Fresno, California, on the third landing attempt, 1821 local, in the dark. The pilot was 72 years old, 1500 hours daytime, low night hours, with difficulty navigating from a familiar lit runway to the taxiway 3 weeks prior. He had a 4 year history of cataracts, 20/20 acuity, but complained of halos around stars. NTSB Report CHI08FA156 is the macular degeneration case. 6/8/08, a Cessna U206C impacted terrain after a stall at a charity fly-in in Freemont, Ohio, 1256 local. The pilot was 86 years old, 55,000 hours, with a 2 year history of macular degeneration which was not reported properly. The pilot had a car accident 10 days before the fatal crash.

DISCUSSION: NTSB recommendations resulted in increased training about how cataracts can degrade night vision. The macular degeneration case resulted in termination of FAA AME designee privileges.

Learning Objectives

1. The participant will understand how cataracts can adversely affect vision in aviation.
2. The participant will understand how macular degeneration can adversely affect vision in aviation.

[388] A MIDAIR COLLISION, VISUAL FIELD DEFECTS, AND THE LIMITS OF THE HUMAN VISUAL SYSTEM

Kevin Gildea¹, Harriet Lester²

¹FAA, Oklahoma City, OK, United States; ²FAA, Jamaica, NY, United States

(Education - Case Study)

INTRODUCTION: This case report addresses a midair collision where one pilot had visual field defects resulting from severe glaucoma. **BACKGROUND:** Detecting other aircraft while in flight can be challenging without visual impairments. Minimal color and luminance contrast between an aircraft and the background can make detection difficult. Any anomalies, such as visual field defects, can make the detection task more difficult. Individuals with glaucomatous defects may also have compromised contrast sensitivity. **CASE PRESENTATION:** The pilot of a PA-12 flying under Part 91 struck the rear portion of a DHC-2 flying under Part 135 in Alaska on July 31, 2020 at 0827 local time (NTSB Report ANC20LA074). The PA-12 pilot had open-angle glaucoma in both eyes with visual field loss; the FAA denied medical certification June of 2012 and sustained the denial July 2012 upon request for reconsideration. The NTSB review of the pilot's personal medical records showed that there were visual field defects in both eyes from severe glaucoma with optic nerve damage. An NTSB cockpit visibility study indicated that the pilot of the PA-12 would have needed to look in the general direction of the sun to observe the DHC-2; the latter aircraft was 20 degrees below the sun. The PA-12 pilot would have had an unobstructed view of the DHC-2 for periods totaling 40 seconds or more prior to the collision. The pilot of the DHC-2 would have had an unobstructed view of the PA-12 for 53 seconds preceding the collision. In spite of the unobstructed views, both pilots failed to avoid the other aircraft. The PA-12 struck the fuselage of the DHC-2 near the tail. The resulting midair collision resulted in fatal injuries to the six people on the DHC-2 and sole occupant of the PA-12.

DISCUSSION: This case presents a fatal midair collision where glaucoma-induced visual field defects made a challenging visual detection task more difficult. The pilot with the visual defect was flying with a denied medical certificate under conditions of sun glare and struck the other aircraft. Although the pilots of both aircraft would have had periods of unobstructed visibility in the direction of the other aircraft, a collision was not avoided. Adherence to FAA vision requirements combined with vigilance and an effective visual scan in the air are necessary to reduce the probability of midair collisions. Additional mitigation recommended by the NTSB was the installation of ADS-B In and Out for Part 135 operators.

Learning Objectives

1. Aircrew, effective visual scanning, and the limits of visual perception.
2. The effects of visual field defects on the ability to detect aircraft in flight.
3. Visual field requirements for pilot aeromedical certification.

Thursday, 05/25/2023
Napoleon Ballroom D1-D2

10:00 AM

[S-71]: PANEL: USAFA GRADUATE CONTRIBUTIONS TO AEROSPACE MEDICINE: LEADERS WHO INSPIRED CADETS IN "THE NEXT GENERATION"

Chair: Jennifer Giovannetti

PANEL OVERVIEW: BACKGROUND: The U.S. Air Force Academy (USAFA) is the only service academy with a dedicated biology major feeding into a larger aerospace medical professional career field. Cadet biology majors researched USAFA graduate's careers and contributions to the aerospace medicine community specifically focused on how former USAFA graduates influenced the next generation of aerospace medical professionals. **OVERVIEW:** USAFA's biology department connected with cadets interested in aerospace medicine careers to find the "Next Generation of Aerospace Medicine." Cadets connected with several USAFA graduates, researched archives, and arranged interviews of those who contributed to the aerospace medicine community. They will share graduate's stories, contributions and how they inspired "The Next Generation." This was a great opportunity for cadets to break out of the day-to-day cycle and expand their horizons to potential career choices and real impact on the broader community. The cadets hope to share a unique presentation that shows how the next generation looks forward to scientific communication in this community. **DISCUSSION:** Standing on the shoulders of giants, cadets learn from these inspiring leaders in the aerospace community. From integration in the joint community on the ground, breaking barriers in the air to breaking records in space, the cadets connect with leaders from the past in order to become our aerospace medicine leaders of the future.

[389] USAFA GRADUATE CONTRIBUTIONS TO AEROSPACE MEDICINE: LT GEN (RET) ROBB'S JOINT EFFORTS

Ayla McKean

U.S. Air Force Academy, Colorado Springs, CO, United States

(Education - Program/Process Review)

BACKGROUND: Lieutenant General (ret) Douglas Robb is a recognized contributor in the aerospace medical community and is an inspiration to the next generation of aerospace medicine specialists. After graduating from USAFA, class of 1979, he attended medical school at Chicago College of Osteopathic Medicine and later Harvard University for a Master's in Public Health. He served as an Air Force flight surgeon, Chief of Flight Medicine, Aerospace Medicine Squadron Commander, Chief Flight Surgeon on the Joint Staff and culminated his career as the Director of the Defense Health Agency. Influential flight surgeons and joint leaders such as Lt Gen Robb enable the next generation to work

as a joint team for the future. **OVERVIEW:** The military is medically educated and prepared to keep pace with technological changes with the support of the aerospace medicine community. The military able to perform at the highest of standards with a physiological and psychologically ready joint force. **DISCUSSION:** Lt Gen Robb served as the command surgeon for U.S. Central Command and Air Mobility Command. During that time, he developed the Joint Trauma systems as the Joint Staff Surgeon. In addition, he responded as the Senior Medical Officer during the Khobar Towers terrorist attack. Lt Gen Robb's dedication to creating a medically adaptable and effective military in all branches is inspiring. With a broad view of how the military can improve through medical interventions and its medical systems inspires the younger generation to innovate in a way that will improve the military as a whole. For cadets at USAFA interested in pursuing aerospace medicine, he inspires the future of medicine from a broad point of view to improve the joint mission. After his efforts in the Joint sector, Lt Gen Robb became the first director of the newly developed Defense Health Agency. This integrated healthcare system across all services modernized medical care, allowing for effective patient care across all branches and better allow the services to focus on medical readiness. With the current national threats, it is more important than ever that our military is a medically ready force.

Learning Objectives

1. The audience will learn how Lt Gen Robb supported joint healthcare.
2. The audience will understand that Lt Gen Robb's education and military training prepared him to hold the high ranking jobs and positions that he had in his career.
3. The audience will understand Lt Gen Robb's impact on the future generation.

[390] ASMA PANEL ABSTRACT_USAFA GRADS_MAU_CADET KINKADE FINAL

Kimberly Kinkade

U.S. Air Force Academy, Colorado Springs, CO, United States

(Education - Program/Process Review)

BACKGROUND: The U.S. Air Force's newest 5th generation fighter aircraft, the F-35A, is one of the most advanced and capable fighter jets. Only 3.17% of all USAF fighter pilots were female in 2015. With these odds against her favor, Lt Col (ret) Christine "Grinder" Mau became the first female F-35A pilot on May 5, 2015. As a female pioneer in this airframe, she helped the aerospace medicine community understand the challenges to fit and equip this airframe. **OVERVIEW:** Growing up Southern California, Grinder continuously watched the Marine Corps station's aircraft. When her mother told her women could not do that "yet," it fueled her to work harder to become a fighter pilot. After she graduated USAFA in 1997, she excelled in pilot training and earned her place as an F-15E pilot. She was later a part of the 389th Expeditionary Fighter Squadron's first all-female combat sortie, providing air support to coalition and Afghan forces in Kunar Valley, Afghanistan. Competitive and thick skinned, she took Squadron Command at Seymour Johnson AFB, N.C. After 16 years and logging over 500 flight hours in the Strike Eagle, she became the 33rd Fighter Wing Operations Group Deputy Commander and the first female to fly an F-35A. Grinder flew F-35s for the rest of her career until retirement in 2017. **DISCUSSION:** Grinder's legacy opened the door for future female fighter pilots in 5th generation aircraft and initiated a diversity spike within the F-35 community. Grinder created the opportunity to study supersonic flight's physiological effects: how decompression sickness, reaction time, and motion sickness affect women specifically. Finally, by becoming the first female F-35A pilot, she proved that while gender should be considered by the aerospace medical and aircrew flight equipment communities to improve their support of women fighter pilots, it does not indicate a pilot's flying abilities. Grinder states, "In order to get the best pilots, we need to recruit the best people. If we want to come up with the best solutions to problems and continue to be an innovative force, we need to have people who think differently and look at problems differently."

Learning Objectives

1. The audience will learn that Lt. Col. (ret) Mau helped the aerospace medicine community understand the challenges to fit and equip the F-35A airframe.
2. The audience will learn that Lt. Col. (ret) Mau created the opportunity to study supersonic flight's physiological effects: how decompression sickness, reaction time, and motion sickness affect women specifically.
3. The audience will learn how Lt. Col. (ret) Mau opened the door for future female fighter pilots.

[391] USAFA GRADUATE CONTRIBUTIONS TO AEROSPACE MEDICINE: DR. MARK MAVITY

Elizabeth Shearns

U.S. Air Force Academy, Colorado Springs, CO, United States

(Education - Program/Process Review)

BACKGROUND: Dr. Mark Mavity is a distinguished graduate of the United States Air Force Academy class of 1984 and received his Doctor of Medicine Degree in May 1988. He is board certified by the American Board of Preventative Medicine in the specialties of Aerospace Medicine and General Preventative Medicine and is a certified Physician Executive. He was a United States Air Force physician for 34 years and after retirement became the NASA Director of Health and Medical Systems. Additionally, he is a Chief Flight Surgeon with over 1400 flight hours in multiple aircraft. **OVERVIEW:** Of all Dr. Mavity's incredible achievements, his most notable work as the Command Surgeon for Air Forces Central Command from 2011-2013 and his work as a Special Assistant for the Invisible Wounds and Wounded Warrior Programs stands out as an inspiration the next generation of aerospace medicine specialists. As the Command Surgeon, he integrated multiple nations' health service support with a focus on sustaining the health of our forces, strengthening partner-nation military medicine capability, and shaping the stability of medical operations through these partners. His work in Invisible Wounds focused on removing barriers to care allow the care process to continue and create better environments for Airmen living with "invisible wounds." **DISCUSSION:** Dr. Mavity broadens our view of what such a long and hard-working career in medicine can be like in the Air Force. As he started from an intern to later a flight surgeon and command surgeon for these major regions, anyone would be captivated by the passion to continue medicine with programs like the Wounded Warrior Program and Invisible Wounds. Beyond working for ground level medicine, however, Dr. Mavity's work goes even further and allows the next generation to see where aerospace medicine can take them, from a flight surgeon to being the chief of aerospace medicine at different bases. The next generation is eager to follow his example with that same drive and investment towards new medical opportunities and advancements.

Learning Objectives

1. The audience will learn about Dr. Mavity's background in becoming a physician the United States Air Force as a physician.
2. The audience will learn about Dr. Mavity's contributions to medicine and aerospace medicine for the Air Force.
3. The audience will learn about how Dr. Mavity's contributions to aerospace medicine will inspire the next generation of physicians.

[392] USAFA GRADUATE CONTRIBUTIONS TO AEROSPACE MEDICINE: LT GEN (RET) HELMS; PIONEER. WARRIOR. LEADER. INNOVATOR.

Grace Newman

U.S. Air Force Academy, Colorado Springs, CO, United States

(Education - Program/Process Review)

BACKGROUND: Lieutenant General (ret) Helms commissioned from the U.S. Air Force Academy with an aeronautical engineering degree as one of the famous "80's ladies," the first graduating class to include females. She started her military career as an F-15 and F-16 flight test engineer then earned a Master's of Science in aeronautics and astronautics

at Stanford University. She attended test pilot school then became a U.S. Air Force Exchange Officer Flight Test Engineer in Canada on the CF-18. Lt Gen Helms became an astronaut in July 1991, and was the first U.S. military woman in space and the first woman to serve on the International Space Station. During her time as an astronaut, she completed five space flights, served 211 total days in space, and performed a spacewalk of 8 hours and 56 minutes (a standing world record). Lt Gen Helms then returned to the Air Force and retired in 2014 as the commander for the Air Force Space Command and Joint Functional Component Command for Space. **OVERVIEW:** Lt Gen Helms stands out as an exemplary role model for all current aerospace medicine professionals and for the next generation. She is a fearless, servant leader and brilliant innovator, but also strives to show the younger generations that it does not take a superhuman to make history. As one of the first women to graduate from USAFA and one of a few women training for NASA in Russia, she displayed that competence and confidence can gain respect in difficult situations. Through her spacewalks and EVA training, she expanded our knowledge and tested the limits of the body. Her story and attitude can help others believe they, too, should be unafraid to attempt greatness. **DISCUSSION:** With her many "firsts", and as the world record holder of the longest spacewalk, General Helms is an inspiration to the next generation of women in STEM attempting to reach for the stars. Lt Gen Helms' story inspires by example, hopefully other graduates from USAFA and other woman in STEM, will pursue the field of aerospace medicine.

Learning Objectives

1. The audience will learn how Lt Gen Helms (ret.) contributed to aerospace medicine.
2. The audience will learn how Lt Gen Helms (ret.) contributed to the air and space forces.
3. The audience will learn how Lt Gen Helms (ret.) inspires women in STEM fields and the military.

Thursday, 05/25/2023
Napoleon C3

10:00 AM

[S-72]: PANEL: EDUCATION IN SPACE MEDICINE

Chair: Dana Levin

PANEL OVERVIEW: The past few years have seen a number of innovations in space medicine education. These innovations reflect a dramatic increase in interest in space medicine as well as the rapidly changing career environment of both government and commercial spaceflight around the world. This panel presents a sample of some of the most developed of these opportunities to highlight how the education space is preparing for the future. It is intended to help those interested in space medicine training learn about the new opportunities, understand the efforts to ensure quality and standards, and highlight the background and rising expertise of the trainees soon to enter the career space.

[393] UTMB AEROSPACE MEDICINE RESIDENCY

Ronak Shah, Serena Aunon-Chancellor

UTMB, Galveston, TX, United States

(Education - Program/Process Review)

For nearly three decades, the Aerospace Medicine Division of the University of Texas Medical Branch has been training physicians to become experts in the field of Aerospace Medicine. The graduates of this Accreditation Council for Graduate Medical Education (ACGME) accredited program have provided support in all arenas of flight including the Federal Aviation Administration (FAA), National Aeronautics and Space Administration (NASA), Department of Defense (DoD) and more recently within the commercial space industry. From short duration to long duration flights, from domestic shuttle launches to international Soyuz launches, our alumni have been supporting the mission from operational, research, and managerial standpoints. The space industry is evolving and as such so has the strategic plan and vision of the Aerospace

Medicine Division of the University of Texas Medical Branch. By pulling on the expertise of its diverse leadership team and that of industry, the Aerospace Medicine Division aims to transform the content of its educational pathway. The result – Aerospace Medicine experts trained in a manner to help ensure the success of every human who endeavors to travel to the skies.

Learning Objectives

1. The participant will be able to describe the unique facets of the Aerospace Medicine Residency training at the University of Texas Medical Branch.
2. The participant will have a working knowledge of the curriculum of the Aerospace Medicine Residency training at the University of Texas Medical Branch.
3. The participant will understand the job opportunities available to graduates of the Aerospace Medicine Residency at the University of Texas Medical Branch.

[394] DEVELOPING ENGINEERING SKILLS FOR FUTURE HUMAN SPACEFLIGHT CLINICIANS

Benjamin Easter¹, Arian Anderson¹, Jay Lemery¹, Allison Anderson²

¹University of Colorado, Aurora, CO, United States; ²University of Colorado, Boulder, CO, United States

(Education - Program/Process Review)

BACKGROUND: NASA's Artemis Program plans to land the first woman and next man on the Moon by 2024. These missions are a prelude to a human mission to Mars, the most complex technological feat our species has ever contemplated. Such missions will involve challenges that push humans to the extremes of their physiology and psychology. Maintaining human health and performance under these circumstances will demand spacecraft engineering and design beyond any current precedent in human spaceflight. These challenges demand partnership between engineers, who are responsible for designing and building spacecraft and habitat medical systems, and clinicians, who will use the systems to provide care to the astronauts. Unfortunately, the integration of clinical and engineering expertise has, historically, been far from seamless. **OVERVIEW:** In response to this need, the University of Colorado created a first-of-its-kind interdisciplinary dual MD-MS degree program, in which students complete a 5-year program to obtain a medical degree and also a Masters of Science in Aerospace Engineering with a focus in bioastronautics. In addition to the traditional requirements of a medical degree, students complete an additional year focusing on aerospace engineering and bioastronautics, specifically studying space life sciences, spacecraft habitat design, systems engineering, life support systems, human operation of aerospace vehicles, extravehicular activity (EVA), and medicine in space and surface environments. In addition to this coursework, students have the opportunity to perform research via a thesis or develop hands-on engineering skills via a Graduate Project to design and build a mock-up of a human spacecraft. **DISCUSSION:** Traditionally, individuals working in aerospace human health and performance are formally trained in one of the encompassed disciplines (i.e., engineering or medicine) and then are introduced to the other through exposure on the job. The intent of this dual degree is to develop professionals with a unique perspective and greater capabilities to contribute to this rapidly advancing field. As clinicians with engineering expertise, they will be well positioned to lead future exploration missions and the expanding commercial spaceflight industry. This presentation will describe the background and goals of the dual degree program, the longitudinal curriculum, and plans for partnering with existing government, academic, and industry leaders.

Learning Objectives

1. The audience will describe the importance of both clinical and engineering expertise for success in human spaceflight.
2. The audience will describe an interdisciplinary curriculum for training physician-engineers.

[395] SPACE HEALTH FOR MEDICAL STUDENTS LAUNCHES IN MELBOURNE

Rowena Christiansen

University of Melbourne Medical School, Melbourne, Australia

(Education - Program/Process Review)

BACKGROUND: From 2022, the four-year University of Melbourne MD includes a linearly integrated 'Discovery Subject' stream alongside the core subjects and clinical school placements. "Human Health in the Space Environment" (12.5 points/100) was selected as one of seven initial flagship topics for MD1, and launched in March 2022 with 32 MD1 students (~10% of the cohort). As Topic Coordinator, the author curated the content and worked closely with learning designers to develop an engaging and interactive online learning experience using the 'flipped classroom' approach. The new course has been well-received by both students and faculty. **DESCRIPTION:** The course is presented as a seven-month mission, with a mission patch and ID badge. The 24-week curriculum is divided into systems-based blocks paralleling the MD1 core biomedical science subject: *Foundation, Cardiovascular, Respiratory, Gastrointestinal, Renal and Locomotor, Endocrine and Metabolism, Neuroscience, and Reproduction*. Students learn through exploring 'spacewalks' (EVAs), which draw on websites, videos, and publications from international space agencies and experts, and interactive tutorial activities. External engagement occurs through virtual 'Meet an Expert' sessions. The incorporated LEGO "Build to Launch" (Artemis I) program educates students about the teamwork and collaboration essential for successful space missions, and students experience a Challenger Center virtual mission. Translational space health is introduced through learning about spinoffs. The assessment tasks are designed to build the skills of the students in accessible public science communication, including group and individual presentations and videos, and a written article about space health. **DISCUSSION:** This innovative and unique new course provides an opportunity to introduce students to human physiology in extreme environments and aerospace medicine as a discipline. It also functions as a stepping-stone in training and building a future space-enabled workforce. It is hoped this initiative will lead to a four-year pathway in space health for MD students. An anonymous informal student survey (~50% response rate) indicated a core body of interest. Further subjects might include the challenges around clinical medicine and surgery in space, and translational space health. In MD4 Discovery, students will have the opportunity to undertake a major research project with potential for international collaboration and engagement.

Learning Objectives

1. Participants will learn about the role of 'Discovery Subjects' in the restructured University of Melbourne four-year MD program.
2. Participants will be introduced to the 'flipped classroom' approach to learning, and how it is integrated into the 'Canvas' Learning Management System platform for this new subject.
3. Participants will gain an awareness of how international aerospace medicine engagement is an essential part of learning about 'space health'.

[396] EDUCATIONAL NEEDS ASSESSMENT IN SPACE MEDICINE

Daniella Ortiz, Erik Antonsen, Amit Padaki, Mohammad Hirzallah, Dana Levin

Baylor College of Medicine, Houston, TX, United States

(Original Research)

INTRODUCTION: Space medicine is a rapidly evolving field that requires collaboration between many different disciplines. As the career adapts to fit the needs of new government and commercial programs it is critical that space medicine educators understand these needs to ensure their trainees are well prepared for the workforce. This study is a snap shot intended to highlight the current practice needs in space medicine and identify any gaps in present training. **METHODS:** A survey of current practice needs, utilization of past training, and training practitioners wish they had was distributed to healthcare providers currently working in support

of Space Medicine. Data from this survey was collected and analyzed.

RESULTS: Key areas in current space medicine practice include; acute care, screening and prevention, engineering expertise, risk assessment, operational experience, administrative skills, clinical research, physiological research, psychological and performance research, human factors design, computational modelling, and epidemiological research. Not all areas of expertise are covered in current training programs. **DISCUSSION:** It is important for educators in space medicine to ensure that training requirements reflect the present and anticipated needs of the industry. The data from this study may be helpful in identifying the key skillsets asked of space medicine practitioners and guiding educational program design.

Learning Objectives

1. It is important to understand skillset needs in order to guide training.
2. Needs assessment surveys can help identify mismatches between skillsets and training.
3. What skillsets are important for healthcare providers in space medicine today and how does this compare to training curricula.

[397] DEVELOPMENT OF A GRADUATE MEDICAL EDUCATION PROGRAM FOR ACUTE CARE AND ENGINEERING IN SPACE MEDICINE

Dana Levin¹, Daniela Ortiz¹, N. Stuart Harris², Erik Antonsen¹

¹Baylor College of Medicine, Houston, TX, United States; ²Harvard MGH, Boston, MA, United States

(Education - Program/Process Review)

BACKGROUND: The development of new government and commercial spaceflight programs has generated demand for space medicine practitioners with new skillsets. While preventive medicine is unquestionably a critical component of spaceflight safety, changes in the volume of flyers, their demographics, and the mission profiles have increased the need for practitioners skilled in acute care, disaster response, and engineering. Commercial entities have not found a sufficient supply of physicians with these skillsets and have begun training practitioners with internal programs to address this gap. It is important for the space medicine community to respond by developing standards and providing guidance to ensure trainees have comprehensive, sufficient, and high quality skills. **DESCRIPTION:** The Baylor College of Medicine – Harvard MGH Space Medicine Fellowship is one example of an interdisciplinary training program working to ensure these standards. This fellowship grew from discussions with industry and government partners to identify training needs. Following these discussions, a team of physicians with extensive clinical and operational experience in engineering, emergency medicine, aerospace medicine, wilderness medicine, hyperbaric medicine, education, and spaceflight operations was assembled. This team sought input from industry leaders, program directors and professional society leaders to develop a robust curriculum that meets industry needs and complements existing training pathways. Additional data to inform curriculum development was collected from a survey of current space medicine practitioners on required skillsets, past training, and desired knowledge. This presentation steps through the development process for this fellowship program to provide insight into the rationale for curriculum considerations and future directions. **DISCUSSION:** The degree of work required to develop new training programs to meet industry needs and academic standards is substantial. However, this effort is essential to ensure that providers are trained and held to sufficiently high standards to ensure astronaut safety. Baylor College of Medicine-Harvard MGH has taken on the work of developing these standards while working with other space medicine training programs and traditional preventive medicine programs.

Learning Objectives

1. The medical support needs of human spaceflight industry are changing rapidly and Industry would greatly benefit from the experience of Aerospace Medicine physicians.

2. Space medicine training programs must adapt their curricula to meet the new requirements of industry in order to ensure qualified candidates exist in the workforce.

Thursday, 05/25/2023
Napoleon Ballroom A1-B3

10:00 AM

[S-73]: PANEL: RESIDENT IN AEROSPACE MEDICINE (RAM) GRAND ROUNDS IV

Chair: Paul Newbold

Co-Chairs: Thomas Jarnot, Jonathan Elliot, David Miller

PANEL OVERVIEW: Resident in Aerospace Medicine (RAM) Grand Rounds consists of 6 clinical case presentations. Each case is presented by current RAMs who will review the clinical case, diagnosis, treatment pathway and current policies from different agencies. The aviator's aeromedical disposition and waiver or special issuance outcome (if applicable) will be discussed. These unique case presentations describe clinical aviation medicine as well as policy updates for common medical and/or mental health conditions encountered in the practice of Aerospace Medicine.

[398] CASE PRESENTATION: CHEST PAIN IN A PILOT

Catie Cole

Naval Aerospace Medical Institute, Pensacola, FL, United States

(Education - Case Study)

INTRODUCTION: A 28-yr-old male developed typical chest pain and was diagnosed with myocardial infarction with non-obstructive coronary arteries (MINOCA) due to myocarditis. This presentation will discuss evaluation and diagnosis, as well as return to flight requirements for this case. **BACKGROUND:** While typical chest pain due to myocardial infarction is seen frequently in the emergency room, approximately 5-10% of these cases are unrelated to coronary artery disease. MINOCA is a diagnosis of myocardial infarction in which no substantial coronary artery stenosis is seen, defined as <50%. This disease can have a variety of different causes, with myocarditis found as an etiology via cardiac MRI (CMR) in approximately 30% of cases. Myocarditis can be caused by different sources of inflammation, with the most common being viruses such as Parvovirus B19, HHV 6, and Coxsackie virus. **CASE PRESENTATION:** A 28-yr-old male naval aviator presented to the ER with typical chest pain and was found to have ST elevations as well as positive troponins. On cardiac catheterization, however, no coronary artery disease was found. The patient had never experienced prior chest pain or shortness of breath, was not taking any medications or supplements, and was in excellent physical health with a high intensity exercise regimen. The patient was diagnosed with MINOCA and had a thorough laboratory, imaging and functional evaluation with full recovery. He was thought to have developed MINOCA due to myocarditis from an HHV 6 infection based on laboratory evaluation. He was cleared by multiple cardiology specialists after 6 months of rehab, monitoring, and workup and was granted a waiver to return to flight. **DISCUSSION:** This case highlights the importance of a thorough medical evaluation in patients with unusual findings. In addition, thorough evaluation of the literature, discussion with subject matter experts, and weighing the pros and cons of a flight waiver is critical in making an appropriate decision for return to flight. This decision making process allows for safe flight in the high reliability organization that is the US Navy.

Learning Objectives

1. Learn about MINOCA and workup of this condition through a case presentation format.
2. Learn about myocarditis and its association with specific viral infections.
3. Understand the aeromedical implications of myocardial infarction and myocarditis.

[399] INTRAOCULAR LENS REPLACEMENT IN A HIGH-PERFORMANCE FIGHTER PILOT: A CASE STUDY

Micah Rejcek, Clifford Nolt

U.S. Air Force, Wright-Patterson AFB, OH, United States

(Education - Case Study)

INTRODUCTION: This case report describes a fighter pilot who was diagnosed with cataracts and required intraocular lens replacement. This resulted in the first case of multifocal intraocular lens waiver approval in a U.S. Air Force fighter pilot. **BACKGROUND:** Cataracts are an opacity of the lens of an eye that cause blurred or distorted vision and glare problems and can progress to blindness. They frequently occur with advancing age, but contributing factors include poor nutrition, metabolic insults, exposure to sunlight and other radiation, trauma, and certain medications such as corticosteroids. In many patients, a myopic shift occurs due to an increase in refractive power of the lens and gradual progression to cataracts as opacities develop. The concern for aviation is worsening night vision, glare, and distance vision degradation with progression of disease. **CASE PRESENTATION:** A 41-yr-old male fighter pilot experienced subjective and objective worsening vision, and during his annual flight physical, he was referred to Optometry for evaluation. An initial diagnosis of cataracts was made at that time, and referral to Ophthalmology ensued. Recommendation of intraocular lens replacement was obtained by primary and secondary opinions. In separate surgeries 3 weeks apart, the aviator received multifocal lens implantation (Johnson and Johnson Model ZXR00). After subsequent recovery, and with recommendation by Ophthalmology, a waiver to return to flight status was pursued. No known associated factors for glaucoma were identified in this aviator. **DISCUSSION:** This case highlights a common age-related concern in our aviator community and recognition that frequently changing prescriptions with loss of distance vision can be a harbinger to cataract progression. Cataract lens replacement with mono-focal lenses has been approved since 1979, but multifocal lenses have not been approved until this case. Newer lens options offer many advantages, but historically did so at the expense of degraded contrast sensitivity, postoperative glare and halos at night, and loss of best corrected visual acuity. This case demonstrates excellent recovery, and the aviator's current state of ocular health demonstrates low risk of acute degradation; therefore, aeromedical waiver was recommended with an annual comprehensive eye exam.

Learning Objectives

1. Understand the natural progression and aviation risk factors of cataracts.
2. Understand early signs and symptoms of cataracts and safety concerns related to the flying community.

[400] INNER EAR BAROTRAUMA AND IMPLICATIONS ON AEROMEDICAL CLINICAL PRACTICE: A CASE REPORT

Karl Kuersteiner, Angel Perez

Naval Aerospace Medical Institute, Pensacola, FL, United States

(Education - Case Study)

INTRODUCTION: This case report describes a Naval Aircrewman (Search and Rescue Swimmer Applicant) who presented to his flight surgeon after experiencing inner ear barotrauma during introductory mask clearing exercises at shallow depth, with clear clinical implications for practitioners in the primary care and aeromedical environment. **BACKGROUND:** Patients engaged in occupational or recreational activities which involve excursions through the barometric pressure continuum have various degrees of experience in mitigating pressure-related hazards. Following operational or training incidents, such patients may commonly seek care from clinicians who have received specialized training pertaining to their expected community exposures. Therefore, in many clinical settings the flight surgeon may be the primary contact with the healthcare delivery system who is best equipped for commencing appropriate and expeditious evaluation and treatment. **CASE PRESENTATION:** We are presenting the case of a 24-year-old Naval Aircrewman (Search and Rescue Swimmer Applicant) approximately seven days after experiencing sudden onset of hearing loss, vertigo, and nausea in the setting of repeated unsuccessful

attempts to aggressively clear his dive mask at shallow underwater depth during his initial training evolutions. During the aircrewman's initial clinical evaluation, unilateral tympanic membrane erythema was noted and the member was referred to the Emergency Room where systemic steroids were commenced and a community Otorhinolaryngology (ENT) consultation was requested. After a week, the patient presented to ENT clinic. Formal audiometric testing was performed which was consistent with inner ear barotrauma, and follow-on management will be discussed.

DISCUSSION: This case serves to highlight important and severe otologic manifestations of dysbarism. Optimal clinical actions include commencement of systemic corticosteroids for sudden hearing loss and early ENT referral for completion of audiometric testing and therapeutic steps to maximize the patient's chances of functional recovery.

Learning Objectives

1. The audience will review the pathophysiology and clinical presentation of inner ear barotrauma.
2. The audience will appreciate the role of correct and timely evaluation and management to minimize the patient's risk of adverse sequelae from inner ear barotrauma.
3. Attendees will consider how to complete the must-do emergency action items in the attendee's unique practice environment.

[401] SUPERIOR OBLIQUE MYOKYMIA IN A FAST-JET PILOT: A CASE STUDY

William Smith¹, Steven Nordeen¹, Joe Zhang²

¹U.S. Air Force, Wright-Patterson AFB, OH, United States; ²U.S. Air Force, Langley AFB, VA, United States

(Education - Case Study)

INTRODUCTION: This case describes a military aviator who experienced spontaneous eye twitching due to superior oblique myokymia (SOM). **BACKGROUND:** SOM is a rare eye condition typically affecting young, healthy adults and more often the right eye. Presenting symptoms include diplopia and oscillopsia (rotating images), making SOM aeromedically significant. Triggers include stress, fatigue, caffeine use, and heat. No definitive treatment has been identified, although some topical medications and microvascular decompression of the trochlear nerve have been used successfully. This case is believed to be the first described in an aviator. **CASE PRESENTATION:** This fast-jet aviator presented in his 30s with years of intermittent right eye twitching. He described a fluttering, upward twitch lasting seconds to minutes and not involving the eyelid or left eye. Symptoms worsened with stress and improved with blinking or changing ocular focus. He sought medical care due to an increased frequency of twitching and inability to self-resolve his symptoms. While he adapted to flying with the condition, he did admit to occasional diplopia looking downward and oscillopsia. He denied pain, headache, blurry vision, or other neurologic symptoms. Ocular history included bilateral photorefractive keratectomy, left eye laser retinopexy for a retinal hole without high-risk features, and prophylactic laser treatment of bilateral lattice degeneration. Neurologic and ophthalmologic workups were normal including electroencephalogram, slit lamp exam, and brain and orbital magnetic resonance imaging. After neuro-ophthalmologic evaluation, he was diagnosed with SOM and started a trial of timolol maleate 0.5% eye drops twice daily. The medication was discontinued after 3 mo without return of symptoms. The aviator reported being symptom free and was granted a waiver for single seat operations. **DISCUSSION:** SOM is a rare, but aeromedically significant disorder requiring careful consideration of the symptoms, treatment, and potential for incapacitation when making an aeromedical disposition. Although SOM is not specifically addressed in the military or civilian waiver guides, symptoms are disqualifying; therefore, return to flight decisions should be made only after careful evaluation of the precipitating factors and success of any treatments. In this case, the waiver authority considered the aviator's stability and demonstrated ability to accommodate in making the decision.

Learning Objectives

1. Ensure aerospace medicine clinicians consider superior oblique myokymia and other eye muscle disorders in their differential diagnosis when evaluating aviators with complaints of eye twitching.

2. Review the common considerations for superior oblique myokymia as it pertains to the aeromedical environment.

[402] BACKPAIN IN A DIFFERENT LIGHT: A RARE CAUSE OF ACUTE KIDNEY INJURY

Kristina O'Connor

U.S. Navy, Pensacola, FL, United States

(Education - Case Study)

INTRODUCTION: This case report describes a 36-year-old Marine helicopter pilot who presented to the aviation clinic with back pain and was subsequently diagnosed with acute kidney injury. **BACKGROUND:** Acute kidney injury is a relevant concern for young military members. Acute kidney injury can present in a variety of ways and has a broad differential. Appropriate work up, diagnostic clarity, and expeditious management of these cases can improve patient outcomes as well as improve overall safety in the aviation environment. Hypothyroidism is not on the common differential for causes of kidney injury but should be considered. **CASE PRESENTATION:** The subject pilot in this case is a 36-year male Marine, experienced helicopter pilot who presented to the aviation clinic with improving back pain and fatigue. Patient noted, "I felt similar to this when I was diagnosed with pancreatitis a few years back". He had completed a combat fitness test four days prior but did not note any muscle soreness. Patient's presentation and exam were unremarkable. Basic metabolic panel was ordered and revealed stage 3 acute kidney injury. The pilot was admitted to the hospital. The underlying cause of the patient's kidney injury was found to be hypothyroidism. Patient was immediately started on Synthroid and as his TSH normalized as his kidney injury resolved. The final diagnosis of hypothyroid induced acute kidney injury presented both aeromedical and military implications. A waiver for hypothyroidism was approved once all requirements were met. **DISCUSSION:** This case will discuss the broad differential of acute kidney injury as well as the inciting factor in this case and the aeromedical concerns. This presentation is intended for Aerospace Medicine Residents and Flight Surgeons.

Learning Objectives

1. The audience will learn about acute kidney injury through a review of physiology and the broad differential, including rare causes.
2. The participants will be familiar with the aeromedical concerns of acute kidney injury and hypothyroidism, and the waiver requirements for each.

[403] ASYMPTOMATIC ADULT DIAPHRAGMATIC HERNIA INCIDENTALLY FOUND DURING INITIAL FLYING PHYSICAL: A CASE STUDY

Isaac Yourison, Phillip Strawbridge

Residency in Aerospace Medicine, Dayton, OH, United States

(Education - Case Study)

INTRODUCTION: This case details a patient presenting for an initial flight physical to qualify as a remotely piloted aircraft (RPA) pilot who was incidentally found to have an asymptomatic anterior diaphragmatic hernia. **BACKGROUND:** Diaphragmatic hernias constitute a rare condition usually identified perinatally. However, a small number can either be unrecognized or do not fully manifest until adulthood. While not always causing an immediate concern for the patient, they could strangulate abdominal contents, leading to a surgical emergency. The timing of that pathology is unpredictable and, if uncorrected, poses a risk for sudden incapacitation incompatible with the risks of flying duties. **CASE PRESENTATION:** The applicant RPA pilot recently had COVID-19 and, incidental to that workup, underwent a chest X-ray that exhibited a thoracic mass later characterized on computed tomography to be a left-sided anterior diaphragmatic hernia. The patient had been previously unaware of this diagnosis, was experiencing no symptoms, and noted no functional limitations. The applicant was then referred to Cardiothoracic

Surgery and underwent laparotomy and thoracostomy repair. His immediate recovery was complicated by a left-sided pneumothorax, acute kidney injury, and small bowel obstruction, all of which resolved upon hospital discharge without long-term sequelae. On follow-up, he was noted on computed tomography to have a small, fat-containing remnant hernia, remained asymptomatic, and had resumed his previous exercise activities absent any problems. He was therefore granted a 2-yr waiver for RPA pilot duties with scheduled follow-up to include physical exam, interim history, and spirometry. **DISCUSSION:** This case discusses anterior diaphragmatic hernia in adults, which is a rare condition often unrecognized by both the aviator and the flight surgeon. Symptoms are usually mild and non-specific, so they are often overlooked and only identified on incidental radiologic findings. Anterior diaphragmatic hernia can be managed with surgical correction from a variety of approaches. Given the rarity of this condition, there is a paucity of long-term follow-up data, and it is completely absent from the aeromedical literature. Most follow-up studies of diaphragmatic hernia are focused on congenital cases that are far more severe and have multi-organ involvement; therefore, they are of limited applicability in this case.

Learning Objectives

1. Describe the epidemiology and pathophysiology regarding non-traumatic/iatrogenic adult diaphragmatic hernias.
2. Describe management and aeromedical disposition of an aviator with an incidental diaphragmatic hernia.

Thursday, 05/25/2023

Nottoway & Oak Alley

10:00 AM

[S-74]: POSTERS: CLINICAL MEDICINE & SAFETY POSTERS

[106] CERVICAL EXERCISE REGIMEN FOR PREVENTION AND MITIGATION OF ACUTE AND CHRONIC NECK PAIN IN HIGH-PERFORMANCE AIRCREW

Ryan Keller, Reece Rosenthal, Nicole Butler, Sawan Dalal, Jeffrey Jones

Baylor College of Medicine, Houston, TX, United States

(Original Research)

INTRODUCTION: Neck pain among aviators is a top 10 aeromedical concern for the United States Navy. High-performance jet aircraft (HPJA) and rotary-wing aircraft (RWA) aviators often experience acute and chronic neck pain as a result of heavy g-loading, abrupt head maneuvering, heavy and sophisticated helmet-mounted systems, and frequent flight hours. These demands impose high risk of cervical spine injury, leading to reduced range of motion (ROM), pain, loss of flight years, and possible disability. We hypothesize that by strengthening and stretching weak and fatigued neck musculature, aviators will adapt to the flight environment so that the long-term risk of neck pain may be decreased. **METHODS:** Aviators and civilians engaged in a 6-week program of five exercises (two sets/day, 10-15 reps, five days/week) using progressive band-loading principles on a head-mounted device. ROM and muscular endurance were measured at weeks 0, 3, and 6. Pain magnitude and frequency were self-reported weekly. Data were analyzed using non-parametric testing. Participants consented and enrolled either through a Naval Air Warfare Center Aircraft Division approved IRB or a Veterans Affairs approved IRB. **RESULTS:** Data was collected and analyzed (n=29). There was a significant (p<0.001) increase across all ROM and muscular endurance measures. In self-reported outcomes, improvements were noted in flexibility, strength, and stiffness, faster recovery time after flying, and decreased magnitude and frequency of pain. Usage of over-the-counter pain medication decreased. **DISCUSSION:** This collaboration between the DoD and academia demonstrated that consistent, specific cervical exercises with a

portable, head-mounted resistance band device can significantly improve cervical ROM and muscular endurance, with subjective improvement of neck pain, flexibility, strength, and stiffness. This may reduce long-term prevalence of cervical pain in aviators, lead to increased mission success, and decrease medical disqualifications. Strengths of the study are multi-aircraft involvement, epidemiologic data, and study of aviators and non-aviators. Limitations are small study size and limited female subjects. We recommend collaboration in developing an inter-service recommendation of cervical exercises for aviators.

Learning Objectives

1. Assess effects of a progressive head-mounted resistance band exercise regimen on cervical range of motion and muscular endurance
2. Summarize how a progressive head-mounted resistance band exercise regimen leads to subjective improvements in neck flexibility, strength, stiffness, and pain

[404] CONSIDERATIONS FOR USE OF COMMERCIAL WEARABLE PHYSIOLOGICAL MONITORING DEVICES IN AVIATION ENVIRONMENT

Veronika Puisa, Peter Hodgkinson

King's College London, London, United Kingdom

(Education - Program/Process Review)

BACKGROUND: Fast jet pilots are subjected to stressors such as hypoxia, altitude exposure, acceleration, fatigue, physical and thermal strain. These stressors elicit physiological response as the body of a pilot adapts to unfamiliar environments. Physiological Episodes (PEs) occur when aircrew are physically impaired, experiencing decreased performance due to a variety of factors. Unexplained PEs occur when no identifying cause for such event is found. PEs have been identified as a cause for mishaps and mission or training failure on multiple high-performance fast jet aircraft. Lack of physiological monitoring and cockpit habitability are cited as shortfalls in addressing PEs. **OVERVIEW:** With the development of the latest generation of fast jet aircraft, the performance envelope of the aircraft surpasses the limits of human tolerance. Several militaries are registering PEs where the pilot is physically impaired and unable to perform their flying duties fully due to a variety of non-specific symptoms, including light-headedness, headache or confusion. In some cases, aircraft or pilot examinations do not reveal a particular cause for PEs which remain unexplained and suspected to be multifactorial. Inflight physiological monitoring could bridge this knowledge gap by directly tracking pilot responses to flight stressors and determining possible causes for PEs. Main challenges are large sensor systems interfering with flight duties, historical reliance on self-detection and reporting of symptoms, as well as lack of comprehensive inflight physiological data analysis. A way to address this issue could be by using wearable monitoring technology developed by the rapidly expanding fitness industry. Commercially available devices that utilise small and inexpensive sensors can provide data about the objective state of the human piloting the aircraft and supply data on actual physiological needs in certain environments. **DISCUSSION:** Commercially available wearable technology has a potential use in aeromedical research to help explore the nature of PEs and shed light on previously unexplored physiological states and adaptations, however it requires validation in aviation-relevant analogue environments. This can be followed by developing a dataset of parameter changes corresponding to a range of physiological states which can be further used in data analysis and implementation of AI solutions.

Learning Objectives

1. The audience will learn about a knowledge gap of what happens to human body in environments that are difficult to study using historically available sensors.
2. The participants will be invited to consider potential uses of commercial wearable technology in aeromedical research, particularly opportunities to gain data from previously inaccessible environments, such as inflight fast jet pilot monitoring.

[405] THE EFFECTS OF SHORT-TERM FASTING ON COGNITIVE FUNCTION IN AIRCREW

Mary Nimmer

Naval Medical Research Unit-Dayton, Dayton, OH, United States

(Education - Program/Process Review)

BACKGROUND: The U.S. Navy Flight Surgeon's Manual emphasizes proper pre-flight nutrition for aviators.¹ In Naval aviation, human error accounts for more than 80% of mishaps.² The Naval Safety Center cites aeromedical factors, including diet and hypoglycemia, as contributing to physiological events,³ and aircrew have reported hunger and symptoms of low blood sugar prior to mishaps, such as runway overshoots and altitude deviations.⁴ Reports are supported by research showing low blood sugar, including levels not severe enough to be clinical hypoglycemia, may affect cognitive performance,^{5,6} and pilots may not recognize impairment until adverse effects have developed.⁷ CNAF M-3710.7 offers the following guideline: "Failure to eat within 12 hours preceding end of flight may impair performance and ability to adequately control aircraft."⁸ This presentation will evaluate research on short-term fasting and cognition to provide evidence for a more specific meal timing guideline. **OVERVIEW:** Fasting affects blood sugar, which may impact brain function, causing changes in cognitive performance, such as concentration, memory, and executive function. A literature review on fasting as it relates to cognitive demands of aircrew was conducted including the following keywords: *blood glucose, fasting, hypoglycemia, executive function, cognition, aviation*. Keywords were combined with "and" (i.e., "fasting and cognition"). Studies with healthy adult participants or those that artificially controlled blood glucose were included. Studies on long-term fasting, religious fasting, and standalone neuroimaging data were excluded. There is a lack of research relating fasting to aviator performance. Research in each domain—physiological and cognitive effects of fasting and cognitive demands of flight—will be presented. **DISCUSSION:** Short-term fasting may have negative impacts on cognition, posing hazards to pilot safety. While studies evaluating the relationship between fasting and cognitive ability have variable methodologies and mixed results, a pattern has emerged suggesting a relationship between fasting and decrements in cognitive ability.⁹ Until research is available to better define how fasting impacts aviator ability, proper nutrition around cognitively demanding tasks such as flight is never detrimental.^{9,10} A more precise nutrition recommendation for pilots may help optimize performance. This work is of interest to those who provide nutrition guidance to aviators.

Learning Objectives

1. The audience will learn about how the physiological and cognitive effects of fasting or meal skipping may impact aviator safety and performance.
2. The audience will learn about the current nutrition timing guideline for naval aviators and understand the evidence for a more specific recommendation.

[406] ALTITUDE DECOMPRESSION SICKNESS IN A MILITARY AIRCREW MEMBER DURING HYPOXIA TRAINING: A CASE REPORT

Tyler Koss

Naval Residency in Aerospace Medicine, Pensacola, FL, United States

(Education - Case Study)

INTRODUCTION: This case report describes the treatment of a military aircrew member who experienced altitude decompression sickness during a hypoxic training evolution in a military hypobaric chamber. **BACKGROUND:** Military service members regularly practice in austere environments that expose their bodies to extremes. One of the extremes experienced is hypobaric environments with flight. Knowledge of how to treat altitude decompression sickness is important for both special operators who regularly dive and for members of the aviation community. Altitude decompression sickness may range from lethal to

debilitating with potentially service limiting conditions if not appropriately treated. Timely recognition and initiation of treatment are important for all healthcare providers to understand. **CASE PRESENTATION:** This patient was a 24-year-old Active Duty male aircrew who was conducting altitude training in the hypobaric chamber to recognize symptoms of hypoxia. During the training, the service member reported experiencing acute left shoulder pain during the rapid alternation of altitudes up to 25,000 feet. He did not report the symptoms until a few hours later. His flight surgeon then directed him to the base's Emergency Department. He underwent medical evaluation and treatment. Pain was rated a 7 upon arrival and decreased to a 5 after receiving ground-level 100% oxygen via non-rebreather mask at 15L. His Flight Surgeon referred him for hyperbaric oxygen therapy (HBOT). Prior to HBOT, pain was a 4. Following a Navy Treatment table 6, he reported complete resolution of symptoms. **DISCUSSION:** This case highlights one of the most common symptoms experienced with altitude decompression sickness, joint pain, and the coordinated approach to treating servicemembers experiencing the condition. Understanding options for medical therapy is important to the aerospace medicine specialist to ensure timely intervention. Navy HBOT treatment tables are readily available but should be implemented only by those with appropriate medical competency given the medical risk versus benefit and logistical implications. From a non-operational medicine aspect, this treatment knowledge is important since recreational diving is a common hobby among servicemembers increasing the likelihood of physicians encountering this condition among their personnel.

Learning Objectives

1. Understand the most common clinical presentation of altitude decompression sickness.
2. Understand the treatment protocol for altitude decompression sickness and the need to identify the nearest treating chamber.

[407] INFLUENCE OF JOB ASSIGNMENT ON MELANOMA INCIDENCE IN COMMERCIAL AIRCREW: A META-ANALYSIS.

Lee Cranmer, Bonny Chau

University of Washington, Seattle, WA, United States

(Original Research)

INTRODUCTION: Commercial cabin and cockpit aircrews are at increased cutaneous melanoma (MEL) risk versus the general population. Occupational and social factors have been invoked to explain this. However, the two groups work in on-board environments with different types/levels of potential exposures. Meta-analysis was conducted to address the hypothesis that differences exist in aircrew MEL risk based on location of in-aircraft job assignment, reflecting differential etiologic occupational exposures. **METHODS:** Medline was searched with the keywords "Cancer," "Aviation," and "Melanoma." Included studies: (1) primarily focused on cutaneous MEL; (2) were in commercial aircrew; (3) measured risk vs a general population; (4) measured risk by Standardized Incidence Ratio (SIR) with 95% confidence intervals (CI); (5) defined the gender distribution; and (7) defined cabin vs cockpit job assignment. Summary SIRs and CIs were calculated using maximum-likelihood, random effects meta-analysis. Values obtained were compared to one another using a z-test, with $p < 0.05$ pre-specified for null hypothesis rejection. **RESULTS:** 6 primary studies were identified in the initial search. These were screened for other pertinent references. The secondary search yielded an additional 9 primary studies. For cabin crew, 10 study groups from 6 studies were included. 411,561 person-years of follow-up among 28,093 subjects (86% female) were included (SIR 2.18, 95% CI 1.83-2.60). For cockpit crew, data from 9 studies representing 830,670 person-years of follow-up among 45,986 subjects (1% female) were included (SIR 2.44, 95% CI 1.94-3.08). z-test for the difference indicated that the two SIR values were not statistically different ($z = 0.77$, $p = 0.441$). **DISCUSSION:** Though cockpit crew demonstrate an increased SIR vs cabin crew, this is not statistically significant. The difference may be explained by the far higher proportion of males among cockpit crew. These results suggest that job assignment to different locations within commercial aircraft does not influence MEL risk. Other

factors, such as cosmic radiation, non-aircraft occupational exposures and avocational exposures, should be the targets of further assessment.

Learning Objectives

1. Appreciate the increased risk of melanoma among commercial flight crew, versus the general population.
2. Understand that a meta-analysis of existing data did not demonstrate an association between in-aircraft job assignment (cabin versus cockpit) and melanoma risk.
3. Be aware of alternative hypotheses for elevated melanoma risk in aircrew, including cosmic ray exposure, other occupational exposures, and avocational exposures.

[408] DUPILUMAB IN ASTHMATIC AND ALLERGIC AVIATORS: A CASE-SERIES

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(Original Research)

INTRODUCTION: Allergic or type 2 inflammatory diseases (T2I), such as asthma, chronic rhinosinusitis with nasal polyps (CRS) and eczema, affect ~10% of U.S. adults, including trained U.S. aviators and potential aviator recruits. These diseases are potentially impairing for aviators in flight, especially high-performance aviators (HPA) in single-seat jet aircraft exposed to dry air and high-G maneuvers without pilot backup should an incapacitating medical event occur. A novel FDA-approved therapy that blocks T2I, dupilumab, significantly improves these diseases, though it has not been aeromedically-approved for routine use by the USAF. We present a case-series of 4 aviators, 3 HPA and 1 rotary wing, with severe atopy, including CRS, asthma, and eczema indicating a need for dupilumab. 3 aviators agreed to treatment, 1 declined. We compare disease states between these aviators and review aeromedical implications. If dupilumab is proven to be effective and tolerated by USAF aviators, it could improve flight performance, deployability and retention of USAF aviators thereby maximizing mission effectiveness while reducing USAF medical and training costs, currently ~\$5-10 million per HPA vs. \$400,000 for 10 years of treatment with dupilumab. **RESULTS:** Two of three treated aviators and 1 control aviator were evaluated for follow-up since starting dupilumab. Significant subjective and objective improvements in atopy occurred in treated vs untreated aviators, including resolution of chronic anosmia within days of starting treatment, a 400cc increase in FEV1, and complete resolution of eczema vs worsening of CRS in control. Treated pilots flew over 100 hours without issue or side effects. **DISCUSSION:** Early results suggest dupilumab can improve atopy without flight impairment or significant side effects, mirroring FDA data, thereby reducing the need for sinus surgery under general anesthesia. If replicated, these data may suggest that dupilumab should be aeromedically-approved for USAF aviators without waiver. Also, many aviators with CRS and/or eczema also have asthma, suggesting a need for screening spirometry in aviators with CRS or eczema. **DISCLAIMER:** The views expressed are those of the authors and do not reflect the official guidance or position of the United States Government, the Department of Defense or of the United States Air Force.

Learning Objectives

1. Attendees will learn the aeromedical and deployability concerns related to asthma, CRS, eczema, and dupilumab.
2. Attendees will learn to utilize the Aeromedical Consultation Service Medical Risk Assessment and Airworthiness Matrix (AMRAAM) for risk assessment pre and post-dupilumab treatment.

[409] ASSOCIATION BETWEEN GZ EXPOSURE AND DEGENERATIVE CERVICAL SPINE CHANGES AMONG FIGHTER PILOTS

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(Original Research)

INTRODUCTION: Fighter pilots' neck pain is usually associated with the degeneration of the cervical spine. However, the evidence of the effect of Gz exposure on cervical degeneration is conflicting. The aim of the study was to explore the association between cumulative G exposure and degenerative cervical spine changes among Finnish Air Force (FINAF) fighter pilots in a 5-year follow-up. **METHODS:** Cumulative +Gz exposure levels were measured using the fatigue Index (FI) of the aircraft. The degenerative changes of cervical spine (from C2 to T1) were assessed by magnetic resonance imaging (MRI). The study population consisted of 56 volunteered FINAF fighter pilots. The MRI examinations were collected at the baseline and after 5 years of follow-up. The intervertebral disc (IVD) degeneration sum score (Pfirrmann class 1-2=0p, 3=1p, 4=2p, 5=3p) was used to assess IVD degeneration. IVD herniations, kyphosis, scoliosis, spinal canal stenosis, Schmorl's nodes and Modic changes were also evaluated. **RESULTS:** The mean FI was 1.98 (± 0.47) after follow-up. IVD degeneration sum score median was 1.5 (IQR 1-3) at baseline and 3 (IQR 2-5) at follow-up. There was no association between IVD degeneration progression and FI (0.11, $p = 0.42$). The prevalence for herniations was 0.23 (± 0.50) at baseline and 0.45 (± 0.60) at follow-up. There was a negative correlation (-0.39 , $p < 0.01$) between IVD herniation incidence and FI. The prevalence for kyphosis was 0.30 (± 0.46) at baseline and 0.21 (± 0.41) at follow-up. There was a positive correlation (0.36 , $p < 0.01$) between incidence of kyphosis and FI. **DISCUSSION:** IVD degeneration progressed significantly among study group with no correlation to individual FI scores. IVD herniations seemed to increase in numbers during follow-up however, the correlation with FI was negative. This could be caused by avoidance behavior in pilots with IVD herniations. The conflicting findings of the present study highlight the need of longer follow-ups and further research to reveal the possible association between the Gz exposure and degenerative cervical spine changes.

Learning Objectives

1. The audience will learn about the cervical spine degenerative changes among young men in 5-year follow-up.
2. The audience will learn about the relationship between G exposure and cervical spine degenerative changes.
3. The novel method of FI (measuring cumulative G exposure) will be presented to the audience.

[410] SUPERIOR SEMICIRCULAR CANAL DEHISCENCE IN A US MARINE CORPS F35B LIGHTNING PILOT: A CASE REPORT

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(Education - Case Study)

INTRODUCTION: This case report describes a U.S. Marine Corps F35B Lightning Pilot that was diagnosed with Superior Semicircular Canal Dehiscence. **BACKGROUND:** Superior Semicircular Canal Dehiscence (SSCD) is a rare condition caused by defects in the temporal bone that expose the superior semicircular canal to the brain cavity. Symptomatic patients experience pressure or sound-induced vertigo, conductive hearing loss and pulsatile tinnitus. To confirm the diagnosis, a patient must have clinical symptoms consistent with the disorder, documented hearing loss and a high-resolution CT scan showing SSCD. The treatment for some symptomatic patients is surgery to re-surface the bony covering of the canal. **CASE PRESENTATION:** The case patient was a 33yo M F35B pilot that presented with tinnitus, vertigo, and hearing loss that started while jogging. The vertigo resolved a few minutes after stopping the run and all symptoms resolved within 24 hours. A thorough physical exam was performed without significant findings. Additionally, an audiogram and an MRI of the brain were ordered and the patient was referred to otolaryngology. Five weeks later, the workup including MRI, audiogram and ENT consults were without abnormal findings. The patient was asymptomatic for five weeks and was returned to flight status. The pilot flew three flights in the F35B and on the third flight the patient experienced vertigo during a G warm up maneuver. The pilot was able to abort the

flight and safely land. After return to medical, a high-resolution CT scan of the head was performed which showed a left superior semicircular canal dehiscence. The patient was successfully treated with surgery and eventually returned to service group 3 flight status. **DISCUSSION:** Inner ear pathology and its resultant incapacitation during flight operations is a serious concern. The symptoms of vertigo, sudden hearing loss, and tinnitus caused by SSCD are not compatible with flight. Superior Semicircular Canal Dehiscence is unique in that, with successful surgical intervention, patients may potentially return to flying duties.

Learning Objectives

1. Know the diagnostic criteria for Superior Semicircular Canal Dehiscence.
2. Know the best treatment option for a symptomatic patient wanting treatment.
3. Understand the aeromedical safety concerns associated with Superior Semicircular Canal Dehiscence.

[411] PREVALENCE TO OVERWEIGHT AND OBESITY AMONG GERMAN MILITARY PILOTS

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(Original Research)

INTRODUCTION: Overweight and obesity are associated with risk factors for several health constraints like cardiovascular disease and type 2 diabetes. Particularly in case of pilots, a poor physical condition can lead to withdrawal of the flight permit. Cardiovascular conditions are the most frequent cause for grounding pilots. This study investigates the prevalence to overweight and obesity among all active German military pilots. **METHODS:** The medical records of all German military pilots and candidates ($n = 2123$; 1.5% female; median age 35.9 years) who had medical examinations between 11.01.2017 and 10.30.2020 were consulted as part of this study. A retrospective view of the data followed; data were acquired usually in a three-year cycle during the mandatory periodical medical examination. Height and weight data were used to determine Body-Mass-Index (BMI). The prevalence determined by this method was compared with the prevalence of the general population. **RESULTS:** It was found that military pilots, like the general population, tend to overweight and obesity with age. It is particularly remarkable that the proportion of overweight military pilots in the youngest age cohort (18 – 29 years) is higher than in the general population. Subsequently, older military pilots have lower BMI than the general population. In addition, it has been noticed that the group of jet pilots has the lowest prevalence of overweight and obesity in comparison to fixed-wing and helicopter pilots. **DISCUSSION:** It is assumed that the obligation to have a higher physical fitness and to do sports on duty is a reason for a lower prevalence to overweight and obesity. Furthermore, German military pilots are provided with rations based on the recommendations of the German Nutrition Society (DGE). The above-average prevalence in the youngest cohort is explained by the lack of time for physical activity during pilot training and university study.

Learning Objectives

1. The participant will learn that German military pilots compared with the general population have a similar tendency to overweight, but less tendency to obesity.
2. The participant will learn that the prevalence of overweight and obesity in this special occupational group increases with age.

[412] WHAT'S UP WITH THAT TOE? A CASE REPORT

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(Education - Case Study)

INTRODUCTION: This case report describes a case of subungual exostosis originally diagnosed as a pyogenic granuloma in a young healthy female who had been having worsening foot pain and symptoms for over five months. **BACKGROUND:** Subungual exostosis is a rare cause

of toe pain and deformation. It's frequently misdiagnosed with the average time to definitive treatment being six months or longer. Depending on the severity of symptoms there are multiple potential duty limitations including the inability to fly as operating rudders could trigger intense pain. **CASE PRESENTATION:** This is the case of an 18-year-old who had a lesion on her right distal great toe underlying the nail which had been present and slowly enlarging over the last year. She had been having pain for the previous five months and had a tennis shoe chi meaning she was allowed to wear shoes instead of boots as her boots worsened her pain. The patient's initial diagnosis was a pyogenic granuloma, and she was referred to dermatology. A radiograph of the nail lesion demonstrated subungual exostosis and the patient underwent surgical excision performed by podiatry 2 weeks later. She had a full recovery and returned to duty 6 weeks postoperatively without restrictions. **DISCUSSION:** This case highlights subungual exostosis, a rare disease common in younger individuals with an average age of onset of 25. It can cause significant pain and disfigurement of the affected digit. It's frequently misdiagnosed causing prolonged symptoms. Radiographs of the affected digit are usually diagnostic for ruling in or out disease and surgical excision is curative with a very low recurrence rate. Knowledge of this rare but sometimes debilitating disease is important for prompt diagnosis and treatment to reduce unnecessarily extended grounding periods in aviators.

Learning Objectives

1. Recognition of subungual exostosis which is a rare but painful cause of toe pain.
2. Understanding treatment and expected recovery of subungual exostosis to decrease potential grounding time.

[413] THE INFLUENCE OF AIRCRAFT NOISE ON THE HEARING CAPACITY OF PILOTS DURING THEIR CAREER

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(Original Research)

INTRODUCTION: Modern military aircrafts are powerful and efficient yet generate high noise levels. Despite state-of-the-art aero engines and noise protection measures, sound pressure levels of over 91 dB (A) are still reachable in the cockpit, which could injure the hearing ability. This would evoke a reduced communication efficiency, a higher stress level, fatigue and especially a temporary and permanently hearing loss. To prevent this wearing a hearing protection, for example an otoplastic, during the flight duty, is necessary. The aim of the study was to analyze the audiograms of fixed wing aircraft, helicopter, and jet pilots to detect possible damage of the hearing capacity caused by noises during the flight duty. **METHODS:** The medical archive of the German Air Force Centre of Aerospace Medicine was accessed for data collection. To focus on all active pilots only subjects who had a periodic medical examination between Nov. 1, 2017, and Oct. 30, 2020, were regarded based in this analysis. Age, gender, particular aircraft type and the first and the last examination of hearing ability for each pilot during the career from 125 Hz up to 10,000 Hz were collected. For anonymous descriptive statistical analysis 1,748 subjects remained. In a comparison with DIN EN ISO 7029:2017-06, it was examined whether the pilots suffered hearing loss deviating from the age-differentiated norm hearing capacity. **RESULTS:** The results of the study showed the greatest decrease in hearing capacity among jet pilots, followed by helicopter pilots, and the least decrease among fixed wing aircraft pilots. However, despite the high intensity of noise exposure for the aircraft pilots, there was no clinical hearing loss in comparison to the norm hearing capacity in all age groups. In addition to these results the hearing ability during the flight career showed no clinical reduction overall. **CONCLUSIONS:** In summary, it can be stated that the high noise levels of the different aircraft types used by the German Armed Forces did not pose any danger to the hearing ability of the examined subject collective while using the provided hearing protection.

Learning Objectives

1. The audience will learn that in modern military aircraft there is still a very high level of noise exposure.

2. The audience will learn that with the hearing protection provided, the flight duty in modern military aircraft presents no danger to the pilots' hearing.

[414] AN OCCUPATIONAL LENS: INTEGRATING MULTI-THERAPEUTIC STRATEGIES TO OPTIMIZE PILOT PERFORMANCE AND WELL-BEING

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(Education - Program/Process Review)

BACKGROUND: There is limited awareness and understanding of the relationship between musculoskeletal workload, psychosocial workload, and flight performance among civilian and military pilots. Challenges of fatigue, sleep impairment, work related stress, and pain pose a threat on aviation safety and pilot quality of life. The future of aviation is contingent on the development of preventative countermeasures that exude evidence-based practice. An informal survey will be presented, using an occupational lens, to explore professional pilots' experience with risks in musculoskeletal functioning, mental health, and pilot well-being. **OVERVIEW:** Pre-habilitation programs are being implemented to improve chronic musculoskeletal symptomatology among military aircrew of various flight environments. However, there are limited therapeutic approaches in place that are capable of considering both the physical factors and the psych-social factors affecting flight performance. Both civilian and military multidisciplinary teams can utilize skilled therapy practitioners to conduct performance-based assessments, provide individualized therapeutic interventions, and optimize aviator performance. The evidence-based therapeutic interventions that will be discussed at greater length are within the scope of pre-habilitation services, airframe ergonomics, and health promotion programs. **DISCUSSION:** Training and operational flight performance is governed by complex interactions among the pilot, environment, and flight task. An overview of this project's proposed therapeutic interventions include:

- Identifying manual therapy techniques and modalities applicable to targeted population
- Providing injury prevention care to at-risk aviators (*ergonomic assessment/postural training; stretching/exercises; etc.*)
- Educating aviators on health management strategies (*pain management; work-life balance; sleep impairment; healthy aging; energy conservation strategies, etc.*)

Through education and training, therapeutic practice can be integrated into multidisciplinary teams to optimize human performance and pilot well-being among civilian and military aviation.

Learning Objectives

1. The audience will learn about therapeutic approaches capable of considering physical, psychosocial, and environmental factors among aviators.
2. The audience will learn about task analysis and performance-based therapeutic assessments to evaluate pilot well-being and risks for disability.
3. The audience will be able to understand the opportunities and obstacles associated with integrating skilled therapeutic practice in aerospace multidisciplinary teams.

[415] FIREFIGHTER SELF-CONTAINED BREATHING APPARATUS COMPARISON: ATMOSPHERIC VS MANUFACTURED COMPRESSED AIR USE DURING EXERTIONAL TRAINING

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(Education - Tutorial/Review)

INTRODUCTION: During the last few years some fire departments, spacecraft recovery & rescue teams, and other mission critical support personnel in both private & government sectors have switched from using traditional atmospheric compressed air (TACA, 20ppm H₂O) to manufactured air (MA, 2ppm H₂O) in their SCBAs (self-contained breathing apparatuses). MA is now utilized for job-related tasks, fitness testing, survival systems, and rescue operations. Understanding the full benefits and limitations to this recent technological shift is vital. **TOPIC:** Some firefighters have anecdotally reported post-exertional reactive airway symptoms while using MA during intense physical training which had not occurred previously with TACA. One potential mechanism is the tenfold decrease in MA moisture content exacerbated by increased exertional intensity. This study aims to evaluate the potential for lower moisture content to incite reactive airway symptoms & negatively impact human performance. Current literature shows that breathing cold & very dry traditional SCBA air during strenuous training negatively affects peak physical performance. Additionally, respirating through SCBA devices increases mechanical pulmonary system strain due to an increased work of breathing. These effects amplify with increased exertional intensity. However, no known studies exist addressing differences in utilizing MA over TACA. We intend to further elucidate any differences between TACA and MA use and provide additional insight on the necessity to solely respire through an SCBA during rigorous training exercises where extended use may be detrimental to performance. **APPLICATION:** As advances in manufactured air provide convenient options for producing high-quality SCBA & life support system air, additional military, private aerospace, and local municipalities may begin to implement these technological advances in addition to the spacecraft recovery & rescue teams, fire departments, and other aerospace personnel currently using MA. Randomized controlled trials are needed to assess the full effects of utilizing MA versus TACA in mission-critical SCBA systems. If a significant effect from low moisture manufactured air is found, this may illustrate the need for a post-regulator humidification device. Additionally, these trials should evaluate the necessity for personnel to exclusively respire through SCBAs during extremely strenuous training exercises and potential overtraining prevention.

Learning Objectives

1. Recognize differences between compressed air and atmospheric air regarding moisture content and the effect on respiratory physiology (TACA ≈20ppm, MA= 2ppm, and atmospheric air ≈20,000ppm). Inspiring cool extremely dry SCBA air can have negative performance impacts and lead to potential reactive airway symptoms during job-related tasks.
2. Gain understanding of the increased work of breathing mechanics while using SCBA systems to respire during training or job-related duties. As a confined, user-actuated system activated by negative inspiratory pressures, SCBAs act as an extra-pulmonary obstructive device, exacerbated by increased demand for oxygen and rapid, deep inhalations in strenuous activity.
3. Acknowledge the limits of human ability when designing and executing training protocol given the intensity of the exercise, the constraints of the survival support system involved, and prepare for additional consequences of increased stressors in situations where reductions in training or job-related demands cannot be reduced.

[416] OPERATIONAL NECK PAIN QUESTIONNAIRE

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(Original Research)

INTRODUCTION: Military pilot neck pain is a common occurrence. To develop useful musculoskeletal models of neck pain development,

one must know the operationally relevant, specific pain location(s), severity, character, and exacerbating or relieving conditions. **METHODS:** An anonymous, web-based questionnaire was developed, vetted, approved, and disseminated to military pilots. Pilots were asked to indicate pain contributing flight tasks, equipment, and maneuvers; the neck and upper back dull-aching and stinging-burning pain and 5-level severity at 14 locations; pain onset time, duration and relief; and three axis neck mobility. A weighted response numerical index was developed with an expert panel to classify severity. **RESULTS:** Fighter, helicopter and other fixed wing pilots submitted 110 responses. Bilateral moderate muscle pain (Level 3 of 5) in the 10 posterior muscle areas was most common (32%). Pilots (43%) reported neurogenic pain with a prevalent response of 17% moderate pain along the 10 posterior muscle areas. Pilots reported multiple muscle (72%) and nerve (36%) pain origin sites. Flexor muscles were indicated less than 5% for both pain types. Typically neck pain started within 30 minutes of flight (72% were already in pain), pain duration was less than 7 days, and pain relief was given by rest with OTC medications or by a chiropractor or physical therapist. For neck motion, 4% of pilots had complete, 33% very limited, 27% slight, and 36% had no restriction. For pain contribution, the helmet was the most indicated equipment followed by the night vision goggles then vest; maneuvers with head turning, high acceleration, and in combination predominated; and piloting and night vision goggle flight tasks predominated. The index scores were computed and divided into 5 severity ranges based on responses. The response scores showed a bimodal distribution with peaks at 53(mild) and 112 (moderate). **DISCUSSION:** This new tool/metric approach addresses significant flight-specific pain and differentiates between musculoskeletal and neurogenic pain by discrete location and severity which addresses the important questions of pain pattern, structural involvement and functional decrement beyond pain absence or presence. The index has potential medical use in tracking pain progression and treatment progress.

Learning Objectives

1. This index demonstrates the multifocal nature of operational pilot neck pain and that means in the medical community to assist in pain relief.
2. This index can provide a means for the pilot and physician to track pain treatment efficacy and progression.

[417] CONTINUING DEVELOPMENTS IN 5G TELEMEDICINE, TELEMENTORING, AND MEDICAL TRAINING FOR THE REMOTE WARRIOR

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(Education - Program/Process Review)

BACKGROUND: 5G is a vital strategic technology that the DoD must master to also touch every operational mission of military medicine. Since June 2020, the Office of the Undersecretary of Defense (Research & Engineering) has established Joint Base San Antonio (JBSA) as a testing site to leverage 5G augmented and virtual reality (AR)/(VR) support for Military Health System (MHS) telemetering and medical training. The Defense Health Agency understands that utilizing AR/VR is a means for enhancing in-garrison readiness and improving global medical training. Progress with 5G core development has shaped several JBSA Objective activities/scenarios to provide realistic experiments with commercially available solutions that when 5G-enabled will take advantage of augmented network characteristics to measurably improve healthcare to save lives. **OVERVIEW:** Phased experimental processes with civilian partners and MHS Virtual Medical (Operational) Centers help shape key component issues/concerns brought up by the JBSA Medical Steering Committee regarding remote warrior care. The Medical Training Prototype addresses frequent battlefield injury/illness scenario recognition, treatment, and tracking with scalable student performance measures. End-user participant access/availability increases while maximizing limited training resources for efficient and effective readiness training.

Telementoring applies AR combined with 3-D real-time interactive digital content overlaying physical space, physiological data sensor reports, high-definition video, digital imaging, and accessible electronic health records to provide remote medical healthcare providers with enhanced clinical situational awareness to supplement on-site care delivery. The likely decreased response time to diagnosis/treat enabled by this technology will measurably reduce casualty morbidity/mortality. **DISCUSSION:** Mission demands, tech applications, or remote care under 5G enhancements create different challenges than those under 4G concepts. JBASA's utmost outcomes are to leverage 5G applications/equipment that will require seamless transition into appropriate DoD medical support missions to cover all global domains. Network solutions must ensure record data security and improve efficiency to allow effective training, proficiency, or competency for military medics. This presentation provides further awareness for the phases of current JBASA experiments in 5G Telementoring and Medical Training for the remote warrior.

Learning Objectives

1. Participants will be able Identify and describe gaps to link medical support initiatives and strategies involved utilizing 5G technology in learning and training performance to enhance the support of remote military medical personnel.
2. Participants will be able to provide and share initiatives and strategies with JBASA consultants involved in learning and improving training performance tools/applications, which will enhance operational care activities of the military medic.
3. The audience will understand the need to maintain an awareness of 5G capabilities projects; focus on risk reduction or mitigation for record/imaging access; and formulate a continuing gameplan to enhance medical support capabilities while working within resource-limited environments.

[418] INHIBITION OF MITOCHONDRIAL SUPEROXIDE OR NITRIC OXIDE DELAYS SEIZURES IN RATS EXPOSED TO HYPERBARIC OXYGEN: THE GOOD NEWS/BAD NEWS

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WITHDRAWN

[419] HUMAN FACTORS CLASSIFICATION USAGE AND RECOMMENDATION INCLUSION IN USAF MISHAPS

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(Original Research)

INTRODUCTION: The United States Air Force (USAF) aims to enhance the safety of aviation through mishap analysis and recommendations. The USAF uses the Department of Defense Human Factors Analysis and Classification System (DoD HFACS) as a tool to provide a framework for identifying and capturing the human factors involved. Anecdotal evidence suggested that HFACS usage and inclusions of recommendations decreased as severity of mishap decreased. This study was undertaken to explore HFACS coding trends and relationship with recommendations. **METHODS:** Used five years of aviation mishap reports (Class A – D, N=7376) to conduct frequency analysis of HFACS usage and recommendations for all aviation mishaps. Compared numbers of HFACS codes included per mishap by class and reports that did not include recommendations by class. Analyzed reports that included at least one human factor but did not include recommendations for trends. **RESULTS:** As mishap class severity decreased (from A to D), the percentage of reports without recommendations increased (from 7.4% to 93.2%). For

class C and D mishaps, reports that coded Act and Precondition level human factors were more likely to omit recommendations compared to reports that coded Supervision and Organization level human factors.

DISCUSSION: Differences between investigative team composition may be impacting HFACS usage. Class A and B mishaps typically have larger investigative teams that frequently include human factors subject matter experts compared to class C and D mishaps. Advertising the availability for human factors consultation may improve the robustness of HFACS classification in class C and D mishap reports. 81.6% of Class C and 93.2% of Class D mishap investigations did not include recommendations. Class C and D investigations that identified at least one human factor in the Act or Precondition bins are more likely to omit recommendations compared to investigations that identified at least one Supervision or Organizational human factor. This suggests it may be inherently more difficult to draft recommendations for human factors pertaining to the person level (e.g., decision making error, performance error, state of mind, mental awareness, physical problem) or environmental factors (e.g., physical, technological). This may indicate an ongoing prevalence of the “old view” of human error. Overall, more research is needed to determine the range of reasons investigators chose not to include recommendations.

Learning Objectives

1. The participant will be able to understand the trends identified in HFACS usage in recent safety investigative reports.
2. The participant will understand the relationship between HFACS codes and inclusion/omission of recommendations in recent safety investigation reports.

[420] THE ROLE OF DAY- AND NIGHTTIME CONDITIONS IN LASER ILLUMINATION OF AIRCRAFT: RESULTS OF A RISK FACTOR ANALYSIS FOR THE LOS ANGELES AREA 2010-2019

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(Original Research)

BACKGROUND: Despite reduced numbers of flights due to the COVID19 pandemic, laser attacks on aircraft continue to increase. By the year 2021, the FAA recorded the highest event rate ever documented for the US, with the city of Los Angeles representing one of the hotspots of occurrences. In this study, we investigated the endemic event rates in this area according to day- and nighttime including twilight conditions. **METHODS:** Laser events from 2010 to 2019 were extracted from the public database as provided by the FAA and retrospectively (re)transformed into local time data. Historical data were set into relation to sunrise, sunset and moonlight conditions, including subdividing in astronomically precise twilight phases and statistical adjustment for local daylight saving times. Since all events were recorded in the hours/minutes format, the overall precision of calculation per astrophysical event was about 1 min. Astronomical terms and conditions were defined as given by the United States Naval Observatory (USNO). **RESULTS:** A total of 1407 laser events was identified for the Los Angeles airport area. Of these, 636 events (45,2%) were allocated to night, 235 (16.7%) to twilight, and 537 (38.1%) to daylight conditions. Substratification of twilight incidences showed that most laser events occurred at astronomical twilight (6,6%), while nautical and civil twilight lasers were less frequent (6.3% and 3.8%). Taken together, laser activities were significantly higher during sunset than at sunrise. Moonlight had no significant effect on event rates. **DISCUSSION:** Our results unmask a considerable rate of laser strikes under daylight conditions which has not been observed in previous reports. The most convincing explanation of this observation is the increased visibility of stronger laser devices including blue, white, and multicolor types of lasers that enable tracking of aircraft even under normal light conditions.

CONCLUSIONS: Although low-light conditions including the transition phases between day and night are still the preferred times for outdoor use of laser pointers, daytime illumination of aircraft appears to increase. Given the much higher air traffic at daytime, this may indicate the need of public health intervention even in areas where the sun keeps shining most of the day.

Learning Objectives

1. The audiences will learn about the flight safety hazards of aircraft illumination by laserpointers.
2. Participants will learn about the environmental light conditions that are preferred by perpetrators for illumination of aircraft.

[421] SAFE TO FLY? A DOUBLE-BLIND PLACEBO-CONTROLLED CROSSOVER STUDY ON MODAFINIL AS A MODEL TO EXAMINE INSIGHT IN FATIGUE SELF-AWARENESS.

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(Original Research)

INTRODUCTION: Pilot fatigue still accounts for 15-20% of fatal flight accidents and its impact is often under-detected by the affected subject. A well-known medical countermeasure is "modafinil", meant to use for maintenance or recovery of wakefulness, alertness, and cognitive performance when sleep deprived. However, intake may be non-effective when self-awareness about fatigue is not optimal. Moreover, it is not yet clear whether modafinil-intake has an impact on this awareness itself. **METHOD:** We conducted 1/an in-depth systematic review of the use of modafinil in sleep deprived and non-sleep deprived subjects (i.e., as a cognitive enhancer or smart drug) and 2/a double-blind placebo-controlled crossover study (2 x 200 mg Modafinil for test period 1 and placebo for period 2; $n = 11$ healthy pilot students) to examine the awareness of fatigue and sleepiness in terms of safe-to-fly estimation and pre/post-test confidence ratings during one night sleep deprivation in a modafinil and placebo condition. Subjective measures were compared with objective psychomotor vigilance (PVT). **RESULTS:** Two-factor repeated measures ANOVAs showed a significant higher vigilance after modafinil-intake compared to placebo during circadian nadir time-points (i.e., 02AM, 04AM, 06AM) ($p = .016$); although in both conditions, vigilance loss was present. After modafinil, confidence significantly increased pre-testing ($p = .013$) immediately after modafinil intake and during nadir hours (whereas there was a decrease in performance). Both after placebo and modafinil, despite performance decreases during nadir-hours, participants indicated that they were safe to fly in 77% (after placebo) and 93% (after modafinil) of nadir time-points. **DISCUSSION:** Modafinil has a beneficial effect on PVT-performances during nadir hours when sleep deprived. However, over-confidence and self-awareness concerning safe-to-fly conditions need to be thoroughly examined and self-awareness training should be implemented in future Fatigue Risk Management Systems. The fact that self-awareness is easily affected may lead to an over-use of modafinil to "be on the safe side". The systematic review, indeed, documented abuse of modafinil as a(n) (ineffective) smart drug in non-military populations; hence, a caveat for military populations. Moreover, the use of modafinil should be individually tailored in function of military profiles, performance level and task characteristics.

Learning Objectives

1. The audience will learn about pilot fatigue self-awareness, the impact of modafinil on it and the importance to implement fatigue self-awareness in future Fatigue Risk Management Systems.
2. The audience will learn about the effect of modafinil when used as a countermeasure against fatigue and sleepiness when sleep deprived versus as a cognitive enhancer without being sleep deprived.

Thursday, 05/25/2023
Grand Ballroom A-B-C

1:30 PM

[S-75]: SLIDES: NASCENT SPACE MEDICINE CHALLENGES

Chair: Jeff Myers
Co-Chair: Adam Lam

[422] CARDIOVASCULAR PRESSURE RESPONSES TO MICROGRAVITY: A REVIEW

Riley Ferguson¹, George Pantalos²

¹University of Cincinnati College of Medicine, Cincinnati, OH, United States;

²University of Louisville, Louisville, KY, United States

(Education - Program/Process Review)

BACKGROUND: It is widely accepted that central venous pressure (CVP) decreases with acute and chronic microgravity exposure. However, the mechanisms regulating this shift remain debated. Specifically, reduced load not only on the thoracic tissues, but throughout the endovascular system allowing for increased tissue expansion has been implicated. However, the role of an orthostatic "set point" adaptation as the body is exposed to long-duration spaceflight remains unclear. Here, we chronicle the most significant past experiments and publications contributing to our current understanding of cardiovascular adaptations in space. Our goal is to illuminate the current gaps in our understanding of this physiologic relationship to provide guidance for future research endeavors. **OVERVIEW:** The initial query using PubMed MESH terms "Central Venous Pressure" and "Microgravity," "Spaceflight," and "Weightlessness" returned 131 results. 13 results were excluded as they were not available in English. 67 of these articles had their full manuscript accessible and a further 12 were excluded as they used only animal models, head-down tilt table studies, were experimenting with a specific countermeasure, or were determined to be beyond the scope of this review. True weightlessness simulations were preferred for their similarity to the long-term space environment. A remaining 55 total articles were fully accessible, ranged in date from 1969 to 2022, and were included in the review. **DISCUSSION:** As the number of humans traveling to space increases, in addition to the increased range and duration of exploration-class missions, so too does our need for effective countermeasures for space-associated pathologies, including the development of procedural and surgical interventions. In order to create procedural or surgical capability, better understanding of CVP in microgravity is required for the correct management of circulating fluid volume. In addition, once astronauts return to partial or full gravity environments, elucidation of the CVP and arterial pressure regulation mechanism will aid in combating debilitating orthostatic hypotension upon landing. These hemodynamic responses reveal fundamental physiologic relationships which are ultimately applicable across military, civilian, and commercial space medicine.

Learning Objectives

1. Review of theories of cardiovascular responses in acute and chronic microgravity.
2. Discuss potential countermeasures for 'set point' adaptations causing orthostatic hypotension.

[423] PREPARATION FOR A SUBORBITAL, HUMAN-TENDED EVALUATION OF MEDICAL TECHNOLOGY

George Pantalos, Sienna Shacklette, Brooke Barrow, Dalton Aubrey, Kessalyn Kelly, Erica Sutton, Michael Ray, Thomas Roussel
University of Louisville, Louisville, KY, United States

(Original Research)

INTRODUCTION: 2021 ushered in the era of passengers on commercial suborbital spacecraft. In anticipation of suborbital flights with researchers interacting with experiments during the 3-minute period of

μ -g, we have conducted ground and parabolic flight-based evaluations of investigator performance and safety. **METHODS:** A surgical system for reduced gravity was evaluated where the researcher performed several surgical tasks in a scripted sequence. Bleeding wound models inside a glovebox enabled interactive experiments during suborbital flight, where the investigator accessed the experiment through one of three pairs of sleeved arm access ports, mimicking flight in either Virgin Galactic's SpaceShipTwo or in Blue Origin's New Shepard. It was assumed the researcher will work alone during suborbital flight, attempting up to 25 surgical tasks. Other project team members observed and provided sequence prompts, minimizing their involvement in the parabolic flight procedures. A second set of evaluations took place in high-fidelity mock-ups of the suborbital spacecraft cabins with the glovebox mounted inside. Researcher movement was considered by an astronaut trainer and a human factors/safety engineer for how and when to leave their seat, position themselves by the glovebox, protocol task performance, glovebox preparation for re-entry, and return to seat. Evaluations considered room for and ease of movement to and from the glovebox, time available for productive work in microgravity, and potential for improvement of the research environment. Attention was given to the physical hazards present, ergonomic efficacy, environmental compatibility, mental stressors, and communications. **RESULTS:** Parabolic flights were conducted in May 2021 and in May 2022, and four surgeons performed scripted tasks for 15 parabolas in both spacecraft configurations. Typically, 15 surgical tasks were successfully completed. Ease of task performance varied with the location of surgical system components inside the glovebox. Suborbital spacecraft in-cabin evaluation emphasized safe movement and investigator restraint as well as efficient choreography of task flow and pre-flight rehearsal to maximize productivity. **DISCUSSION:** With careful planning and prior experience working in reduced gravity, a researcher will be able to successfully and safely accomplish many sequential and intricate research tasks in the extended microgravity of suborbital space flight. [NASA T0287-P, 80NSSC21K0359]

Learning Objectives

1. The audience will learn about the current opportunities to conduct human-tended suborbital flight research activities.
2. The audience will learn about the challenges and strategies for the researcher to safely and effectively conduct involved, interactive research experiments during suborbital flight.
3. The audience will learn about preparations for a human-tended suborbital flight by conducting simulation procedures during the reduced gravity of parabolic flight and inside the cabin of suborbital spacecraft.

[424] STANDARDIZATION OF THE COMMERCIAL ASTRONAUT

Mark Bourne, Susanna Gebhardt, Riley Ferguson
University of Cincinnati College of Medicine, Cincinnati, OH, United States

(Education - Program/Process Review)

BACKGROUND: With the advent of commercial spaceflight, more civilian astronauts, or spaceflight participants (SFP), are being launched into lower earth orbit and beyond. As commercial spaceflight becomes increasingly accessible to civilian participants, the question of formal safety regulation is paramount. The success of any future medical standards or screening guidelines hinges on the availability of evidence-based methods for evaluating physiological and psychological fitness of potential SFPs. This literature review explores the commonalities and differences between all currently published medical standards and screenings for SFPs, and the viability for their adaptation into a standardized, industry-wide guideline for the commercial spaceflight industry. **OVERVIEW:** We initially searched ResearchGate with query terms "(commercial AND spaceflight) AND (medical OR screening OR standards) AND (civilian OR participant OR passenger)" yielding 24 publications matching search criteria, of which 18 were deemed relevant and included for revision. An additional 6 publications were

found as relevant citations. There are published medical standards and screenings for SFPs in use by the U.S. National Aeronautics and Space Administration (NASA) and the International Space Station (ISS), as well as guidelines and screening tools compiled by the U.S. Department of Transportation (USDOT) and Federal Aviation Administration (FAA), Aerospace Medical Association (AsMA), Center of Excellence for Commercial Space Transportation (COECST), University of Texas Medical Branch (UTMB), International Academy of Astronautics (IAA), and International Association for the Advancement of Space Safety (IAASS), among others. All frameworks are concerned with minimizing the risk of adverse events during spaceflight by prevention, but differ in their approach to medical screenings in a variety of measures. **DISCUSSION:** There is no set standard with regard to medical screening for SFPs across the commercial spaceflight industry, though many frameworks have been proposed, and some evaluated experimentally. Establishing consistent guidelines for pre-flight medical requirements across government and commercial spaceflight is ultimately in the best interest of passenger safety and reduces liability. Through this review, we suggest an actionable framework for the creation of a uniform SPF medical evaluation in all spaceflight endeavors.

Learning Objectives

1. Explore the benefit of a standard medical screening for potential commercial space flight participants to minimize risk of adverse events.
2. Discuss compilation of currently proposed guidelines addressing medical screening standards for commercial space flight participants.

[425] LONG DURATION MEDICAL SYSTEM FOUNDATION FOR LUNAR ORBITAL AND LUNAR SURFACE EXPLORATION MISSIONS

Jay Lemery¹, Ben Easter¹, Kris Lehnhardt¹, Sarah Arai², Christopher Laing³, Mike Krihak⁵, John Odina⁶, Kerry McGuire⁶
¹NASA Exploration Medical Capabilities, Houston, TX, United States; ²Leidos, Houston, TX, United States; ³Analytical Mechanical Associates, Hampton, VA, United States; ⁵KBR, Houston, TX, United States; ⁶NASA, Houston, TX, United States

(Education - Program/Process Review)

BACKGROUND: For long-duration lunar orbital and lunar surface (LDLOS) exploration missions, the NASA Human Research Program (HRP) Exploration Medical Capability (ExMC) Element has developed a medical system foundation through which clinical considerations may be represented via a systems engineering-based model. **OVERVIEW:** Components of the Long Duration Medical System Foundation model include a concept of operations (ConOps), functional decomposition, medical conditions to be addressed, clinical capabilities and resources, technical requirements, and traces of requirements to NASA standards documents and parent-level (Program- and Vehicle habitat system-level) requirements. The Foundation model offers the means to present information in a readily accessible format that is understandable across all clinical, engineering, scientific, and managerial disciplines. Collectively, these components constitute a foundation that serves future programs with similar long duration mission profiles as a starting point for medical system design. **DISCUSSION:** The Foundation was developed by a multidisciplinary team of systems engineers, scientists, and clinicians across NASA. The process started with ConOps development, subsequently decomposed into the functionalities needed to diagnose, treat, and prevent medical conditions. The clinical team identified medical conditions most likely needed to be diagnosed and treated during a long-duration lunar exploration mission. Through these approaches, requirements were codified for the LDLOS medical system. These requirements were then traced to NASA standards, medical conditions, medical capabilities, and medical resources, facilitating stakeholders' use of the Foundation model to analyze traces and to identify medical system interfaces with other vehicle systems or subsystems. In addition, the Foundation may be used as a basis for performing risk trades on medical system mass and volume allocation. This discussion will focus on the processes through which the LDLOS Medical System Foundation was developed, how the Foundation

builds a bridge between the medical and engineering domains, and how these processes may be applied more broadly to a crew health and performance system and other system domains.

Learning Objectives

1. Understand the rationale and strategy for establishing foundation models for future missions.
2. Understand how foundation models trace NASA standards to establish model requirements.
3. Understand how foundation models may build a bridge between the medical and engineering domains, and how these processes may be applied more broadly to a crew health and performance system and other system domains.

[426] DESIGN FOR TRUST AND TRUSTWORTHINESS OF FUTURE SPACE MEDICAL SYSTEMS IN HUMAN-AGENT TEAMING: A TRANSDISCIPLINARY APPROACH

Anna Berenika Wojdecka^{1,2}, Don Platt², Rhonda Lyons³, Ondrej Doule², Aldo Fabregas², Tibor Balint¹, K. Jeffrey Myers⁴

¹Royal College of Art, Pasadena, CA, United States; ²Florida Institute of Technology, Melbourne, FL, United States; ³NYRAD, Inc., Melbourne, FL, United States; ⁴University of Florida, Gainesville, FL, United States

(Original Research)

INTRODUCTION: Exploration-class missions and future commercial space stations will require increased medical autonomy from earth-based support. Integrating emerging technologies, including machine agents and robotics, can open new pathways to crew self-reliance in medical decision-making, just-in-time training, and treatment delivery by enabling the shift towards astronauts working together with smart agents as Cyber-Physical-Human (CPH) teams. The design of new CPH-teams-oriented system architecture will require involving a wide range of stakeholder perspectives in a transdisciplinary approach. Incorporating human-centered design considerations alongside the optimization of occupied mass, volume, and reliability will play a crucial role in designing-in trust within the agent-crew interactions and facilitating a synergistic human-agent collaboration, maximizing safety and minimizing mission risks. **METHODS:** Within a human-centered design approach, we conducted expert interviews, design workshops and reviewed the state of the art. Twenty-five Subject Matter Experts (SMEs) participated in two rounds of qualitative interviews, focusing on identifying challenges and opportunities related to astronaut medical systems and defining trust components within agent-crew interactions. The SMEs represented diverse backgrounds and expertise: Space Medicine (Flight Surgeons, Exploration and Emergency Medicine), Astronauts and Training (public and private sector), Space Systems and Engineering, Architecture and Human Factors, Computing and Human-Computer Interaction. **RESULTS:** Thematic analysis of the interviews highlighted key themes around trust, challenges of medical interfaces, and performance gaps, which we present in the context of three dimensions of trust: human>agent, agent>human, and agent>database. A preliminary high-level model of future space system architecture has been developed, which illustrates data flow within the proposed Exploration Medical Ecosystem Infrastructure (ExMEDI), including the identified key data input sources. **DISCUSSION:** The results stress the importance of the interaction design in building trust relationships. Our next steps involve an iterative design of the agent-team interface of the ExMEDI clinical decision support to facilitate autonomy. Key opportunity areas of focus include the dynamic context-aware interfaces, design for medical privacy, shared decision-making, and explainability of the interface through visualizing risks.

Learning Objectives

1. The audience will learn about the identified key themes around trust, challenges of medical interfaces, and performance gaps, which we present in the context of three dimensions of trust.
2. The audience will learn about the developed preliminary high-level model of future CPH-teams-oriented space system architecture.

[427] INVESTIGATING THE POTENTIAL FOR PARASTRONAUTS: SUPPORT FOR THE ESA PARASTRONAUT PROJECT

Irene Di Giulio¹, Ryan Anderton², Stephen Harridge¹, Peter Hodgkinson¹, Marco Narici³, Ross Pollock¹, Jörn Rittweger⁴, Thomas Smith¹, Mike Miller-Smith⁵

¹King's College London, London, United Kingdom; ²UK Civil Aviation Authority, Crawley, United Kingdom; ³University of Padova, Padova, Italy; ⁴German Aerospace Center (DLR), Cologne, Germany; ⁵Aerobility, Camberley, United Kingdom

(Education - Program/Process Review)

BACKGROUND: The degree of disability that a person experiences depends on the condition or limitation and the environment. The environment changes dramatically in space. Our work supports the ESA parastronaut project to investigate the physiological feasibility of space missions being undertaken by people with a physical disability. The aim is to investigate the physiological challenges, risks and benefits associated with parastronauts' participation in space missions. **OVERVIEW:** We have established a multidisciplinary team to review the literature and investigate existing practices relating to people with physical disability and the aerospace environment. We investigate the feasibility of a parastronaut's space mission considering requirements and processes occurring before, during and after a mission. We ask three questions: What are the physiological limitations and considerations for safety? What are the environmental and technological adaptations needed? Is the space environment better suited for individuals with specific disabilities? As this field is unexplored, the lessons from para-athletes' training and recovery, and adaptations for pilots with disabilities are used as a foundation to define the problem, and to suggest relevant technological solutions and adjustments to existing processes. Given the diversity of disabilities, a personalised-medicine approach is followed. In the preliminary stage of the project, two additional tools are used, surveys and focus groups, where people with disabilities, charities, aerospace and medical experts share their insights on current practices and unmet needs. **DISCUSSION:** This work is in line with the ESA parastronaut feasibility project, which has global relevance. Our ambition is to show that space can be for everyone and every body. Space exploration has driven innovation in a variety of fields, and this project will show new solutions to make space exploration more accessible, supporting the development of tools that can lower the level of disability experienced in aviation and on Earth. This work is increasingly relevant for the civilian field, with the advent of commercial space flight and space tourism, where more heterogeneous groups of individuals may seek access to aerospace related opportunities. The work of our team will be fundamental in advancing our understanding of the human body adaptability to changes in environment and to make space travel more inclusive.

Learning Objectives

1. To discuss the differences in level of physical disability experienced on Earth and during a space mission.
2. To identify the risks and benefits of parastronaut missions, with a focus on adjustments before, during and after a mission.

Thursday, 05/25/2023
Grand Ballroom D-E

1:30 PM

[S-76]: SLIDES: BODY OF KNOWLEDGE: PHYSIOLOGY UPDATES

Chair: Amanda Lippert
Co-Chair: Katie Samoil

[428] ASSESSMENT OF CARDIAC OUTPUT DURING PHYSICAL EXERCISE USING NONINVASIVE TECHNIQUE

Munna Khan, Kashif Sherwani
Jamia Millia Islamia, New Delhi, India

(Original Research)

INTRODUCTION: Cardiac output (CO) measurement has become increasingly important during physical exercise and critical care. The CO increases because of large increase in the heart rate and a small increase in stroke volume. A non-invasive method would be preferred over an invasive approach that may no longer be acceptable due to considerable morbidity linked to balloon tipped flow directed pulmonary artery catheters. An attempt has been made to monitor the CO using noninvasive technique before and after exercise. **METHODS:** The hemodynamic parameters such as CO, heart rate (HR), and stroke volume (SV) were measured using tetra polar electrodes configuration. One pair of electrodes placed at the level of the sternal-xiphoid junction and other pair placed at the base of the neck. The thoracic length (L) is determined by measuring the distance between inner electrodes. The transmitting thoracic electrodes introduced alternating current with high frequency of 50 kilohertz (KHz) and low amplitude of 1.5 milli ampere rms (mA). The 24 subjects (20 males and 4 females) were participated in the study. Bioelectrical impedance (BI) of thorax was recorded using LCR meter. The SV determined by measuring weight in kilogram (WiK) and approximating WiK into milli litres (mL). The HR was recorded using standard automatic blood pressure instrument. The CO as a product of SV and HR monitored during rest, before and after exercise. Further, the graph was plotted between CO and oxygen consumption (O_2). **RESULTS:** The BI values of thorax were found in the range from 70 Ω to 75 Ω at rest state. The BI value decreased upto 52 Ω during exercise. The average value of the CO was found as 6.2 L/min at rest and 13.5 L/min after exercise. The plotted graph between CO and Oxygen (O_2) consumption yielded the mean slope of 7.1, which found in the range from 5.4 to 7.8 as per standard. **DISCUSSION:** The BI values decreased during exercise because of systole by increased in blood volume, increased blood flow, and aligned red blood cells. The CO values changed linearly with O_2 consumption and may be used to predict the O_2 consumption for additional subjects.

Learning Objectives

1. Assessment of Cardiac Output (CO) using Bioelectrical Impedance Analysis (BIA).
2. Prediction of O_2 consumption at rest, before and after exercise.

[429] ASSESSMENT OF WET BULB GLOBE TEMPERATURE (WBGT) HEAT STRESS LIMITS FOR APPLICATION IN THE AIR DOMAIN

Andrew S. Weller, Jonathan W. R. Boyd
QinetiQ, Farnborough, United Kingdom

(Original Research)

INTRODUCTION: Heat stress can degrade the performance and well-being of aircrew (heat strain). WBGT is an empirical heat stress index which takes account of the sources of heat stress (thermal environment, clothing and physical activity) with limits intended to prevent heat strain. The UK military has recently updated its heat illness prevention guidance, which include WBGT limits that are relevant to all service domains, including air. The aim of this study was to assess selected limits through laboratory simulations incorporating representative aircrew equipment assemblies (AEAs) and physical workloads, and to use mathematical modelling to extend the scope of the findings. **METHODS:** Ten men completed two 160-minute tests simulating rotary-wing (RW) 'Pilot' and 'Rear crew' sorties, each at two WBGTs (26 and 20°C). Aircrew workloads were generated through leg-press and treadmill exercise, and a Summer RW AEA was worn. Physiological (including gastro-intestinal (GI) temperature and metabolic rate), subjective (including thermal comfort) and cognitive performance measures were obtained. Modelling allowed WBGT limits to be generated as a function of flight time, crew role and AEA (Summer and Winter Sea). **RESULTS:** The time-weighted metabolic rate was higher in the Rear crew (258 Watts (W)) vs. Pilot (184 W) tests, but both were categorized as 'Easy' (< 250 W). Physiological and subjective measures indicated modest physiological strain in all tests with the highest GI

temperature recorded in the RW Rear crew simulation at the higher WBGT ($37.7 \pm 0.2^\circ\text{C}$). Cognitive performance measures were similar for all tests. From modelling, WBGT limits of 31 and 27°C were predicted for Pilot and Rear crew roles respectively, with Summer AEA and a 2 hr flight duration. This reduced by 1°C with flight duration of 4 hrs, and by 5°C with Winter-Sea AEA. **DISCUSSION:** Two role-specific WBGT limits are not practicable, therefore, the lower WBGT limit should be used. Given the unknown impact on heat strain risk associated with other factors not accounted for in the trial (e.g. female aircrew, solar load, different rear crew physical tasks), the results support a WBGT limit of 26°C for RW aircrew wearing Summer AEA undertaking 2 hr flights. This is broadly consistent with current UK military guidance. Empirical evidence is advised to investigate whether this limit is valid for longer flights up to 4 hours and that a 5°C reduction will confer protection with Winter-Sea AEA.

Learning Objectives

1. The audience will learn about the use of the heat stress index WBGT to inform the risk assessment for helicopter aircrew undertaking hot-weather operations.
2. The audience will learn about the use of physiological trial data and mathematical predictions to inform the heat stress risk assessment.

[430] FLIGHT RELATED NECK PAIN CAN EFFECT PERCEIVED IN-FLIGHT TASK PERFORMANCE IN UK MILITARY HELICOPTER AIRCREW

Richard Vail¹, Stephen D. R. Harridge², Nicholas D. C. Green³, Marousa Pavlou², Peter D. Hodgkinson²

¹RAF, Elgin, United Kingdom; ²King's College London, London, United Kingdom; ³RAF, Henlow, United Kingdom

(Original Research)

INTRODUCTION: Flight-related neck pain (FRNP) has been reported as an occupational concern amongst military rotary-wing (RW) aircrew. This study aimed to establish the 12-month prevalence of flight-related neck pain (FRNP) amongst UK military helicopter aircrew and its impact on perceived flight task performance. **METHODS:** A cross-sectional survey of UK military RW aircrew was conducted via an anonymous electronic questionnaire. 312 responses were received (pilots 60.9% (n=190); rear crew 20.2% (n=63); Observers 17.9% (n=56); Other 1% (n=3); 96.8% (n=302) male, 3.2% (n=10) female or not disclosed. The questionnaire used core questions defined by the NATO Task Group HFM-252 report and included the recommended definition of significant FRNP. Descriptive statistics and stepwise logistical regression were used for data analysis. The study protocol was approved by the UK MOD (Royal Air Force) ethics review process. **RESULTS:** The prevalence of significant FRNP was 39%. Rear crew reported the greatest proportion of significant FRNP (54%, n=34, 95% CI [41.8, 65.7]), followed by observer 42.9% (n=24, 95% CI [42.3, 55.9]) and pilots 34% (n=65, 95% CI [27.8, 41.2]). Amongst aircrew who reported significant FRNP (n=123), 46% (N=57) of aircrew indicated that significant FRNP affected task performance that began to impact flight safety (31.5%, n=39) or meant they were unable to complete the task (14.5%, n=18). Aircrew who reported significant FRNP flew a greater amount of flight hours (164hrs compared to 138hrs) (t=2.674 df 310, p=0.008) and hours with Night Vision Goggles (NVG) (24hrs vs 13hrs) (t=2.879, df 185.2, p=0.004). **DISCUSSION:** Prevalence of significant FRNP in UK rotary wing aircrew was lower than in previous studies but greater than neck pain in non-aircrew populations. This study is a shift in emphasis through the use of newly recommended criteria defining significant FRNP in military aircrew, linking the presence of FRNP to its effect on task performance. While FRNP is considered to have a multi-factorial etiology, our data suggest the overall exposures to increased head-mounted loads, especially for RW rear crews, and options to reduce these loads remain an important area of operational doctrine to consider. **LEARNING OBJECTIVES:** The prevalence of significant FRNP amongst UK military RW aircrew is higher than the general population; it can impair aircrew's ability to complete their in-flight tasks and is associated with both flying hours and NVG use.

Learning Objectives

1. The prevalence of significant FRNP amongst UK military RW aircrew is higher than non-aircrew military populations and the working-age general population.
2. Aircrew reporting FRNP is associated with greater levels of flying hours and NVG use.

[431] WATERPROOF OCULOMETRIC ASSESSMENT TOOL TO MONITOR AND ASSESS ILLNESS AND INJURY RELATED TO OPERATION IN HYPERBARIC AND HYPOBARIC ENVIRONMENTS

Connor Tate, Savannah Richardson, Jeffrey Philips, Timothy Hutcheson, Landon Casey
Florida Institute for Human and Machine Cognition, Pensacola, FL, United States

(Education - Tutorial/Review)

INTRODUCTION: Human operations in hypobaric and hyperbaric environments present several health risks including neurological syndromes such as: neurologic decompression sickness, hypoxia, hypercarbia, and CNS O₂ toxicity. These syndromes manifest as cognitive decline, fatigue, vertigo, visual impairment, or hearing loss; increasing danger to the operator and their team. To provide early detection and monitoring of these syndromes, a mask fitted, waterproof video-oculographic (VOG) device was developed for in situ monitoring of operator cognitive function and physiological status. **TOPIC:** The developed tool integrates addressable LEDs and the Pupil Labs camera and software into the US Navy Divator MKII full face mask for waterproof operation at pressures of 73 psi up to 4 hours. The system provides unobtrusive monitoring of physiological status and cognitive function by measuring blink rate, fixation, gaze and pupillometry. To measure eye movement an IR camera has been enclosed in a small format custom pressure housing and mounted in the mask to optimize positioning and data capture. Embedded with the eye-camera is a LED which allows for programmable control of frequency, intensity, and wavelength; allowing for elicitation of pupil dilation and latency through via controlled pulses of 500 nm light. The eye-camera and embedded LED link to a rail mounted external housing where a world-view camera and sensor integration are housed. The world-view camera provides a mapping of the operators gaze angle to the world.

APPLICATION: This system delivers a waterproof, pressure resistant VOG system as a research tool to detect early signs of neurological syndromes associated with extreme environments. Insight into operator oxygenation status, neurological dysfunction, intracranial pressure, decompression sickness and fatigue can be gained through the measurement of gaze, fixation, blink rate and pupil latency. The compatible Pupil Labs software offers a mobile, open-source, natural gaze-based system ensuring automatic slippage compensation making it possible to run eye-tracking studies in dynamic environments. The open-source software allows for extension of VOG based measures for scaling detection variables based on application. **RESOURCES:** Stepanek, Jan, et al. "Acute hypoxic hypoxia and isocapnic hypoxia effects on oculometric features." *Aviation, space, and environmental medicine* 85.7 (2014): 700-707.

Learning Objectives

1. The audience will learn about a new tool for the measurement and detection of hypobaric and hyperbaric related neurological syndromes.
2. The audience will learn about minimum detection parameters and sensor requirements for the capture of physiologically and neurologically significant eye-tracking.
3. The audience will learn about the process, difficulties and methods of developing a new detection tool for use in extreme environments.

[432] EFFECT OF LOWER BODY NEGATIVE PRESSURE ON OCULAR PERFUSION PRESSURE

Eric Hall, Richard Whittle, Ana Diaz-Artilles
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(Original Research)

INTRODUCTION: Lower body negative pressure (LBNP) has been proposed as a method to mitigate the cephalad fluid shifts during space-flight associated with the development of Space Flight Associated Neuro-ocular Syndrome (SANS). This study aims to quantify the effect of LBNP on intraocular pressure (IOP), mean arterial pressure at eye level (MAP_{eye}), and ocular perfusion pressure (OPP). **METHODS:** Twenty-four subjects (12M/12F) were subjected to graded LBNP in 0° supine and 15° head down tilt (HDT) postures from 0 mmHg to -50 mmHg, in 10 mmHg increments. IOP and MAP_{eye} were measured at each condition and OPP calculated as MAP_{eye} - IOP. Dose-response models quantifying the effects of pressure, sex, and posture were constructed over the range of LBNP using linear mixed models. **RESULTS:** Between 0 and -50 mmHg of LBNP, OPP significantly increased in 15° HDT from 90.5 ± 3.1 mmHg to 95.5 ± 3.1 mmHg ($p = 0.009$) but showed no significant change in 0° supine ($p = 0.539$). MAP_{eye} significantly decreased from 89.1 ± 2.6 mmHg to 84.2 ± 2.7 mmHg in 0° supine ($p = 0.018$) but remained constant in 15° HDT. IOP decreased significantly from 22.8 ± 0.9 mmHg to 17.5 ± 0.9 mmHg (1.0 ± 0.095 mmHg per 10 mmHg LBNP) in 15° HDT ($p < 0.001$). IOP also decreased from 19.1 ± 0.75 mmHg to 15.4 ± 0.76 mmHg (0.7 ± 0.09 mmHg per 10 mmHg LBNP) in 0° supine ($p < 0.001$). Sex did not have a significant effect on OPP or IOP. Sex differences were only found to be significant in MAP_{eye} in 15° HDT where MAP_{eye} in females was, on average, 11 ± 4.8 mmHg lower than in males ($p = 0.023$). Tilt angle was found to have a significant impact on OPP ($p < 0.001$), MAP_{eye} ($p < 0.001$), and IOP ($p < 0.001$). **DISCUSSION:** The reduction in IOP during increasing LBNP led to the increase in OPP in 15° HDT. Observed sex differences in MAP_{eye} can possibly be explained by the stature (i.e., females had, on average, a shorter hydrostatic column between heart and eye) and MAP differences between male and female subjects. Six of the twelve females did not complete the protocol in either 0° supine or 15° HDT conditions past the -30 to -40 mmHg pressure level. Only one male subject was unable to complete the full protocol (at 0° supine). The etiology behind this sex disparity should be well understood prior to long duration space missions. Future work should also seek to understand the relationship between OPP and SANS, and the impact of LBNP on these ocular responses as part of countermeasure development.

Learning Objectives

1. The audience will learn about the effect of lower body negative pressure on ocular perfusion pressure, mean arterial pressure at eye level, and intraocular pressure.
2. The audience will learn about sex differences observed in ocular perfusion pressure, mean arterial pressure at eye level, and intraocular pressure during lower body negative pressure

[433] PHYSIOLOGICAL MEASUREMENT METHODS TO AID AIR TRAFFIC CONTROLLERS PRE-TRAINING SELECTION SYSTEM

Botond Szűcs, Krisztina Szabó
PharmaFlight, Debrecen, Hungary

(Original Research)

INTRODUCTION: The 2-year training period for air traffic controllers puts heavy financial burden on the training organization, and means a continuous high workload to the ATCO-trainees. The high percentage of drop-outs during the training makes the procedure very expensive. To select the best candidates – thus reducing the number of drop-outs - we have been involved in the multistage selection process of the Hungarian ANSP, HungaroControl. **METHODS:** Monitoring and evaluating certain physiological parameters can contribute to a better assessment of an individual. The candidates, after FEAST-2 test were involved in a standard aeromedical examination and anthropometry, 6-min physiological evaluation, dry electrode EEG, sleep assessment and cognitive function test. We used heart rate variability (HRV), which gives information of the autonomic nervous system, the electric and the mechanical state of the heart, and the possible inflammations. Arteriography demonstrates the characteristics of large arteries and the endothelial function, cardiovascular risk factors. It reveals several parameters: augmentation index (AIX, optimal range < -30%) traces the degree of pulse

wave reflection, state of peripheral circulation, and is related with cardiovascular mortality. Pulse wave velocity (PWV, optimal range < 7 m/s) represents the speed of the pressure wave on the aorta generated by the heart's contraction, which is crucially affected by the elasticity of the aorta. PWVao is a solid, independent, proven risk factor of cardiovascular mortality. Diastolic area index (DAI, 50-60% among healthy individuals) represents the diastolic proportion of the cardiac cycle, gives information on pressure properties of the left coronary artery. With dry electrode EEG we also monitored the well-known brain wave range combinations. During the sleeping assessment by using a special device we got valuable information about the examinees sleeping habits, heart rate, breath frequency, deep sleep time, apnea time, sleep efficiency. **RESULTS:** We evaluated the findings of the 85 candidates and wrote a detailed report of all the candidates for HungaroControl. Based on our report a "ranking" could be given, and it was used as an important data for HungaroControl in the recruitment decision. **DISCUSSION:** The rate of the drop-outs from the 2-year training could be reduced by admitting the most competent applicants, based on our ranking. On average, the drop-out rate was decreased by a considerable 24%.

Learning Objectives

1. The audience will learn about air traffic controllers' selections system, possible helps in the selection protocol.
2. The participant will be able to understand some resting physiological measurement methods, optimal ranges of markers, deviations from optimal ranges. The possible good practices to help a participant to maintain high level of loadability and performance.

Thursday, 05/25/2023
Grand Chenier

1:30 PM

[S-77]: PANEL: ABPM ASAMS BOARD REVIEW PREPARATION

Sponsored by ASAMS

Chair: Jeffrey Jones

Co-Chairs: Dwight Holland, James Elliot, Thomas Jarnot

PANEL OVERVIEW: INTRODUCTION: To assist American Society of Aeromedical Specialists members prepare for periodic written examinations for those educated on the topics defined by the American College of Preventive Medicine GME requirements and wishing to become certified or re-certified under the American Board of Preventive Medicine, and to provide education on relevant topics to anyone interested in Aerospace and Preventive Medicine; the ASAMS education committee assembles topics for review by knowledgeable invited experts in the field. **TOPICS and Speakers:** Introduction to the Aerospace Medicine Board Exam- Jeff Jones Epidemiology- James Elliot Human Factors: Human-machine interface and Human performance- Dwight Holland Visual Illusions and Spatial Disorientation- Thomas Jarnot Physical Effects of Flight on Air and Space Operations- Jeff Jones. **APPLICATION:** The knowledge gained in this panel can be applied by the attendee to preparation for the knowledge examination in both the preventive medicine core and the aerospace medicine specialty examination. Others considering their possible involvement in clinical Aerospace Medicine or AM applied research may find the review topics interesting and educational. Preventive Medicine Core Content Outline: 25% - I. Clinical Preventive Medicine 25% - II. Public Health/Population Health Medicine Knowledge 20% - III. Epidemiology, Biostatistics, and Informatics Knowledge 15% - IV. Environmental Medicine 15% - V. Strategic Healthcare Leadership Knowledge Aerospace Medicine Content Outline: 40% - The Flight Environment 30% - Clinical Aerospace Medicine 20% - Operational Aerospace Medicine 10% - Management and Administration. **RESOURCES:** American Board of Preventive Medicine – American Board of Preventive Medicine – The American Board of Preventive Medicine was established to promote the health and safety of the American people through our high standards in the certification and maintenance of certification in

the profession of preventive health. (theabpm.org) American College of Preventive Medicine- American College of Preventive Medicine | ACPM.

[434] ABPM ASAMS BOARD REVIEW COURSE

Jeffrey Jones¹, Thomas Jarnot², James Elliot³, Dwight Holland⁴
¹Baylor College of Medicine, Center for Space Medicine, Houston, TX, United States; ²U.S. Air Force, Dayton, OH, United States; ³FAA, Fort Worth, TX, United States; ⁴InnovaSpace, Roanoke, VA, United States

(Education - Tutorial/Review)

INTRODUCTION: To assist American Society of Aeromedical Specialists members prepare for periodic written examinations for those educated on the topics defined by the American College of Preventive Medicine GME requirements and wishing to become certified or re-certified under the American Board of Preventive Medicine, and to provide education on relevant topics to anyone interested in Aerospace and Preventive Medicine, the ASAMS education committee assembles topics for review by knowledgeable invited experts in the field: Introduction to the Aerospace Medicine Board Exam- Jeff Jones. **APPLICATION:** The knowledge gained in this panel can be applied by the attendee to preparation for the knowledge examination in both the preventive medicine core and the aerospace medicine specialty examination. Others considering their possible involvement in clinical Aerospace Medicine or AM applied research may find the review topics interesting and educational: 25% - I. Clinical Preventive Medicine; 25% - II. Public Health/Population Health Medicine Knowledge; 20% - III. Epidemiology, Biostatistics, and Informatics Knowledge; 15% - IV. Environmental Medicine; 15% - V. Strategic Healthcare Leadership Knowledge. Aerospace Medicine Content Outline: 40% - The Flight Environment; 30% - Clinical Aerospace Medicine; 20% - Operational Aerospace Medicine; 10% - Management and Administration. **RESOURCES:** American Board of Preventive Medicine – American Board of Preventive Medicine – The American Board of Preventive Medicine was established to promote the health and safety of the American people through our high standards in the certification and maintenance of certification in the profession of preventive health. (theabpm.org) American College of Preventive Medicine- American College of Preventive Medicine | ACPM.

Learning Objectives

1. To familiarize the audience with an understanding of key principles of epidemiology needed for practitioners of preventive medicine, e.g. to explain the difference between sensitivity, specificity, and positive and negative predictive value.
2. To enhance the understanding of human factors involved in the operation of aircraft and space vehicles, and the key elements of the human-machine interface.
3. To outline the important visual illusions in the cockpit that can produce spatial disorientation and possible aircraft mishaps.

Thursday, 05/25/2023
Napoleon Ballroom C1-C2

1:30 PM

[S-78]: PANEL: UPDATES ON HEALTH PROMOTION IN AEROMEDICAL REGULATION

Sponsored by the Air Transport Medicine Committee

Chair: Ben Johnston

Co-Chair: Ian Hosegood

PANEL OVERVIEW: In 2018 ICAO amended their SARPS to include a requirement for Civil Aviation Regulators to apply SMS principles to Aeromedical Regulation, and to include health promotion activities in the aviation medical process. Due to the COVID pandemic there has been very little discussion of progress in this area since 2019. Regulators, Airlines, Aviation Medical Practices and Health Promotion Programme providers will be invited

to present their contributions to developing knowledge and practice in this area of Air Transport Medicine.

[435] ICAO OVERVIEW OF PROGRESS WITH HEALTH PROMOTION IN AEROMEDICAL REGULATION

Ansa Jordaán

ICAO, Montreal, PQ, Canada

(Education - Program/Process Review)

BACKGROUND: In 2016, the International Civil Aviation Organization (ICAO) amended the medical Standards and Recommended Practices (SARPs) to include a "Health Promotion Standard". This amendment formed part of moving away from strict, prescriptive medical protocols to more flexible evidence-informed protocols, based on medical findings during aviation medical examinations, reasons for loss of licence, and causes of medical incapacity. Since then, both aviation operations and the science of medicine have developed at a fast pace. In addition, the COVID-19 pandemic had a significant effect on the health of aviation personnel. The implementation of health promotion is essential in current and future aviation activities. **OVERVIEW:** This presentation describes the evolution of the health promotion standard from 2016 to date, and the progress in its application in the medical certification process. The presentation includes lessons learned from COVID-19, and the need for closer connection with other existing aviation SARPs and guidance material, such as human performance, flight operations and safety management systems, to ensure a holistic health promotion approach to maintaining fitness to fly and flight safety. **DISCUSSION:** Implementing health promotion activities necessitates multi-disciplinary collaboration at several levels, involving all relevant stakeholders. Successful implementation of health promotion activities not only supports the wellbeing and career longevity of aviation personnel, but also aviation safety. ICAO will discuss its approach to consultation and publication of health promotion material, including best practices, updating the health promotion guidelines in the ICAO Manual of Civil Aviation Medicine, and aligning these guidelines with ICAO's Flight Operations, Human Performance, and Safety Management manuals and best practices.

Learning Objectives

1. The audience will learn about ICAO's perspective and approach to integrate health promotion in aviation to support the wellbeing and career longevity of aviation personnel, as well as aviation safety.
2. The participant will be able to understand ICAO's progress in the application of health promotion in the aviation medical process, since the implementation of the SARP.

[436] INTEGRATING HEALTH PROMOTION INTO AVIATION LICENCE-HOLDERS' MEDICAL ASSESSMENTS: A REGULATOR'S PERSPECTIVE AND EXPERIENCE

Chun Hon Chong, Benjamin Tan

Civil Aviation Authority Singapore, Singapore

(Education - Program/Process Review)

Routine medical assessments for pilots and controllers have traditionally been viewed as means to identify and mitigate medical conditions of flight safety significance. Based on the recommendation of the Medical Provisions Study Group, ICAO adopted Amendment 173 to Annex 1, which included the implementation of "aviation-related health promotion for license holders to reduce future medical risks to flight safety". This new paradigm recognized the role of regulators in health promotion. Since January 2017, the Civil Aviation Authority of Singapore (CAAS) instituted structured health screening within its licensing medical examination protocols and provided personal health appraisal (PHA) reports to pilots and controllers along with their medical assessments. The aim was to integrate early identification and preventive health advice to minimize future medical-related risks. On the first year of implementation, 4.65% (95/2042) were found to have abnormal fasting blood glucose, of which 2.35% (47/2042) were newly diagnosed cases of Impaired Glucose Tolerance or Diabetes Mellitus. More than 10% of the

screening population had hypercholesterolemia. All affected pilots and controllers had commenced on lifestyle modification and/or medication. The PHAs were generated from a bespoke electronic medical platform developed by CAAS, designed to engender greater ownership of health outcomes. Information provided included individualized cardiac event risk (calculated using the Framingham Risk Score), risks of development of hypertension and Diabetes Mellitus, assessments of sleep adequacy, as well as trending of other key health parameters (eg. BMI). Future studies will be conducted to assess the impact on health outcomes from these health promotion efforts and interventions.

Learning Objectives

1. Participants would learn a regulator's approach and experience in integrating structured health screening processes within a licensing medical examination protocol, with the aim of minimizing future medical-related risks. They will be able to have access into the findings and evaluation of health data captured through this new initiative.
2. Participants would be able to observe and learn how to generate and automate customized personal health appraisal reports using health data captured in a regulator's electronic medical records.
3. Participants will understand the approach from a regulator's perspective on health promotion for Aviation certificate holders.

[437] A STITCH IN TIME - INCORPORATION OF PRIMARY CARE PREVENTIVE ACTIVITIES INTO THE AVIATION MEDICAL EXAMINATION IN AUSTRALIA

Kate Manderson

CASA Australia, Canberra, Australia

(Education - Program/Process Review)

BACKGROUND: Medical certification focuses mostly on the risk management of diseases once they have developed, while most health gains in modern medicine are made in the field of preventive activities. It is appropriate therefore that a safer approach to aviation medical certification is not to wait for a system failure, but to incorporate status checks and planned maintenance. This may prevent medical failures from ever happening, or reduce the impact and management needed when an issue is found. **OVERVIEW:** This presentation discusses the effectiveness of incorporating evidence-based primary care preventive activities into the aviation medical examination process, supporting early identification and management of medical conditions that may lead to an unsafe situation, loss of medical certification or even death. **DISCUSSION:** The Royal Australian College of General Practitioners publishes guidelines for preventive activities in general practice – "The Red Book". These guidelines have been optimised for the Australian health context based on epidemiology of preventable diseases. The Red Book recommendations are based on age, gender, ethnicity and risk profile for each patient. The treating GP then implements a patient-centred plan for screening or for surveillance of existing diseases to prevent deterioration. The Australian approach to building prevention into the aviation medical examination will start with a simple yes/no question on our electronic medical questionnaire for medical examiners: "Is this applicant up to date with the recommended RACGP Red Book preventive activities for their population?" A hyperlink will be provided to access The Red Book directly from the examiner's desktop for reference, and a prompt will also pop up when ANY response is recorded: "Preventive activities can help your aviation medical certificate-holder stay healthy and stay in the air safely." The response will not impact their medical certification, but will provide an opportunity for the discussion to be raised by the medical examiner, and a referral to the treating GP for an appropriate discussion. Following implementation, data can be analysed to look for any change in early disease detection, and in uptake of prevention/surveillance activities compared with the non-aviation population. In the very long term, we may be able to demonstrate a health benefit to the aviation community of having this relatively small interaction regularly with their AME.

Learning Objectives

1. The audience will learn about the schedule of preventive activities in Australian General Practice, and how these can be used to improve aircrew health and flying safety.
2. The audience will learn about the role of motivational interviewing as a tool for improving aircrew uptake of preventive health activities.

[438] HEALTH PROMOTION IN AEROMEDICAL REGULATION: AIRLINES' PERSPECTIVE

Ben Johnston¹, Ian Hosegood²

¹Air New Zealand, Auckland, New Zealand; ²Qantas, Sydney, Australia

(Education - Program/Process Review)

In 2016 ICAO updated their SARPs to include a recommendation that Civil Aviation Regulators include appropriate health promotion activities in the aeromedical regulatory process. As the employers of aviation certificate holders airlines have a role to play in the delivery of effective health promotion programs. There is potential for effective health promotion programs to deliver mutual benefit for aviation safety, the individual certificate holder, and also for the employer. This presentation will discuss the perspective of two airlines on existing health promotion initiatives and also opportunities and priorities for future development, in collaboration with regulators and experts in behavioral change. The presentation will also discuss how the Health Promotion concept fits within an integrated airline SMS, with reference to gaining senior leadership buy-in and commitment.

Learning Objectives

1. The audience will learn about current airline operator approaches being applied to health promotion for Aviation Medical Certificate holders.
2. The audience will learn about airline operator perspectives on key opportunities and priorities for future development of health promotion programs for Aviation Medical Certificate holders.
3. The audience will learn about how health promotion programs for Aviation Medical Certificate holders support other organizational interests.

[439] MULTI-COMPONENT HEALTH BEHAVIOR PREVENTIVE MEDICINE INTERVENTIONS TO IMPROVE CARDIOMETABOLIC HEALTH OF AIRLINE PILOTS

Daniel Wilson¹, Matt Driller², Ben Johnston³, Nicholas Gill⁴

¹University of Waikato, Tauranga, New Zealand; ²La Trobe University, Melbourne, Australia; ³Air New Zealand, Auckland, New Zealand; ⁴New Zealand Rugby and University of Waikato, Wellington, New Zealand

(Original Research)

INTRODUCTION: The occupational demands of professional airline pilots such as shift work, sleep disruption, fatigue, physical inactivity, and psychological stress may promote adverse outcomes to cardiometabolic health. Indeed, recent studies indicate similar notable prevalence of physiological, behavioral and psychological cardiometabolic health risk factors to general population estimates globally. Obtaining adequate sleep, consuming healthy nutrition, and engaging in sufficient physical activity are three lifestyle behaviors that significantly reduce all-cause mortality and have a positive effect on short and long-term cardiometabolic health. In a series of controlled clinical trials utilizing face-to-face and digital modes of delivery, the effectiveness of a 16-week personalized healthy eating, sleep hygiene, and physical activity program was evaluated for enhancing cardiometabolic health parameters among airline pilots. **METHODS:** Parallel-group (intervention and control) studies were conducted among airline pilots in New Zealand. The intervention group received a personalized nutrition, sleep and physical activity program over a 16-week period. The control group received no intervention. Outcome measures of objective health (body mass index, blood pressure, resting heart rate, body composition,

cardiorespiratory fitness, push-ups, plank hold) and self-reported health (weekly physical activity, sleep quality and duration, fruit and vegetable intake, self-rated physical and mental health, fatigue severity scale, and perceived stress scale) were collected at baseline and post-intervention. The control group completed the same assessments. **RESULTS:** Significant time x group interactions were observed for all outcome measures at post intervention ($p < 0.001$). All outcome measures significantly improved in the intervention group when compared to the control group ($p < 0.001$). Face-to-face consultations were associated with larger effect size improvements than the digital mode of delivery. **DISCUSSION:** Our findings demonstrate that a personalized 16-week healthy eating, physical activity, and sleep intervention can elicit and sustain long-term improvements in cardiometabolic health parameters in pilots and may support quality of life during an unprecedented global pandemic. These findings are of interest to professionals who may be in a position to apply preventive medicine research findings to occupational settings.

Learning Objectives

1. The audience will gain insight into evidence-based strategies utilized to deliver health behavior interventions.
2. The audience will understand the efficacy of health behavior interventions delivered to airline pilots.

Thursday, 05/25/2023

Napoleon Ballroom D1-D2

1:30 PM

[S-79]: PANEL: THE SELF-REPORTED IMPACTS OF THE COVID-19 PANDEMIC ON PSYCHOLOGICAL HEALTH OF U.S. AIR FORCE PERSONNEL

Chair: Kristin Galloway

PANEL OVERVIEW: Adjusting to COVID-19-related requirements likely increased the stress of already stressful jobs for military members and their families, which could have resounding impacts on emotional, social, and physical well-being. Therefore, it is important to evaluate the psychological health outcomes reported by military personnel and the self-perceived impacts of the changes presented by the COVID-19 pandemic to these personnel. This panel presents the results from three occupational health assessments given to U.S. Air Force personnel (cyber, Air Force Special Operations Command remotely piloted aircraft (RPA), National Air and Space Intelligence Center) and interviews conducted with RPA personnel and their embedded providers during the COVID-19 pandemic. The assessments and interviews were administered by Air Force Research Laboratory (AFRL) aeromedical operational clinical psychology researchers in late 2020 to 2021. The occupational health assessment study protocols were reviewed and approved by the AFRL Institutional Review Board at Wright-Patterson Air Force Base and assigned protocol numbers FWR-2011-0068-E and F-WR-2009-0063-E. The embedded care interviews protocol was reviewed by the AFRL Institutional Review Board and designated as a programmatic evaluation (protocol number F-WR-2020-0117-N), exempting it from further oversight (AFRL Common Rule 32 CFR 219). The first presentation includes an overview of results from the three occupational health assessments and a comparison of psychological distress and self-reported stressors to previous studies. The second presentation provides feedback received from interviews with RPA airmen and their embedded providers during the COVID-19 pandemic. The third presentation discusses self-reported COVID-19 stressors and their association with work role strain within the RPA community. The fourth presentation is a qualitative review of the open-response self-reported negative and positive impacts (work, relationship, personal, and pandemic-specific) of the COVID-19 pandemic on cyber personnel. The fifth presentation is a review of the various aspects of concern during the COVID-19 pandemic and their relation to feelings of loneliness and psychological distress within the National Air and Space Intelligence Center community.

[440] IMPACTS OF THE COVID-19 PANDEMIC ON INTELLIGENCE PERSONNEL AND THE ASSOCIATION WITH LONELINESS AND PSYCHOLOGICAL DISTRESS

Tyler Mulhearn¹, Tanya Goodman¹, Neal Scheuneman¹, Nicole Devlin-Giarrusso¹, Rachael Martinez², Kristin Galloway²

¹Neurostat Analytical Solutions, LLC, Great Falls, VA, United States;

²USAFSAM, Wright-Patterson AFB, OH, United States

(Original Research)

INTRODUCTION: The nature of work and operational stressors among Air Force National Air and Space Intelligence Center (NASIC) personnel raise potential risk for loneliness. The physical distancing restrictions and changes to a remote workplace during the COVID-19 pandemic raise the risk for loneliness. Previous literature has shown links to loneliness and negative psychological health outcomes. **METHODS:** A total of 1128 NASIC operators completed an anonymous, web-based occupational health assessment from June-July 2021. The assessment included questions on demographics, sources of stress, health and occupational factors, and stress outcomes. The 3-item UCLA Loneliness Scale was used to measure loneliness, the 45-item Outcome Questionnaire was used to assess psychological distress, and the 16-item Maslach Burnout Inventory was used to measure burnout. The study protocol was reviewed and approved by the Air Force Research Laboratory Institutional Review Board and assigned protocol number F-WR-2011-0068-E. **RESULTS:** Loneliness was moderately correlated with exhaustion ($r = 0.418$), cynicism ($r = 0.399$), and psychological distress ($r = 0.682$). Both risk factors and protective factors for NASIC operators with high levels of loneliness were identified based on burnout, psychological distress, COVID-related impacts, and demographic variables. Individuals at higher risk of loneliness include unmarried individuals (relative risk (RR) = 2.262, 95% confidence interval (CI) = 1.835-2.793), individuals younger than 26 yr of age (RR = 1.419, 95% CI = 1.110-1.814), as well as individuals with higher rates of exhaustion (RR = 2.59, 95% CI = 2.124-3.158) and cynicism (RR = 2.50, 95% CI = 2.051-3.050). A worsening relationship with one's significant other (RR = 2.42, 95% CI = 1.886-3.117) and worsening mental health (RR = 2.716, 95% CI = 2.175-3.392) also increased risk of loneliness.

DISCUSSION: Mental health support can be tailored to individuals based on the risk and protective factors found at the different levels of risk for loneliness.

Learning Objectives

1. The audience will learn about the prevalence of loneliness among intelligence personnel.
2. The audience will learn about risk factors for loneliness among intelligence personnel.

[441] SELF-REPORTED COVID-19 STRESSORS AMONG REMOTELY PILOTED AIRCRAFT AIRCREW

Neal Scheuneman¹, Tyler Mulhearn¹, Kristin Galloway², Tanya Goodman¹, Nicole Devlin¹, Rachael Martinez²

¹NeuroStat Analytical Solutions, Great Falls, VA, United States; ²USAFSAM, Wright-Patterson AFB, OH, United States

(Original Research)

INTRODUCTION: U.S. Air Force remote warfare operations require the continuous coordinated efforts of remotely piloted aircraft (RPA) aircrew. In addition to the considerable demands placed on RPA aircrew during missions, these individuals encounter unique stressors such as long work hours and shift work that may exacerbate psychological health issues. The changes that the COVID-19 pandemic brought to the workplace as well as changes to their personal lives may have increased personal stress. **METHODS:** The present study included 207 Air Force Special Operations Command (AFSOC) and 516 Air Combat Command (ACC) RPA aircrew who responded to a comprehensive occupational health assessment (AFSOC: from November 2021-January 2022; ACC: from January 2022-July 2022). The assessment included questions on demographics, sources of stress, health and occupational factors, and

stress outcomes. The study was reviewed and approved by the Air Force Research Laboratory Institutional Review Board at Wright-Patterson Air Force Base and assigned protocol number F-WR-2009-0063-E. **RESULTS:** COVID-19-related policies were rated as highly stressful (6+ on a 1-7 scale) by 14% of ACC and 20% of AFSOC RPA. The most commonly reported concerns among ACC and AFSOC RPA aircrew, respectively, included changing rules, regulations, and guidance (31%; 30%), social activities (25%; 25%), changes to work schedule (22%; 17%), concern for time spent with friends and family (22%; 29%), childcare or school status (closures) (17%; 18%), changes in work tasks (19%; 15%), and someone close to you getting COVID (19%; 14%). Personal mental health and physical health were reported as worsening for 56% and 64% of ACC, respectively, and 50% and 56% of AFSOC, respectively. Low social support among unit members was more commonly reported than in a similar study conducted in 2018, with 22% of ACC and 26% of AFSOC reporting low member social support compared to 19% and 18% from 2018, respectively. The rates of low leader social support decreased from the previous study, with 17% from ACC and 16% from AFSOC reporting low leader social support compared to 21% and 23% from 2018, respectively. **DISCUSSION:** Action-oriented recommendations related to the most commonly reported stressors will be discussed.

Learning Objectives

1. The audience will learn about COVID-19 specific stressors reported by Remotely Piloted Aircraft Aircrew.
2. The audience will learn about the COVID-19 impacts on physical and mental health among Remotely Piloted Aircraft Aircrew.

[442] A QUALITATIVE REVIEW OF SELF-REPORTED COVID-19 IMPACTS ON CYBER PERSONNEL

Tanya Goodman¹, Rachael Martinez²

¹Neurostat Analytical Solutions, LLC, Great Falls, VA, United States;

²USAFSAM, Wright-Patterson AFB, OH, United States

(Original Research)

INTRODUCTION: While there is extensive evidence demonstrating the negative psychosocial impact of COVID-19 on the general population, very few studies have examined the impact of the pandemic in unique employment contexts such as U.S. Air Force personnel. These personnel faced changes in their workplace, fitness routines, and personal lives during the COVID-19 pandemic. It is important to evaluate the perceived impacts of the changes presented to these personnel because of the pandemic. **METHODS:** An online occupational health assessment was administered to 1488 cyber personnel from November 2020 to February 2021. The assessment included demographics, standardized measures of burnout, psychological distress, work role strain, health behaviors, and perceived impacts of the COVID-19 pandemic. Qualitative analyses of impact themes and analyses of variance for types of impact on psychological health outcomes were conducted. The study protocol was reviewed and approved by the Air Force Research Laboratory Institutional Review Board and assigned protocol number F-WR-2011-0068-E. **RESULTS:** From qualitative coding for responses to the open-ended question "How has the COVID-19 pandemic impacted you as an individual?" 32 negative themes and 13 positive themes were created within 4 impact categories—work, relationship, personal, and pandemic-specific (e.g., COVID-19 fatigue, illness, and precautions). Of the themes created, 966 (68%) reported at least one negative impact, 440 (31%) reported at least one positive impact, and 195 (14%) reported at least one positive and at least one negative impact. Top-reported negative impacts were limited face-to-face interactions (12%), loss of personal activities (10%), separation from family and friends (7%), COVID-19 fatigue (7%), and physical and fitness limitations (5%). Negative impacts were associated with negative psychological health outcomes (e.g., psychological distress, exhaustion, cynicism) and work role strain. Top-reported positive impacts were improved relationships (9%), teleworking preference (8%), self-care (4%), and work-life balance (4%). **DISCUSSION:** The findings from the current study provide evidence that COVID-19, specifically, heightened work stress, physical fitness stress, and relationship/personal stress for many, which was linked to

higher levels of negative psychological health outcomes. Action-oriented recommendations are given in the event of another pandemic.

Learning Objectives

1. The audience will learn about the associations found between COVID-19 pandemic related stressors and negative psychological health outcomes.
2. The audience will be provided with action-oriented ways to mitigate the top reported stressors in the event of another pandemic.

[443] PROVIDER AND AIRMEN PERSPECTIVES ON EMBEDDED MENTAL HEALTHCARE SERVICES DURING THE COVID-19 PANDEMIC

Rachael Martinez, Kristin Galloway

USAFSAM, Wright-Patterson AFB, OH, United States

(Original Research)

INTRODUCTION: The COVID-19 pandemic posed changes to the workplace and personal lives of workers worldwide. While a large portion of the workplace transitioned to remote work, mission-essential workers remained in the workplace. Current available literature on mission essential workers is limited to frontline workers, such as healthcare personnel (nurses, doctors), and teachers and does not account for other career fields that were required to remain in their current roles in the changing COVID-19 pandemic environment. During the pandemic, embedded mental healthcare providers played a critical role in supporting the psychological health and operational success of airmen tasked with defending our nation. Providers and airmen spoke to the COVID-19-related challenges/strategies associated with delivering and accessing embedded mental healthcare services during the pandemic. **METHODS:** We conducted semi-structured interviews with 26 embedded mental healthcare providers and 15 airmen. Interviews were audio-recorded and transcribed verbatim for qualitative analysis, involving thematic content analysis to identify and tabulate key themes emergent from the data. The embedded care interviews protocol was reviewed by the Air Force Research Laboratory Institutional Review Board and designated as a programmatic evaluation (protocol number F-WR-2020-0117-N), exempting it from further oversight (Air Force Research Laboratory Common Rule 32 CFR 219). **RESULTS:** The most commonly reported themes were staying engaged with the team when not face-to-face, safety, higher incidence rates of mental healthcare, delayed initiatives, unavailability of resources, shifting responsibilities, and technology as a substitute for face-to-face communication. Providers and airmen also agreed that the top strategy for delivering/accessing care during COVID-19 was using technology (e.g., telehealth) to interact with each other and other unit members. **DISCUSSION:** This is the first systematic qualitative exploration of provider and airmen perspectives on embedded mental healthcare services, including COVID-19 considerations. Action-oriented recommendations related to the most commonly reported themes will be discussed.

Learning Objectives

1. Describe the perspectives of embedded mental health providers on the barriers and strategies to delivering mental health services during the COVID-19 pandemic.
2. Describe the perspectives of U.S. Air Force airmen on the barriers and strategies to accessing mental health services during the COVID-19 pandemic.

[444] OCCUPATIONAL HEALTH ASSESSMENTS DURING THE COVID-19 PANDEMIC: A REVIEW OF SOURCES OF STRESS AND RATES OF PSYCHOLOGICAL DISTRESS

Kristin Galloway

USAFSAM, Wright-Patterson AFB, OH, United States

(Original Research)

INTRODUCTION: U.S. Air Force researchers conducted occupational health assessments on cyber, intelligence analysis, and remotely piloted aircraft (RPA) personnel during the COVID-19 pandemic to

provide a deeper understanding of self-perceived impacts of the pandemic on these samples. **METHODS:** In all, 1128 intelligence analysis, 2010 cyber, and 723 RPA participants responded to a comprehensive occupational health assessment covering demographics, sources of stress, health/occupational factors, and stress outcomes. The Outcome Questionnaire assesses difficulties in interpersonal relationships, social roles, and overall quality of life and was used to rate psychological distress. The Maslach Burnout Inventory was used to measure exhaustion, cynicism, and professional efficacy, the three burnout facets. The study protocols were reviewed and approved by the Air Force Research Laboratory Institutional Review Board and assigned protocol numbers FWR-2011-0068-E, FWR-2011-0070-E, and F-WR-2009-0063-E. Rates of burnout and psychological distress were examined, most commonly reported stressors were compiled, and comparisons among the studies and to findings from previous assessments were conducted. **RESULTS:** Organizational issues were rated as one of the top two sources of high stress (6+ on a scale of 1-7) for intelligence analysis and cyber (20-25%). Unit manning concerns (20%), training issues (15%), being in a one-deep position (10-14%), and long work hours (11%) were also rated as a source of high stress for cyber. The most commonly reported source of high stress in intelligence analysis was mission-related equipment and technology (28%); other sources included environmental issues (17%), being in a one-deep position (15%), physical support facilities (14%), and unit manning concerns (14%). Commonly reported sources of high stress for RPA were COVID-related policies (14-20%), schedule changes (14-16%), administrative duties (14-19%), lack of professional opportunities (14-15%), and unit manning concerns (14%). High exhaustion was endorsed by 30-31% of RPA and 24-26% of intelligence analysis and cyber participants. High overall psychological distress was reported by 15-20% of RPA, 14-18% of cyber, and 14% of intelligence analysis participants. **DISCUSSION:** Action-oriented operational recommendations are discussed in relation to the sources of stress and psychological health concerns among cyber, intelligence analysis, and RPA personnel during the COVID-19 pandemic.

Learning Objectives

1. Members will understand the similarities and differences between the Psychological Distress and Burnout reported by several high demand career fields in the USAF.
2. Members will be able to clarify the most commonly reported and impactful sources of stress among different high demand USAF career fields.

Thursday, 05/25/2023
Napoleon C3

1:30 PM

[S-80]: SLIDES: SPACEFLIGHT IS RISKY BUSINESS

Chair: Yael Barr

Co-Chair: Erik Antonsen

[445] ACUTE INHALATIONAL EXPOSURE TO HYDRAZINES: SPACEFLIGHT RECOVERY CONSIDERATIONS

Brian Hanshaw¹, Valerie Ryder², Benjamin Johansen², James Pattarini², HoanVu Nguyen³, Craig Nowadly⁴, Rebecca Blue¹

¹UTMB, Galveston, TX, United States; ²NASA JSC, Houston, TX, United States;

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(Original Research)

INTRODUCTION: Inhalation of hydrazine or hydrazine-derivative vapors during spaceflight operations remains a risk to crew and ground support personnel. Exposure can cause adverse health effects ranging from distracting mucosal irritation to life-threatening respiratory, hematologic, and central nervous system (CNS) dysfunction. However,

with a limited number of human exposure cases, much of the evidence driving the regulatory and medical treatment standards is anecdotal or extrapolated from animal studies or non-inhalational human case reports. An evidence-based approach to inform acute clinical treatment guidelines for inhalational exposures during a non-catastrophic contingency spaceflight recovery scenario is necessary. **METHODS:** A review of published literature was conducted concerning hydrazine/hydrazine-derivative exposure and clinical sequelae. Priority was given to studies that described inhalation through studies of alternative routes of exposure were additionally reviewed. Where possible, human clinical presentations were prioritized over animal studies. **RESULTS:** Rare human case reports and multiple animal studies of exposures to hydrazine and derivatives provide evidence of varied clinical sequelae, including mucosal irritation, respiratory concerns, neurotoxicity, hepatotoxicity, hemotoxicity (including Heinz body development and methemoglobinemia), and longitudinal risks. In an acute timeframe (minutes to hours) of inhalational-only exposures, clinical sequelae are likely to be limited to mucosal and respiratory risk; neurological, hepatotoxic, and hemotoxic sequelae are unlikely without recurrent, longitudinal, or non-inhalational exposure. **DISCUSSION:** This presentation will highlight the acute clinical management concerns as supported by existing data. We will detail the evidence that should drive recovery medical posture for management of potential exposures. Acute rescue posture should focus on the management of mucosal irritation and respiratory concerns, including the potential need for advanced airway management. There is little evidence supporting the need for acute interventions for neurotoxicity, and there is no evidence driving a need for on-scene management of acute hemotoxic sequelae. Overemphasis on neurotoxic or hemotoxic treatments may increase the risk for inappropriate treatment or operational fixation.

Learning Objectives

1. The audience will learn about the evidence base regarding physiological sequelae of acute hydrazine exposure.
2. The audience will understand the risk stratification and time frame of likely or anticipated sequelae following acute hydrazine exposure.

[446] DYNAMIC CARBOXYHEMOGLOBIN MODEL FOR CARBON MONOXIDE EXPOSURE

Esther Putman, Diana Dayal, Jaime Mateus

Space Exploration Technologies, Hawthorne, CA, United States

(Education - Program/Process Review)

BACKGROUND: A major medical risk associated with a spacecraft cabin fire is the production of toxic combustion products. Carbon monoxide (CO) is one such product, and can be produced in large quantities even from small fires. As a competitive inhibitor of oxygen, CO binds with hemoglobin to form carboxyhemoglobin (COHb), reducing the body's capacity to carry oxygen to vital organs. In the era of commercial human spaceflight in new vehicles with unique environmental control and life-support subsystems (ECLSS), it is critical to develop dynamic models to define and address short-duration toxic exposure for diverse crew member populations, particularly for contingencies such as emergency deorbit planning in the setting of limited consumables. **DESCRIPTION:** The Coburn-Forster-Kane (CFK) equation is a well-validated method of predicting CO uptake in the blood. It captures changes in COHb, a clinically relevant indicator of carbon monoxide poisoning, as a function of CO exposure. A Python model of the CFK equation was created to model changes in COHb concentrations as a function of parts per million CO exposure and time. This dynamic model allows for user input of any cabin pressure and oxygen concentration, allowing for estimation of COHb in scenarios beyond nominal atmosphere. The model can be further customized to crew-specific physiological parameters, such as average blood volume and ventilation rate. **DISCUSSION:** Previous uses of the CFK model rely on assumptions that are often invalidated in spaceflight scenarios, such as the effect of increasing carboxyhemoglobin on oxyhemoglobin concentration which is likely invalid at higher concentrations of carbon monoxide exposure. Through a comprehensive

literature review, our model sought to address assumptions that are invalidated in off-nominal atmospheres, such as mean pulmonary capillary O₂ pressure. This model enables the creation of a concept of operations for fire scenarios, and can be used in real-time alongside data from CO cabin sensors to evaluate physiological risks to crew. The operational value of a robust carboxyhemoglobin model is significant, particularly for post-fire procedures and emergency deorbit timeline planning. This tool is useful for determining maximum allowable exposures for environments that are being considered for future exploration missions, such as NASA's exploration atmosphere.

Learning Objectives

1. The audience will understand how to model carboxyhemoglobin following acute carbon monoxide exposure over time.
2. The audience will understand how to customize the model to unique environmental conditions, such as NASA's exploration atmosphere.

[447] MAPPING MITIGATION RISK CONSEQUENCE FOR CREW NEEDING ASSISTANCE OR RESCUE ON THE LUNAR SURFACE

Marlei Walton¹, Jason Norcross², Robert Sanders¹, Storm Myers¹, Nathaniel Newby², Scott Ross¹

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(Original Research)

INTRODUCTION: Extravehicular activity (EVA) on the lunar surface presents unique risks to crew with possibility for injury. Without appropriate assistance or rescue capability, inability to nominally ambulate and return to a lander, especially during early Artemis missions, could have catastrophic consequences. Mapping likelihood and consequence safety risk associated with identified injury scenarios establishes a baseline from which to assess potential mitigation solutions to ensure crew health and safety. **METHODS:** Causes leading to the need for incapacitated crew rescue (ICR) during EVA on the lunar surface were previously identified and classified using an ICR/Acute Injury scenario spectrum. Severe scenarios are those when the affected astronaut requires either partial or full continuous assistance from the rescuer. Evaluation of these continual reliance conditions included calculating event probabilities (likelihoods) associated with an early Artemis mission and mapping them to established Exploration System Directorate (ESD) probability thresholds; safety consequences were analyzed and correlated to defined ESD personnel safety categories. These resulting likelihood and consequence values served as a baseline for assessing risk reduction of three mitigation capabilities: crew assistance (rescuer crew) only, walking assist devices, and a wheeled transport device. **RESULTS:** Of the twenty-five continual reliance conditions, ten were evaluated as "catastrophic" (Level 5, loss of life) during EVA on the lunar surface with probabilities ranging from moderate to very low during an early Artemis mission. Crew assistance only and walking assist devices showed similar potential for risk reduction, with four of the ten causes decreasing to Level 4. A wheeled transport device further increased risk reduction with six of the ten conditions decreasing to Level 4. **DISCUSSION:** Given the catastrophic consequence of several identified conditions, assessments should be performed to determine the feasibility of mitigation capabilities. It is currently unknown whether a rescuer astronaut could effectively provide continuous assistance to enable both crew to return safely to the lander from the standpoint of both suit geometry and human performance. Although resulting in an increase in resources, providing a wheeled transport provides the highest risk reduction potential, and walking assist devices may have prevention as well as mitigation benefits.

Learning Objectives

1. Learn about continual reliance medical conditions that lead to possible catastrophic consequence during an early Artemis EVA on the lunar surface.
2. Learn about consequence risk reduction associated with three potential mitigation capabilities during an early Artemis EVA on the lunar surface.

[448] USING VIRTUAL REALITY AS A COUNTERMEASURE FOR ASTRONAUT MOTION SICKNESS AND SENSORIMOTOR IMPAIRMENT IN POST-FLIGHT WATER LANDINGS.

Taylor Lonner, Aaron Allred, Aadhit Gopinath, Luca Bonarrigo, Torin Clark

University of Colorado-Boulder, Boulder, CO, United States

(Original Research)

INTRODUCTION: Prolonged microgravity exposure results in motion sickness and impaired sensorimotor function in astronauts returning to Earth. This is caused by the reinterpretation of vestibular cues while in microgravity which produces “sensory conflicts” upon re-exposure to Earth gravity. During water landings, symptoms of motion sickness (e.g. nausea and vertigo) may become more severe when astronauts awaiting recovery are subjected to ocean wave motion in their capsule. This impairment poses increased operational risk, a decreased ability to perform tasks, and crew discomfort. Certain pharmacological countermeasures have proven effective in reducing motion sickness severity, but they have undesirable side effects such as drowsiness. This study explored the efficacy of using virtual reality (VR) to reduce motion sickness and sensorimotor impairment, relevant for post-flight water landings. **METHODS:** Gravity transitions were simulated using the “sickness induced by centrifugation” paradigm wherein subjects were exposed to 2G’s in the body-centered –x-axis for one hour. The centrifuge used for this study was the Human Eccentric Rotator Device (HERD) from U of Colorado-Boulder. Following centrifugation, subjects were transferred into the Tilt-Translation Sled (TTS) where they experienced wave-like motion for up to an hour. Following centrifugation, motion sickness was quantified using the Motion Sickness Questionnaire (MSQ) in five-minute intervals, and a modified Romberg balance test was used to assess sensorimotor impairment before centrifugation (baseline), following wave-like motion, and after an hour of recovery. During wave-like motion, both experimental groups wore a VR headset. The countermeasure group (N = 4, female = 2, age = 25 ± 4.97) was shown an Earth-fixed visual scene with congruent cues of self-motion. The control group (N = 4, female = 1, age = 23.5 ± 5.74) was shown a non-moving white fixation point on a black background with no cues of self-motion. **RESULTS:** Peak motion sickness was higher in the control group (MSQ = 14.5 ± 9.15) than the countermeasure group (MSQ = 12.75 ± 5.31), and following wave-like motion, balance was worse in the control group (Pass% = 0.72) than the countermeasure group (Pass% = 0.97). **DISCUSSION:** These results suggest providing congruent visual cues of self-motion in VR can help reduce sensory conflict, mitigating motion sickness and sensorimotor impairment during post-flight water landings.

Learning Objectives

1. Understand how the sensory conflict theory relates to motion sickness in astronauts during post-flight water landings.
2. Learn how virtual reality can be used to combat motion sickness caused by sensory conflict and improve sensorimotor function after gravity transitions.
3. Consider how ground-based analogs can be used to simulate the experiences of astronauts in microgravity.

[449] ORION LIGHTING WORKAROUND FOR MAINTAINING CREW CIRCADIAN ENTRAINMENT

Matthew Lindsey¹, Carlos Dostal²

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(Education - Program/Process Review)

INTRODUCTION: Light is the primary environmental time cue of our endogenous circadian pacemaker. Suboptimal crew circadian entrainment (CCE) is common and associated with acute and chronic medical symptoms. Additionally, fatigue from suboptimal CCE promotes use of countermeasures such as sleep medications. The Orion Cabin Lighting System (OCLS) consists of monochromatic light-emitting diode (LED) lamps. However, light is a powerful suppressor of melatonin, and it is a disruptor of CCE if used at incorrect times. A commercial off the shelf

(COTS) dynamic lighting system (COTS-DLS) is a potential workaround for maintaining CCE. **METHODS:** A literature review aided selection of appropriate COTS-DLS for maintaining CCE. Our team conducted preliminary testing utilizing COTS lighting and developed recommended concept of operations for COTS implementation. **RESULTS:** A tunable and dimmable COTS-DLS can reduce 480 nm light peak wavelength and alter lighting temperature and intensity close to desired pre-sleep lighting specifications. **CONCEPT OF OPERATIONS:** Three concept of operations were recommended based on existing studies suggesting 3 hours of pre-sleep is desired. **DISCUSSION:** COTS-DLS is a potential workaround to maintaining CCE. However, implementation requires formal testing to ensure illumination goals are met while achieving optimal lighting design and placement within operational demands. Power capability with power utility panels (PUPs) must be achieved, and PUP use must be weighed against other competing power needs to meet operational requirements. Further testing in visual performance/color discrimination, flammability, frangibility, and off-gassing must be achieved. **RECOMMENDATION:** Concept of operations 1, providing 3-hours of pre-sleep lighting with automated COTS-DLS, is recommended for optimal crew circadian entrainment due to terrestrial studies that indicate capture of the entire wake maintenance zone.

Learning Objectives

1. To consider three concepts of operations for use of commercial off the shelf lighting onboard the Orion capsule for optimal crew circadian entrainment.
2. To consider advantages and disadvantages for use of commercial off the shelf lighting onboard the Orion capsule for optimal crew circadian entrainment.

[450] DEVELOPMENT OF A DIRECTED ACYCLIC GRAPH FOR VENOUS THROMBOEMBOLISM DURING SPACEFLIGHT

Alexander Svoronos¹, Travis Lambert², Robert Reynolds³, Karina Marshall-Goebel³, Erik Antonsen⁴

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(Original Research)

INTRODUCTION: Recent studies have reported the development of venous blood flow stasis in astronauts along with a case of occlusive venous thrombosis during spaceflight. Subsequent investigations revealed approximately one-quarter of surveilled crew members had some degree of blood flow stasis in the left internal jugular vein. Therefore, NASA’s Human System Risk Board now formally tracks venous thromboembolism (VTE) as a “concern” for human spaceflight. To investigate potential mechanisms by which exposures concomitant with spaceflight (e.g., microgravity, radiation) may contribute to VTE, we developed a causal diagram in the form of a directed acyclic graph (DAG). **METHODS:** The mechanisms by which spaceflight exposures may elevate the risk of VTE and the downstream effects on mission outcomes were critically analyzed, taking into account scientific literature and subject matter expertise consultation, and a DAG was generated. A Level-of-Evidence score for each causal relationship was assigned based on assessing the literature against a set of criteria derived from the A. Bradford Hill Causal Guidelines. **RESULTS:** The set of three main factors that predispose people to VTE (hypercoagulability, endothelial damage, and blood stasis) is known as Virchow’s Triad. In constructing the DAG for VTE we articulated various mechanisms by which the principal spaceflight hazards (microgravity, radiation, closed hostile environment, isolation and confinement, distance from Earth) are thought to interact with or cause the components in Virchow’s triad. We found sufficient evidence to at least speculate that fluid shifts from microgravity, compensatory alterations in hematologic indices, spaceflight atmospheric conditions, and oxidative stress/inflammation from radiation may be potential contributors to VTE development. **DISCUSSION:** Developing the DAG entailed a systematic and repeatable approach for visualizing relationships between contributing factors that may lead to VTE in spaceflight. Articulating pathways linking spaceflight exposures to VTE

risk factors and possible VTE development enables subject matter experts from different domains to construct a shared mental model. Assignment of levels of evidence scores to the relationships helps identify knowledge and capability gaps that should be considered for further investigation. Furthermore, the DAG highlights modifiable variables and may therefore facilitate the development of new VTE risk mitigation strategies.

Learning Objectives

1. The audience will gain an understanding of how exposures concomitant with spaceflight (e.g., microgravity, radiation, spaceflight atmospheric conditions) might influence the risk for venous thromboembolism.
2. The audience will gain an understanding of what directed acyclic graphs are and their utility in the assessment of spaceflight-associated risks.
3. The audience will be shown how the process of constructing a directed acyclic graph and assessing levels of evidence within the graph fosters critical insights that may reveal otherwise unrecognized mechanisms contributing to a spaceflight risk, along with knowledge and capability gaps, and Earth-based analogs for their assessment.

Thursday, 05/25/2023
Napoleon Ballroom A1-B3

1:30 PM

[S-81]: PANEL: EXTENDED REALITY APPLIED TO AEROSPACE MEDICINE AND HUMAN PERFORMANCE

Chair: Brennan Cox

PANEL OVERVIEW: The next generation eligible for careers in aviation and aerospace medicine will have grown up during a period in which immersive digital technologies transitioned from "pie-in-the-sky" concepts to commercially available, household staples. With dozens of eXtended Reality (XR) devices on the market, current and future users are busily exploring the realm of possibilities offered through Augmented, Virtual and Mixed Reality (AR/VR/MR). As the name implies, XR effectively extends reality by blending real world and computer-generated experiences, most readily with head-mounted devices. These tools are not just for entertainment, but also hold great promise for reshaping how we plan, execute, and understand the nature of complex tasks. As such, they are already being employed across aerospace, military, and medical environments for training, logistics, situation awareness, and human performance enhancement, among other applications. This invited panel provides five presentations on research and practical considerations of XR in areas of aerospace medicine and human performance. Using a human systems integration framework, panelists will incorporate the domains of human factors engineering, personnel, training, safety, and habitability in their discussions. The first presentation introduces XR devices, their unique characteristics and features, and how users should evaluate their overall utility. The second presentation gives insights on the use of XR for assessing individual differences and performance constructs that are difficult (if not impossible) to measure through traditional means, with applications to personnel selection and classification. The third and fourth presentations will focus on the training domain, to include meta-analytic evidence supporting transfer of training, as well as a case study on the operational use of XR for training student naval aviators. The final presentation will explore how XR can inform and enhance aviation safety and mishap investigations. This panel will conclude with audience discussion on the current state and future use of these technologies, with an eye toward the next generation.

[451] EVALUATING EXTENDED REALITY DEVICES

Mike Lowe

Naval School of Aviation Safety, Pensacola, FL, United States

(Education - Tutorial/Review)

INTRODUCTION: This presentation will provide an overview of extended reality (XR) and a multifaceted approach to evaluating XR

systems. Specifically, this lecture will identify technological components, system requirements, and Human Factors (HF) considerations that support successful employment of XR systems. **TOPIC:** Technological advances in virtual, augmented, and mixed reality (VR, AR, MR) has led to significantly more powerful, affordable, and lighter systems. As these technologies have matured, the term extended reality (XR) has become the nomenclature used to refer to any combination of VR, AR, and MR. These developments have led to XR being an increasingly attractive tool to support tasks such planning, training, rehearsing, and the conduct of operations. From aviation to maintenance to health care, XR has the potential to meet a variety of needs. To determine if XR is appropriate to meet these needs, it is critical that practitioners understand the technological and human centric requirements for assessing XR capabilities.

APPLICATION: As the confluence of the real and synthetic environments, the application of XR is dependent on users' ability to understand and operate in this blended space. While technological assessments within prescribed engineering specifications are relatively straightforward, HF considerations present challenges to the acceptance and utilization of many systems. XR is not immune. For example, it can be difficult to define and assess the immersion and presence required to facilitate the accurate perception and understanding of information presented in XR. Further, assessment of the performance of actions in a naturalistic manner in XR can be complicated and subjective. Ultimately, the successful evaluation of XR requires an interdisciplinary understanding and approach. The lecture presented here provides a framework that describes the unique characteristics and features of XR technology, and the HF considerations needed for comprehensive evaluations. From a technological perspective, the framework identifies capabilities such as tracking, controls, interactivity, design, and display requirements. From the HF perspective, the framework introduces concepts that explain physiological, psychological, perceptual, cognitive, and user acceptance considerations. Using both perspectives, the framework offers an actionable methodology to examine XR systems for a wide range of applications.

Learning Objectives

1. Participants will learn about specific technological requirements for XR systems.
2. Participants will learn about Human Factors and Human Computer Interaction considerations that must be considered when evaluating extended reality technologies.

[452] ASSESSING INDIVIDUAL DIFFERENCES AND PERFORMANCE IN VIRTUAL REALITY: APPLICATIONS FOR PILOT AND PERSONNEL SELECTION

Alexandra Kaplan, Brennan Cox

Naval Medical Research Unit-Dayton, Dayton, OH, United States

(Education - Program/Process Review)

BACKGROUND: Virtual Reality (VR) has the ability to evoke and measure human behaviors in ways that traditional assessments cannot. This is due to the immersive nature of VR as well as the ability to incorporate physiological measures directly into VR-based scenarios. The next generation eligible for careers in aviation and aerospace medicine has grown up in an era during which VR devices have expanded use beyond entertainment, to include use in organizational business practices.

One particular area in which VR holds practical utility is personnel selection, as VR provides a mechanism through which candidates can be exposed to job-relevant scenarios while both active and passive assessments of individual differences and performance may be obtained.

DESCRIPTION: VR provides a modality for measuring constructs that underlie the decision process behind a person's behaviors and responses. For instance, many VR devices include eye tracking capability, thereby enabling pupillometry assessments of gaze, scan, fixation, workload, and even stress state, with eye tracking data indicating which elements within the VR environment the person attends to, skips over or returns to, or outright ignores. These data can better inform personnel experts of candidates' decision-making processes, to include how easy or difficult

it was for them to arrive a decision/response. Such assessments would be especially useful in aviation, where success relies on skills involving psychological constructs that cannot be directly measured, such as fuzzy decision-making skills, prioritization strategies, and spatial reasoning. The more precise and scientific we are about measuring what is observable (e.g., time-to-decision, eye movements, pupillometry, hesitation, answer choices), the more inferences we can make about constructs that are *not* technically observable (e.g., decision-making strategies, stress-related performance decline) but give rise to observable behavior. **DISCUSSION:** A shortcoming of traditional testing methods is that the final answer does not reveal the person's decision-making process. Researchers in the assessment domain are rapidly investigating how psychological constructs such as testing strategy can be elicited via VR. This presentation will discuss published and ongoing research efforts and propose future directions for the use of VR as an assessment for pilot and personnel selection.

Learning Objectives

1. Participants will learn about the psychological constructs that VR can evaluate in personnel selection assessments that are not currently fully captured in traditional testing methods.
2. Participants will learn about physiological indicators that can be registered while a VR task is performed.

[453] THE USE OF XR-BASED TRAINING: META-ANALYTIC SUPPORT

Ben Sawyer¹, Alexandra Kaplan²

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(Education - Program/Process Review)

BACKGROUND: The value of Extended Reality (XR) as a training tool has been fiercely debated. While its benefits are numerous, the integration into existing training pipelines is sometimes questioned due to the possibility of negative transfer. Due to the training taking place in a different (virtual) environment compared to the eventual real-world performance, both the principles of encoding specificity and state-dependent learning indicate that training transfer may be impacted. However, recent meta-analytic efforts have shown that training transfer from XR is, on average, no lower than training transfer from other, more traditional training methods. When studies, and fielded technologies, underperform new research calls out the vital need for training in XR use, and human-centered design of XR technologies and platforms. **DESCRIPTION:** Transfer of training can be measured through the Transfer Effectiveness Ratio (TER) which examines the efficiency of time spent training in a virtual environment. Additionally, training effectiveness is often measured in straightforward real-world performance outcomes. Performance outcomes was the focus of a recent meta-analysis that supported the integration of XR technologies into training pipelines as an addition to in-person training, or a replacement wherever the inclusion enhances safety, reduces time needed, or conserves resources. However, not all XR training is created equally, and up-front investments in training users on the XR equipment, and XR human-centered design, pay dividends in superior outcomes. **DISCUSSION:** It has been quantitatively shown that XR-based training does not differ from traditional training methods in terms of TER. Therefore, benefits such as safety, financial, and time savings can and should be taken into account when XR interventions are being considered. The technology is not a panacea, and as with tradition training, up-front consideration of the tools used is vital to outcomes.

Learning Objectives

1. Participants will learn about the barriers to, and benefits of, integrating XR into training programs.
2. Participants will learn about the measurement methods for determining efficacy of new, technologically advanced training interventions.

[454] NAVAL AVIATION TRAINING NEXT: INTEGRATING XR TECHNOLOGY TO ENHANCE STUDENT TRAINING

Michael Natali

Naval Air Warfare Center Training Systems Division, Orlando, FL, United States

(Education - Case Study)

INTRODUCTION: With growing pilot shortages, the United States Navy (USN) is exploring new technologies and re-imagining training methodologies to create more efficient and effective aviation training. The rapid advancements in capability, utility, and fidelity of extended reality (XR) technologies are facilitating this innovation by providing low cost and immersive environments for learning. Under the term "Naval Aviation Training Next (NATN)", the USN is integrating XR technologies across its aviation training via experimental syllabi designed to capitalize on the advantages provided by these new tools. **BACKGROUND:** While integrating XR within training, an adage was quickly adopted: "New technology added to old training methods only equals more expensive training; but new technology integrated into a new training method can achieve more efficient training." XR technologies offer new and exciting capabilities but they are not a "silver" bullet that will fix a training system – they have to be leveraged appropriately to optimize their strengths and recognize their weaknesses. **CASE PRESENTATION:** NATN redesigned training around psychology-based principles to integrate XR technology. These "3 ½ Guiding Principles" provide the foundation that allows XR to enhance training: 1. Competency-based Training – guiding students towards mastering skills instead of just performing them via: Focus on underlying behavioral skillsets, not just specific aircraft technical skills; Students progress as they display competence in a skill. 2. Cyclical Learning – providing practice throughout the syllabus, cycling back to previously learned skills for repetition across a wider variety of situations. 3. Cohesive Cohorts – students grouped into small, cohesive cohorts with structured characteristics. 3.5 Technology Updates – integrating XR systems. **DISCUSSION:** By adopting these principles, the Navy has been able to leverage benefits provided from XR such as tailored learning, higher repetition, greater training immersion, and improved skill mastery. Studying results of the operational use of the NATN methods with XR technology shows students are reaching equal or better performance in less time, with fewer flight hours, while attempting more difficult events, i.e., NATN training is more effective and efficient. These positive findings demonstrate that by integrating new technologies with new methods, the Navy is now producing better aviators.

Learning Objectives

1. Participants will learn about the development and need of new methods based in psychology-based learning principles for leveraging extended reality benefits for training.
2. Participants will learn about how extended reality has been adopted in aviation training and how it has affected student performance.

[455] THE USE OF EXTENDED REALITY TECHNOLOGY IN AVIATION MISHAP INVESTIGATIONS: CONCEPT IN PRACTICE AND TRAINING

Michael Lowe, Eric Carroll

Naval School of Aviation Safety, Pensacola, FL, United States

(Education - Program/Process Review)

BACKGROUND: The Naval School of Aviation Safety (SAS) is an echelon three command under the Naval Safety Command and is the training command for educating Aviation Safety Officers (ASO) and leaders in several areas of safety, including hazard identification, risk management, mishap investigations, reporting and how to develop the Safety Management System in their squadron or wing. A key

function that SAS serves is with fleet support regarding all aviation safety matters. A necessary, though unfortunate, portion of SAS's instructional time is on the mishap and its immediate aftermath. With the maturing of extended reality technology, two areas that could lend itself quite efficiently when focusing on aviation mishaps will be discussed. **OVERVIEW:** Extended reality can enhance Aviation Safety directly in two ways. The first way is the investigation of mishaps. Often, a limited number of officials are allowed at mishap sites due to a variety of reasons, such as safety and inaccessibility. In those cases, the members of the Aviation Mishap Board (AMB) are relegated to photos and videos of the crash site as the only means to visualize and develop a mental model of what occurred. The second way comes once we achieve this capability. Previous mishaps can be fully utilized when training our ASOs in-house. SAS already has a physical "crash lab" where students can walk around previous mishaps, gaining insight on a factor or series of factors leading to the mishap. But benefit is limited as the mishap is a recreation in a sterile hanger environment. **DISCUSSION:** Recent mishaps have demonstrated the usefulness of drones to collect key and vital information regarding the mishaps and can even help inform the timeline immediately before the mishap. With this data becoming more readily available and combining it with other data, such as the flight data recorder and other aircraft performance measures, the natural next step would be to create a virtual environment where the AMB member can step immersively into the scene. With the enhancement that the various extended reality capabilities can offer, these educational opportunities can be fully maximized, producing better trained and prepared safety professionals.

Learning Objectives

1. Participants will learn about the conceptual use of Extended Reality in Aviation Mishap Investigations.
2. Participants will learn about the potential use of Extended Reality in the education and training domain for Aviation Safety Officer Certification in the Safety Management

Thursday, 05/25/2023
Nottoway & Oak Alley

1:30 PM

[S-82]: POSTERS: SPACE MEDICINE POSTERS 2

[456] FLIGHT SURGEON SURVEY RESULTS REVIEW: LONG-DURATION ARTEMIS MEDICAL SYSTEM CONOPS

Takuma Ishibashi¹, Andrew Bushong², James Locke³, Christopher Haas³

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(Education - Program/Process Review)

BACKGROUND: The Artemis Mission Functional Medical Concept of Operation (ConOp) is an operational document that describes the functional medical capabilities and concept of operations for early Artemis missions of around 30 days duration. It is currently under revision for longer missions (180+ days), aiming to build a foundational diagnostic and treatment capabilities list considering mission parameters, crew selection and training, and mass/volume constraints. An interview of NASA operational flight surgeons was completed to start the revision of the medical ConOp. **METHODS:** In the survey, 20 experienced NASA flight surgeons responded to 57 standardized questions covering 17 categories, 22 questions of which were covered in this analysis including 4 categories: Cardiovascular, Catastrophic Situations, Pulmonary, and Respiratory/O2 Support. These results were categorized into recommendations and observations. The recommendations were used

to objectively quantify the responses to look for consensus, differences and uncertainty among responses. The observations remain important but were not included in this review. **ANALYSIS:** Regarding questions related to changes in medical conditions treated for long-duration missions, percentage of "No Change" responses varied from 20% to 75%. In the "Change" treatment plan responses, a variety of recommendations were made, which were further analyzed through graphical analysis. Additionally, recommendations on capability questions in multiple systems were visualized within one product. **DISCUSSION:** This work demonstrates the importance of collaboration and thorough analysis amongst experienced NASA flight surgeons to help establish medical systems and contributing to the likelihood of mission success during Artemis long-duration missions. Through this review analysis, we were able to identify some positive attributes and areas for improvement, which will facilitate further discussions.

Learning Objectives

1. The audience will learn about collaborative and comprehensive approach for helping establish medical systems during Artemis long-duration missions.
2. The participant will be able to understand the importance of a systematic approach to objectively quantify NASA flight surgeon interview responses to look for consensus, differences and uncertainty.

[457] PERCUTANEOUS CHOLECYSTOSTOMY TUBES AND LONG DURATION SPACEFLIGHT

Margaret Siu¹, Dana Levin², Tovy Kamine¹

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(Original Research)

INTRODUCTION: Cholecystitis is one of the most common surgical pathologies, with an incidence of 1 in 10 people presenting with an infected gallbladder in their lifetime. Cholecystectomy is the mainstay treatment. However, modalities such as antibiotics and percutaneous cholecystostomy tube placement have been proposed as definitive alternatives in environments where surgery maybe limited, such as space travel. We reviewed the outcomes of percutaneous cholecystostomy tube (PCT) placement to assess the utility of the procedure during spaceflight.

METHODS: A literature review involving 30 peer reviewed articles was completed to describe the use of PCT, its efficacy, and patient outcomes following procedure. We evaluated benefits, or lack thereof, for PCT during space flight. **RESULTS:** Terrestrially, the main indication for PCT placement is inability to tolerate cholecystectomy. Symptoms usually resolve within 4 days following placement, with concomitant antibiotic administration. Mean tube indwelling time was approximately 71 days. Cholecystitis recurrence rate was 15% at 2 months following PCT placement. Complication such as mortality from sepsis, hemoperitoneum, and tube malfunction ranged 39-46%. There is no consensus on optimal timing of tube placement. On average, 32.9% of patients required cholecystectomy. **DISCUSSION:** Long term success rates of PCT for cholecystitis is poor, as patients continued to require antibiotics and the high rates of recurrence without subsequent cholecystectomy. In cislunar space, the return to Earth for definitive procedure maybe achieved even prior to completion of required antibiotics dosage needed with PCT. However, with missions to Mars, PCT is most likely inadequate. Surgical capabilities and expertise should be seriously considered for long duration spaceflight.

Learning Objectives

1. The audience will understand the utility of percutaneous cholecystostomy tubes and outcomes associated with its placement.
2. The audience will understand the benefits of cholecystectomy over percutaneous cholecystostomy tubes during spaceflight.

[458] EVA DATA AND ASSOCIATED MEDICAL EVENTS IN THE PUBLIC DOMAIN

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(Original Research)

INTRODUCTION: Since 1965, NASA has conducted Extravehicular Activities (EVA) in Earth's orbit, transEarth, and on the lunar surface. Astronaut medical events are commonly caused due to activities performed during an EVA and the EVA suit itself. Currently, no comprehensive database is dedicated exclusively to EVA-related medical events, but information exists in other sources. **METHODS:** Study data were collected from publicly available sources including: NASA Historical Archives, Existing Databases, Publications, Oral histories, Astronaut Biographies and Astronaut Debriefs. To address credibility, we created a 4-question credibility tool to assess the quality of sources used in this study. This tool was modified from existing DISCERN and Stanford Credibility tools, and produces a credibility score ranging from 1 (low credibility) to 3 (highly credible). **RESULTS:** EVA medical information from the Gemini, Apollo, and Skylab missions were found using public domain sources. We identified 23 medical events during these three eras. Resources such as the NSSDCA were scored at a 3 (high reliability), while other sources, such as Spaceflight Now or Space.com, were ranked as a 2 and 1 (low reliability), respectively. EVA medical sources such as Scheuring et al., Diaz et al., and Ramachandran et al. ranked at 2.5. Overall sources used had a combined mean rank of 2.7. MSK injuries are the most common and frequently reported issues. Injuries were predominantly on the hands, feet, shoulders and arms. Lunar surface medical events were predominantly MSK in nature, but instances of tachycardia, and tachypnea were also reported during lunar excursion. The incidence rate of MSK injuries from 1965 to 2009 was 0.26 injuries per EVA, with the EVA suit being the second most common cause on injury. **DISCUSSION:** Initial data is comprehensive, but questions remain on data validity due to the relationship between astronauts and flight surgeons. Astronauts may withhold information for fear of putting flight status in jeopardy. This is evidenced by recorded instances of crewmembers experiencing in-flight medical events but not disclosing these instances until retirement. Following Skylab, EVA medical information, was much more challenging to obtain likely due to federal protections of medical information, such as The Privacy Act of 1974 and the Health Insurance Portability and Accountability Act of 1996. However, these laws do not protect deceased astronauts.

Learning Objectives

1. The audience will learn about common medical events experienced by astronauts during extra vehicular activity.
2. The participant will be able to understand the risks associated with future lunar excursion events and possible mitigation strategies.

[459] SPACE RADIATION INDUCED CARDIOVASCULAR INFLAMMATION & COAGULATION VIA PROTEOMIC ALTERATIONS

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(Original Research)

INTRODUCTION: The exact health implications of prolonged exposure to space radiation, known as Galactic Cosmic Rays (GCRs) is largely unknown in humans. Previous studies utilizing mono-energetic components of GCRs displayed minimal cardiovascular degeneration in mouse models long-term. Efforts in future investigations to mimic the space radiation environment through exposure to sequential GCR components resulted in increased damage to the cardiovascular system than individual components. This study exposed healthy mice to simplified GCR_{5-ion}, and aims to acquire a mechanistic understanding of how space

radiation alters cellular processes that may result in cardiovascular inflammation & ultimately coagulation via proteomic alterations in the plasma of experimental mice. **METHODS:** The plasma of male C57BL6 mice that were exposed to 150cGys of GCR_{5-ion} at the NASA Space Radiation Laboratory (NSRL) at Brookhaven National Laboratories were analyzed at 8 months post radiation by quantitative mass spectrometry (n=10) and compared to the plasma of sham-irradiated mice. Differentially Expressed Proteins (DEPs) were identified, filtered for significance, and then analyzed based on fold change (FC). **RESULTS:** In the plasma, 456 proteins were identified, and 4 of those proteins were perturbed to a level of statistical significance using an adjusted p-value. The proteins with a FC ≥ 2 were Major Urinary Protein 20 (MUP20), Serum Amyloid A-1 (SAA1), and Glutathione S-transferase theta-3 (GSTT3). Proteins perturbed to a level of statistical significance using an unadjusted p-value with a FC ≥ 2 were various immunoglobulin components and enzymes that function in numerous metabolic pathways. **DISCUSSION:** Upregulation of SAA1, an acute phase reactant that is a known biomarker in inflammation, may indicate chronic inflammation in the vasculature. Perturbed enzymes that function as mediators within the citric acid cycle, fatty acid synthesis, xenobiotic metabolism, and inflammatory processes may indicate oxidative stress and activation of various defense mechanisms. These findings allude to irreversible alterations in the vasculature after GCR_{5-ion} exposure that may increase risk of thrombus development, and may provide clarity on the health risks of prolonged exposure to space radiation in humans.

Learning Objectives

1. The audience will understand and be able to identify key cardiovascular protein groups and pathways that are perturbed in the plasma after exposure to space radiation.
2. The participant will be able to understand the potential cardiovascular risks posed to humans after exposure to space radiation.

[460] VALIDATION OF AN AUTOMATED PUPILLOMETRY DEVICE IN A MICROGRAVITY ENVIRONMENT

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(Original Research)

INTRODUCTION: Quantitative pupillometry examining pupillary constriction velocity and pupillary light reflex is emerging as a rapid, non-invasive, easy-to-use, and reliable marker of increased intracranial pressure. Automated pupillometry allows reliable and quantifiable assessment of pupillary function which may allow rapid diagnosis of intracranial pathology that affects clinical decision making. The Spaceflight Associated Neuro-ocular Syndrome (SANS) is a constellation of findings affecting intraocular pressure, intracranial pressure (ICP), optic disc edema, globe shape, and more. Per our review, automated pupillometry has been suggested, but not yet deployed in spaceflight as a surrogate measure for ICP. It is hypothesized that daily pupillometry measurements pre and in- and post-flight might serve as an early surrogate of SANS-related changes in spaceflight, and might aid in the development of future countermeasures in the management of SANS. In this study, we demonstrate the first-ever deployment and validation of the Neuroptic^(TM) handheld pupillometer in the microgravity environment during parabolic flight as a first step, with follow-on plans for deployment in commercial orbital spaceflight. **METHODS:** The automated pupillometer underwent standard payload integration, hazards analysis and modification so as to be compatible within the microgravity environment. The crew underwent ground testing as to obtaining measurements in the 1g environment, and was then briefed as to the parabolic flight pupillometer procedure for retrieval, power-on, positioning, measurement, power-down and

stowage. The crew then performed the pupillometry procedure in flight. **RESULTS:** The pupillometer was successfully deployed within the microgravity environment during parabolic flight. Pupillometry measurements were successfully obtained. Debris shedding from foam and plastic material from the device was not an issue. **DISCUSSION:** Based on the results of this demonstration, the NPi-300 pupillometer can successfully be used within the microgravity environment to obtain measurements in pupillary latency. The pupillometer will be deployed on upcoming commercial orbital flights to obtain regular pupillometric measurements to serve as a surrogate marker of ICP changes pre, during, and post-flight.

Learning Objectives

1. To educate the audience about the value of automated pupillometry as a potential tool for intracranial pressure (ICP) monitoring during spaceflight as a surrogate marker for the Spaceflight Associated Neuro-Ocular Syndrome (SANS).
2. To educate the audience as to the results of the first deployment and validation of an automated pupillometer in a microgravity environment.
3. To educate the audience as to next steps for deploying pupillometry during orbital spaceflight as a potential monitor for ICP and SANS-related changes during spaceflight.

[461] LSAH EVIDENCE FOR THE TREATMENT AND PREVENTION OF SPACE MOTION SICKNESS

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(Original Research)

INTRODUCTION: On average, 84% of astronauts report experiencing symptoms of space motion sickness. These symptoms are most prevalent in the first 72 hours after a transition in gravity. Symptoms commonly include nausea and vomiting (86%), anorexia and poor appetite (78%), headache (64%), stomach awareness (61%), and malaise (58%). To date, there have not been any standardized agency guidelines on the treatment of space motion sickness (SMS), or for its prophylaxis, despite its prevalence in space travel and its risk towards mission and crew.

METHODS: De-identified data from the Lifetime Surveillance of Astronaut Health database was compiled for all astronauts comprising shuttle and ISS crews. This data was analyzed for symptoms of space motion sickness, which medications were used for treatment, how effective those medications were at symptom relief, and what, if anything, was given for prophylaxis. **RESULTS:** Of 8449 LSAH entries of space motion sickness symptoms between ISS and Shuttle missions, 79% of astronauts were either treated for SMS symptoms or were given prophylactic medications to prevent symptoms. A total of 102 astronauts (15% of the total) were considered repeat fliers, with 45 (44%) of the 102 reporting less significant SMS symptoms on their second flights compared to their first. Effectiveness was judged on a spectrum that included very effective, effective, moderately effective, somewhat effective, not effective, and unknown. Medication effectiveness for treatment of SMS symptoms and prophylaxis against SMS symptoms were compared based on the percentage of their total doses given that were each level of effectiveness. Phen/Dex 50mg/5mg, and Ondansetron all had 100% of their given doses leading to very effective prophylaxis, with Meclizine having 59.3% of its doses leading to very effective prophylaxis. However, Meclizine represented the highest percent of all very effective prophylactic medications at 39%. For treatment, Phen/Dex 12.5mg/2.5mg and Scopolamine 0.4mg were both very effective with 100% of their doses. Meclizine was very effective with 43.8% of all its given treatment doses. **CONCLUSION:** Based on these findings, Meclizine may be the most effective medication for preventing space motion sickness symptoms, while Promethazine was most effective at treating already present symptoms. However, Promethazine can lead

to mission-impacting side effects that are best mitigated by combining Promethazine with Dexamphetamine in combination.

Learning Objectives

1. Treatment for space motion sickness in astronauts based on efficacy of prior treatment in Shuttle and ISS astronauts.
2. Prophylaxis space motion sickness in astronauts based on efficacy of prior treatment in Shuttle and ISS astronauts.
3. Background information on prior research regarding space motion sickness, including causes, on-Earth analogues and treatments.

[462] VENOUS GAS EMBOLISM: REVIEW TO QUANTIFY A SAFE VOLUME OF AIR IN INTRAVENOUS FLUIDS BAGS FOR SPACEFLIGHT APPLICATIONS

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(Original Research)

INTRODUCTION: The ability to create intravenous fluids (IVF) in-situ from the potable water supply of a spaceflight vehicle or habitat is a desired capability for an exploration medical system. In order to define an acceptable volume of air in IVF bags, an understanding of the volume of venous gas embolism as it relates to negative outcomes is needed. The purpose of this study is to review the literature to determine if there is a known minimum volume of gas that contributes to mortality and/or morbidity that could be used to define requirements for rapid IVF infusion in microgravity. **METHODS:** A literature review was conducted of the PubMed database using the syntax: (Venous) AND (Gas OR Air) AND (Embolism) AND (Morbidity) AND (Mortality) AND (Volume) as well as manual review of references from relevant articles. 151 articles were screened excluding partial text and pediatric articles. Studies were reviewed for identification of volume of venous gas embolism associated with morbidity and/or mortality, which identified 27 articles. **RESULTS:** Reviewed literature included animal studies, case reports, and review articles. A high variation of proposed volumes contributing to mortality was reported. The limited human data values ranged from 20 ml to 200 ml of infused air with mortality estimated to be 48 – 80%^{3,4,5}. No studies evaluated human morbidity in any capacity. **DISCUSSION:** The lack of consensus on the safe volume of infused air has potential ramifications for IVF use in spaceflight as current technologies to create IVF from potable water may introduce air in IVF bags. While current microgravity infusion protocols call for the use of inline air removal filters, commercially available options have flow rate limitations that preclude rapid infusion in a resuscitation scenario. Such filters may be used in parallel to increase flow rate, but the time required to set up such a system may exclude its use during a medical emergency. Additionally, these consumable filters drive up the overall mass and volume of the medical system. Identification of a safe volume of air threshold in IVF would allow for guidelines for the in-situ production of IVF in future spaceflight vehicles/habitats.

Learning Objectives

1. The audience will understand the current limitation in fundamental understanding of air embolism during IVF infusion in spaceflight.
2. To promote study of mortality AND morbidity as it relates to volume of venous gas embolism as it will have considerable impact on resuscitation protocol in future spaceflight.

[463] 3D-PRINTED, NEGATIVE-PRESSURE NASAL GUARD TO CAPTURE AEROSOLS GENERATED DURING IN-FLIGHT NASAL SINUS AND SKULL BASE SURGERIES

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(Original Research)

INTRODUCTION: Body fluid containment presents a challenge in microgravity. Immune dysregulation, compact co-habitation and reduced clearance of environmental aerosols complicate the risk of infectious transmission during in-flight surgery, especially in the setting of aerosol-producing procedures. A number of surgical adjuvant devices has been proposed to contain body fluid from injuries or procedures with open body cavities, including the Aqueous Immersion Surgical System. However, head and neck surgery presents additional challenges given its proximity to the airway. We have designed a 3D-printed, negative-pressure device that affixes over the nose to capture aerosols generated during nasal sinus and skull base surgeries. **METHODS:** The device was designed using Solidworks modeling software and subsequently 3D-printed in durable resin. The ergonomics of the device were improved through iterative design with qualitative feedback from surgeons. The efficacy of aerosol capture was interrogated *in silico* through a Solidworks Flow Simulator model. The particles were simulated as 5 μm water droplets in air with a forward velocity of 4.5 m/s and a vacuum pressure of 16 kPa. The device was also tested in real-world, terrestrial conditions where aerosolized water was generated in the oropharynx of a mannequin and forced through the forward openings at speeds mimicking off-shoot from surgical debridement. The mass flux of aerosol escape from the device was measured using high-speed particle velocimetry. **RESULTS:** The device consists of two parts: a rigid, resin-based shell with an internal vacuum chamber encircling forward-facing instrument ports and a moldable, silicone gasket to form a seal against a patient's face. Particle velocimetry demonstrated near undetectable levels of mass flux from the forward opening when the vacuum was on compared to the control condition with the device off. The *in silico* simulation agreed with the real-world test. **DISCUSSION:** The device is a promising, low-cost intervention that works at the source to reduce the amount of aerosol released into the environment during in-flight head and neck surgery. Future work includes cadaver-based testing with device-naïve surgeons for more formalized ergonomic assessment and higher-fidelity simulation using actual debridement and drilling to generate aerosols. Future testing in parabolic flight could provide insight into the effects of microgravity currently explored only by simulation.

Learning Objectives

1. The viewers will be able to understand the challenge of body fluid containment in microgravity and the risk of infectious transmission via aerosols.
2. The audience will be able to describe a novel device to reduce the amount of aerosol emission generated by in-flight nasal sinus and skull base surgery.

[464] SIMULATING SPACE RADIATION-INDUCED CHANGES IN CARDIOVASCULAR BLOOD FLOW

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(Original Research)

INTRODUCTION: Participants in space flight missions are exposed to significantly higher doses of ionizing radiation than on Earth, damaging vascular endothelial cells and leading to cardiovascular diseases. The effects of radiation on blood vessels can be analyzed through computational modeling. Previous vascular simulations are limited in size or neglect integral components such as radiation damage and blood flow. We have developed a multi-scale methodology to model structural changes to vessels in the human heart after whole-body irradiation. **METHODS:** The vascular geometry is constructed by a fractal algorithm to generate 3-dimensional scalable vessel networks. Radiation transport is simulated with an amorphous track-structure method to model dose deposition from protons and secondary particles, mimicking the space radiation environment. The biological response of the vessels is modeled to fit experimental data. The resulting changes in blood flow are then calculated utilizing a special case of the Navier-Stokes equations, known as the Poiseuille equation. **RESULTS:** Preliminary results from

our laboratory have shown the computational feasibility of calculating blood flow in a network of 17 billion vessels, approximately the size of the human body. We have also shown the feasibility of demonstrating injury in single organ systems from 2 million protons, and the relative changes in blood flow. Changes in vessel radii varied from a 5% increase to complete closure, leading to large blood flow changes in the entire network. Computations in a 128-node high performance computer cluster has an execution time of 87-CPU hours. **DISCUSSION:** Our preliminary results have shown the feasibility of demonstrating radiogenic changes in cardiovascular models. The systemic flow disruptions from small vessel injury indicates the significance of blood flow on radiation-induced cardiovascular response. Building on our current model, we plan to integrate dynamic time scales and non-local continuum methods to further analyze the effects of space radiation damage on the vascular system. Future studies in this line of research can help to understand and even prevent deleterious results of space radiation, such as coronary artery disease, atherosclerosis, and ischemic heart disease.

Learning Objectives

1. The audience will be able to understand the effects of space radiation damage on cardiovascular blood flow.
2. The audience will learn about biophysical modeling and radiation transport simulations.
3. The audience will learn about the radiobiological response of blood vessels in the space radiation environment.

[465] SURGICAL DISCIPLINES IN LONG-TERM SPACE FLIGHT

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(Education - Program/Process Review)

BACKGROUND: The new paradigm of long-term space flight rendered surgical capabilities ever more important. The goal is to go beyond the Lunar Gateway, explore outer space and make humanity a multi-planetary race by reaching Mars. During deep space travel, several factors will affect crew health, therefore mission success. Both surgical necessities and capabilities will differ from LEO (Low Earth Orbit). In addition to the microgravity encountered in LEO, long-term missions will pose the challenges of sustained radiation, and the lack of available support and equipment. **OVERVIEW:** A survey of the existing scientific literature considering the potential medical conditions that are likely requiring surgical care was conducted to estimate the relevance of surgical disciplines in preparation for future long-duration missions and to develop an integrated surgical model. Due to the long-term exposure of pathological extraterrestrial environments and factors like microgravity or radiation, a great variability of medical cases may be presented, involving a broad spectrum of surgical disciplines. Based on the severity of the manifestation, adequate conservative care may be a curative solution, however some of these conditions can develop alarming, life-threatening symptoms that will require surgical intervention either under local or general anesthesia in order to reduce morbidity or even mortality. **DISCUSSION:** This individual thorough survey of the relevant published papers to state diversification of potential on-board operative or non-operative surgical conditions from 2004 - 2022; 48 potential surgical conditions were identified: 13 cases general surgery (27.08%), 9 cases trauma-orthopedic surgery (18.75%), 5 cardiac surgery (10.41%), 3 thoracic surgery (6.25%) and other disciplines: 19 cases. Consequently, the importance of well-trained surgical specialists during long-term space flight is a crucial part of the mission. As long as robot assisted telesurgery is unavailable in space, –based on our analysis–, 4 out of the top 5 surgical conditions that are most common and most likely to occur in space (cholecystitis, appendicitis, cataract, breast lesions and abdominal wall hernia), can be treated by a general surgeon. Onboard surgical expertise will be an absolute necessity for the improved safety of future deep space missions.

Learning Objectives

1. The audience will learn about the great variety of the potential surgical cases, their pathophysiology and the surgical disciplines that may be needed for adequate medical care.
2. The listener will be able to gain a broader understanding on potential surgical specialties/knowledge necessary on a long-term mission and the surgical disciplines most needed to reduce morbidity and mortality.
3. The participant will learn about a proposed training curriculum/disciplines necessary for the potential specialty of Aerospace Surgery.

[466] INFLUENCE OF THE ACTN3 GENE ON MUSCLE HEALTH AND PHYSICAL FITNESS TO INFORM FUTURE INTERVENTIONS IN SPACEFLIGHT MISSIONS

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(Education - Tutorial/Review)

INTRODUCTION: Exposure to reduced gravity environments leads to diminished muscle size, strength, and endurance. Preservation of physical fitness is critical for mission essential tasks such as extravehicular activities, adaptation to changes in gravity loads, and crew egress from spacecraft. Current countermeasures to maintain ISS astronauts' muscle mass and fitness include dedicated time for a combination of cardiovascular exercise and resistance training. Countermeasure effectiveness is monitored before, during, and after missions. It is important to understand both environmental and genetic contributors to astronaut physical fitness. Multiple genes, including ACTN3, are known to correlate with exercise phenotypes and have the potential to help personalize countermeasures based on an astronaut's genotypic makeup. **TOPIC:** The ACTN3 gene encodes a protein expressed only in fast-twitch muscles and correlates with sprint and power phenotypes. A common polymorphism in ACTN3 gene is R577X (rs1815739), produced by a C-to-T base substitution, resulting in a nonsense mutation from arginine (R) to a premature stop codon (X) present in approximately 18% of the population. This polymorphism causes an absence of α-actinin-3 in type II muscle fibers but does not lead to a disease phenotype. The RR genotype is associated with elite athletes, especially in sprint and power sports. The XX genotype is believed to be more common in endurance athletes. The ACTN3 gene also has potential associations with training adaptation, post-exercise recovery, and exercise-associated injuries. **APPLICATION:** Understanding how ACTN3 and other genetic determinates of fitness phenotypes affect astronaut physical performance can inform personalized exercise and recovery prescriptions. For example, individuals with the RR or RX genotype may respond better to high-load and low repetition exercise, while XX may benefit from high repetition with low weight exercise. Since the wild-type protein may confer more resistance to muscle damage, those individuals with the RR or RX genotype may benefit from high intensity interval training for improved VO₂ max, whereas those with an XX genotype may benefit from low intensity, high volume endurance activity. Additionally, omics data related to health and performance could be used as biomarkers to monitor astronaut fitness and the effectiveness of training regimens during a mission.

Learning Objectives

1. Learn about the phenotypic effects on muscle function and fitness secondary to R577X mutation in the ACTN3 gene.
2. Learn how mutations in the ACTN3 gene may inform future countermeasures for future spaceflight missions.

[467] DOES SKELETAL DEVELOPMENT DURING SPACEFLIGHT RESULT IN LONGER BONES?

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(Original Research)

INTRODUCTION: Endochondral ossification is an important biological process in determining the size, shape, and mechanical strength of adult long bones that is affected by mechanical loading¹. However, how unloading could alter the development of long bones is unclear. The purpose of this study was to determine the potential effects of long bone development of growing rodents experiencing unloading from spaceflight. The primary hypothesis of this study was that spaceflight animals would have longer bones as compared to their age and sex matched ground controls. **METHODS:** Male Sprague Dawley rats were exposed either to ground or spaceflight conditions during STS-40 and STS-58 missions for 9 and 14 days respectively. At the time of launch, the rats were aged 8 weeks and 5 weeks old respectively. Rodent bones were harvested postflight and length of humeri, femora, and tibiae was determined by caliper. Groups were compared using a student's t-test. An average, standard deviation, and percent difference was also calculated. **RESULTS:** No significant differences were found between the length of humeri, femora, and tibiae of spaceflight animals as compared to ground control animals. On average the bones of the spaceflight group were longer than the ground controls. The percent difference of the spaceflight group ranged from +1.2 to +2.1% as compared to the ground control group.

DISCUSSION: The primary hypothesis of this study was not supported as the spaceflight animals did not have statistically significant longer bones as compared to their age and sex match ground controls. Despite of this, the finding that the spaceflight animals consistently had longer bones from a relatively short exposure to unloading may mean that longer durations would demonstrate an appreciable difference. Future work should examine not only length but other osteologic parameters.

Learning Objectives

1. How the skeleton may develop differently during spaceflight conditions at different periods of life (before vs after skeletal maturity)
2. Using NASA's Life Science Data Archive (LDSA) to conduct space medicine research

[468] CONSIDERATIONS FOR PNEUMOTHORAX MANAGEMENT IN EXPLORATION SPACEFLIGHT

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(Original Research)

INTRODUCTION: On the spectrum of chest injury that could occur during human spaceflight, pneumothorax is a serious but potentially treatable condition. Pneumothorax can be diagnosed with high fidelity using ultrasound, an imaging modality anticipated to be available on a remote exploration mission such as to Mars. Treatment strategies for this condition have been outlined for low Earth orbit and lunar platforms, but there are additional challenges presented by the resource and communication limitations of an exploration mission. **METHODS:** Terrestrial standards of care for traumatic and spontaneous pneumothorax were reviewed including the utilization of imaging for diagnosis and treatment. Reports of diagnosis and treatment of pneumothorax in austere environments were additionally considered. Available versions of International Space Station (ISS) Integrated Medical Group (IMG) Medical Checklist were evaluated for relevance of treatment plans for low Earth orbit to exploration missions. **RESULTS:** The likelihood of traumatic pneumothorax is low but increases with time of mission and potentially with the introduction of partial gravity. Primary spontaneous pneumothorax is generally thought to be of low incidence among a highly screened crew. Observation for small pneumothorax, followed by needle aspiration for large or symptomatic pneumothorax, remains a viable strategy for treatment of this condition in human spaceflight. Adjuncts for larger pneumothorax or in the case of persistent or rapid reaccumulation of air must be considered against mass and volume restrictions of the medical system. There is some evidence that ultrasound is well equipped to determine not only presence or absence of pneumothorax but also

reliably predict volume of lung collapse. **DISCUSSION:** The increasing constraints of mass and volume on an exploration mission significantly impact how far treatment options will deviate from terrestrial standard of care. Further characterizing the capabilities of ultrasound to reliably indicate the degree of lung collapse would be worthwhile as this could increase likelihood to observe and may assist with surveillance of known pneumothorax.

Learning Objectives

1. Understand how limitations in the medical system influence the pneumothorax management in human spaceflight, especially with regards to exploration missions.
2. Appreciate the gaps in knowledge that if filled would improve planning for management of pneumothorax on exploration missions.

[469] THE UNIVERSITY OF MINHO'S SPACE MEDICINE COURSE - LESSONS AND OUTCOMES

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(Education - Program/Process Review)

BACKGROUND: The future of Space Medicine will encompass a set of new challenges that we have not yet faced in these 60 plus years of human spaceflight, from the increase in accessibility that comes with commercial spaceflight to the exploration of deep space. There is a need for the development of this field, not only to address these challenges, but also to its relevance for life on Earth. This can be exemplified by the transversality of medical knowledge between the space context and intensive care patients, the use of spinoffs in our daily life, and space technologies and data for health and humanitarian purposes, to name a few. There is no denying that a try for space medicine research translates into benefits for a variety of different fields. In an effort to tackle these issues, a strive for the younger generations must be undertaken, in order to provide the needed critical mass that pushes for new initiatives and attracts funding. **DESCRIPTION:** The School of Medicine of the University of Minho's Space Medicine Short-Course (EM-UM SMSC) was created with the aim of providing students with the fundamental medical knowledge applied to the (aero)space context, as well as the impact and usefulness of Space Exploration to the life and health on Earth. The overall structure of the course consists of one week of concept introduction, composed of 45-60 minutes classes, culminating in an evaluation at the end of the week, followed by three weeks dedicated to the ideation of an academic and/or entrepreneurial group project, culminating in a presentation of the work before a jury. **DISCUSSION:** The first edition of the EM-UM SMSC was implemented between the 14th of November and the 9th of December of 2022. With this presentation, we describe the intricacies of the course, the challenges that our team faced, what went well and where there is room for improvement, as well as some of the projects thought-out by our students, detailing the different stages of development achieved.

Learning Objectives

1. The audience will learn about the Space Medicine Education efforts being undertaken in Portugal and at the University of Minho.
2. Participants will have the chance to understand some of the challenges that come with implementing such a program.
3. The audience will have the chance to learn about some of the project thought out by our students.

[470] OTOLITH FUNCTION AND COGNITIVE PERFORMANCE IN COMMERCIAL SPACEFLIGHT

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(Original Research)

INTRODUCTION: Human spaceflight involves the simultaneous response to multiple stressors. Astronauts are often the subjects of biomedical studies, but these are rarely examined for synergies reflecting the interaction of various adaptive processes. **METHODS:** Two sets of studies, Ocular Alignment and Cognition, were performed by 4 civilian astronauts on the Inspiration4 mission before and after spaceflight. Ocular Alignment, a measure of otolith asymmetry, is assessed with perceptual nulling to determine vertical and torsional skew. Cognition is a battery of 10 tests spanning cognitive functions including risk-taking, emotion recognition, memory, spatial orientation, vigilant attention, and abstract reasoning. We performed mixed-effects analyses of the relationships between Cognition and Ocular Alignment scores, response times, score shifts pre- to post-flight, and space motion sickness (SMS). **RESULTS:** Spaceflight and SMS were significantly associated with performance changes from pre- to post-flight on a combined 8 of 12 Alignment and Cognition tests. Similar measures of relative spatial orientation from Alignment and Cognition yielded different outcomes: while spaceflight reduced (improved) torsional misalignment by 0.31 degree ($p=0.017$), it decreased performance in the Cognition test of Line Orientation (0.95 StD decline, $p=0.014$). Directly comparing Alignment and Cognition, each degree of increased vertical skew from pre to post flight was associated with a decrease in time to complete individual Cognition tests by 0.92 StD ($p=0.056$). Furthermore, each degree of increased vertical skew was associated with an increase in individual Cognition test accuracy of 1.15 StD when looking at all 4 astronauts ($p=0.030$). This effect was driven by those with SMS (1.23 StD increase for vertical skew ($p=0.050$), 1.55 for torsional ($p=0.050$)) rather than those without. **DISCUSSION:** While SMS and spaceflight are associated with changes in Ocular Alignment and Cognition performance, comparisons between tests are important to validate results when measuring similar outcomes especially given the small sample size of astronaut studies. We find that change in ocular skew from pre- to post-flight is associated with improved Cognition performance and hypothesize that larger changes in ocular skew reflect greater vestibular adaptation to spaceflight. Further testing is needed to elucidate SMS associations with vestibular adaptation, ocular skew, and Cognition performance.

Learning Objectives

1. The participant will learn about the importance of adequate vestibular adaptation in spaceflight for cognitive functioning in commercial astronauts.
2. The participant will learn about the cognitive and vestibular health of astronauts before and after the Inspiration 4 flight.
3. The participant will be able to appreciate the synergies across astronaut biomedical studies that reveal more information than any one study alone.

[471] GALVANIC VESTIBULAR STIMULATION POSTFLIGHT SENSORIMOTOR TRAINING

Caroline Austin, Chris Yan, Torin Clark

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(Original Research)

INTRODUCTION: The peripheral vestibular system and central interpretation undergo changes when exposed to microgravity and must readapt when returning to a gravitational environment. During this readaptation period, astronauts experience illusory vestibular sensations of self-motion. Specifically, head tilts are perceived as larger than they actually are and can result in a sense of translation. Such illusions can lead to increased risk of spatial disorientation while in or operating a landing vehicle and can lead to degraded performance of functional tasks. This decreased performance poses a serious risk for emergency procedures and may limit astronauts' performance on the Moon following extended microgravity exposure. Previous studies have shown that the application of electrical stimulation to

the mastoids can stimulate the vestibular system and alter perception; however, it is unclear how well galvanic vestibular stimulation (GVS) can mimic the orientation misperceptions that astronauts experience post-spaceflight. **METHODS:** The study uses the Tilt Translation Sled to subject participants to a series of tilt sequences with varying roll angle and velocity GVS proportionality schemes. Electrodes are attached to the subject's (n=10, 3 F) left and right mastoids and up to 2mA of current is applied, which is coupled to the roll tilt motion. The participant's sense of orientation is reported using a subjective haptic horizontal task. This study was approved by the University of Colorado Boulder's Institutional Review Board. **RESULTS:** Preliminary results indicate that bi-lateral current can produce alterations to tilt perception during static roll head tilts. By coupling current to the amount of roll head tilt, the perception of tilt can be exaggerated, similar to the illusions experienced by astronauts post-flight. The altered perceptions of tilt appear proportional to the current applied and fairly consistent across individuals. **DISCUSSION:** The tilt overestimation induced by bi-lateral GVS is consistent with astronaut post-flight illusions, and presents a promising opportunity to develop a training tool to prepare astronauts for the illusory vestibular sensations they will feel post-spaceflight. This was the first in a series of experiments designed to inform the development of such a tool that can use IMU data to provide GVS cue stimulation in real-time and accurately recreate post-flight vestibular illusions.

Learning Objectives

1. Determine whether bi-lateral GVS can be used to reproduce roll tilt-gain illusions.
2. Gain understanding of the perceptual effects of GVS when current is proportional to roll angle and/or velocity.

Thursday, 05/25/2023
Grand Ballroom A-B-C

3:30 PM

[S-83]: SLIDES: GRAVITY, IT'S THE LAW

Chair: Tom Hoffman
Co-Chair: James Elliott

[472] ACUTE DOSE-RESPONSE OF THE INTERNAL JUGULAR VEIN TO GRADED HEAD UP AND HEAD DOWN TILT

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(Original Research)

INTRODUCTION: Microgravity induced cephalad fluid shift has recently been associated with altered jugular venous flow, including flow stasis and reversal. On long-duration missions, it has been hypothesized that this altered flow could lead to increased thrombogenicity, with a resultant elevated embolic risk. The aim of this study is to generate gravitational dose-response curves of the common carotid artery (CCA) and the internal jugular vein (IJV) hemodynamic responses using a tilt paradigm. This investigation will improve the understanding of the vascular response to altered-gravity and provide a baseline that can be used to compare the magnitude of these changes during spaceflight, as well as the efficacy of measures to counteract altered blood flow in the neck. **METHODS:** Twelve male subjects (age 27.2 ± 2.7 years, height 179.0 ± 8.3 cm, weight 84.7 ± 18.7 kg) were subjected to graded tilt from 45° head-up through to 45° head-down in 15° increments, in both supine (face up) and prone (face down) positions. Ultrasonography of the left and right CCAs and IJVs, and jugular venous pressures (P_{IJV}) were recorded at each tilt angle. **RESULTS:** The cross-sectional area of the CCA, A_{CCA} , did not significantly change with tilt ($p=0.262$) or position ($p=0.361$), and there was no significant difference between the left and right sides ($p=0.849$). In contrast, IJV cross-sectional area, A_{IJV} , and pressure, P_{IJV} , were both highly dependent on tilt in a non-linear fashion ($p<0.001$ in both). Further, the right IJV was significantly larger than the left IJV ($p<0.001$) and expanded more rapidly with tilt than

its left counterpart. P_{IJV} was equivalent in the left and right sides ($p=0.775$) but was significantly higher in the prone position ($p<0.001$). **DISCUSSION:** Gravitational dose-response models quantifying the expansion and increase in pressure of the IJV in tilt were constructed using generalized additive mixed-effects models. These dose-response curves were compared with existing data from parabolic flight and spaceflight studies, showing good agreement on an acute timescale. The quantification of fluid shift in altered-gravity informs the understanding of the pathogenesis of spaceflight-induced venous thromboembolic risk. Future investigations will collect similar data in female subjects and will compare these dose-response curves to interventions focused on reducing cephalad fluid shift, such as lower body negative pressure and short-radius centrifugation.

Learning Objectives

1. The audience will learn about quantitative changes in the common carotid artery and internal jugular veins due to altered-gravity environments.
2. The audience will learn about the relationship between spaceflight induced cephalad fluid shift and increased risk of venous thromboembolism events.

[473] AN EXPLORATION OF LOWER BODY NEGATIVE PRESSURE'S POTENTIAL APPLICATION MITIGATING SPACEFLIGHT'S EFFECTS ON MUSCULOSKELETAL AND NEURO-OCULAR SYSTEMS

Michael Gallagher¹, Jamila Siamwala², Sunny Narayanan³, David Wassell², Erik LeRoy⁴

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(Education - Tutorial/Review)

INTRODUCTION: Lower body negative pressure (LBNP), originally designed as a cardiovascular spaceflight countermeasure, shows promise mitigating additional human spaceflight risks. This session will explore evidence for this. **TOPIC:** Bone loss in astronauts during spaceflight occurs quickly without effective countermeasures. Much lost bone mass is often not recoverable postflight. Terrestrial animal studies in which venous tourniquets were applied to the limbs of subjects demonstrated increased bone formation distal to these tourniquets, suggesting increased venous pressure could cause bone formation. Moreover, skulls of humans and other animals gain mass in space, which could be correlated with fluid shifts towards the head in space. Given these effects of fluid pressure on bone, LBNP might also help mitigate microgravity-induced bone loss by counteracting the fluid shift. Astronauts have a greater than 400% increased risk of spinal disc herniation one year after spaceflight compared with commercial and military pilots. Results of a study involving simultaneous use of LBNP and a treadmill showed reduced spinal intervertebral disc changes in astronauts, which may reduce spinal disc herniation in these individuals. In human subjects in a head down tilt position, LBNP reduced intraocular pressure back down to levels observed when they were seated. Should elevated intraocular and intracranial pressure play a key role in SANS pathology, LBNP could help mitigate this condition. Anecdotal use of LBNP on Earth also raises questions worth answering scientifically. Some athletes use LBNP in combination with compression therapy to improve post-exercise muscle recovery, though higher quality studies regarding its effectiveness are needed. Should LBNP have beneficial effects on muscles of athletes on Earth, investigating its ability to mitigate muscle loss in astronauts in space could be worthwhile. **APPLICATION:** More studies on a broader range of physiologic systems, including the musculoskeletal and visual systems, of astronauts wearing LBNP devices during space missions are warranted to clarify if LBNP can help counteract the negative effects of spaceflight on these systems. Should LBNP have a significant, positive effect on mitigating bone loss in space, it may also be effective in treating osteoporosis on Earth, which exists in a significant proportion of the elderly.

Learning Objectives

1. Participants will gain knowledge about animal studies illustrating the effects of venous pressure on bone and how this might apply to lower body negative pressure (LBPN) as a countermeasure in space.
2. Participants will learn about the potential application of lower body negative pressure to mitigate spaceflight-associated neuro-ocular syndrome (SANS).
3. The audience will gain an understanding of other ways lower body negative pressure (LBPN) is being studied scientifically and used by athletes on Earth.

[474] CHARACTERIZATION OF JUGULAR VENOUS BLOOD FLOW DURING ACUTE FLUID SHIFTS

Karina Marshall-Goebel¹, Jason Lytle², David Martin², Steven Laurie², Christopher Miller², Stuart Lee², Millennia Young¹, Brandon Macias¹

¹NASA JSC, Houston, TX, United States; ²KBR, Houston, TX, United States

(Original Research)

INTRODUCTION: Recently, altered internal jugular vein (IJV) blood flow dynamics, including stasis and retrograde flow, were reported during long-duration spaceflight. These findings may contribute to various risks of spaceflight, including thrombosis or other risks affected by cerebral venous blood flow. To date, our understanding of cerebral venous outflow dynamics in weightlessness is limited to ~50 and ~150 days into spaceflight, and therefore, it is unknown how quickly the alterations in venous blood flow dynamics change as a result of weightlessness. The purpose of this study was to characterize the immediate effects of weightlessness on bilateral IJV structure and blood flow. **METHODS:** We investigated the effects of acute weightlessness during parabolic flight on the right and left IJV in 13 healthy subjects (7 male, 6 female, mean height: 174 ± 10 cm). Baseline ultrasound images were obtained on the ground (1G) in the seated and supine postures and during 0G parabolic flight. We used 2D ultrasound to measure IJV cross-sectional area and Doppler ultrasound to characterize venous blood flow patterns in the IJVs. **RESULTS:** There appeared to be a similar pattern of response in the left and right IJV cross-sectional area across postures and G-levels. IJV area increased from seated to supine by 0.74 mm² (95% CI: 0.56 to 0.91 mm², p<.001) and increased further during weightlessness by 0.29 mm² (95% CI: 0.11 to 0.47 mm², p=.0015). IJV Doppler images revealed stagnant flow in the left IJV in one subject during 0G exposure that was not present during on the ground in the seated or supine posture; the subject's right IJV maintained pulsatile, normal flow patterns in 0G. **CONCLUSIONS:** This study characterized the immediate effect of the weightlessness-induced headward fluid shift on venous parameters in the left and right IJV. The left IJV appears to be more susceptible to flow alterations, including stagnant flow, during both short and long-duration exposure to weightlessness that may contribute to the risk of thrombosis in flight.

Learning Objectives

1. The audience will learn about changes in venous hemodynamics during acute exposure to weightlessness.
2. The audience will learn about the significance of stagnant blood flow in the spaceflight environment.

[475] MITIGATING THE EFFECTS OF PUSH-PULL ACCELERATION IN COMMERCIAL SUBORBITAL SPACEFLIGHT

Lauren Church¹, Eleonor Frost², Maia Gummer³, Chloe Mohanadass⁴, Nina Purvis⁵

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(Original Research)

INTRODUCTION: The push-pull effect describes blunted or altered physiological response to hyper-G following a period of <1G. This effect is well documented in aviation, particularly high performance aerobatics. There is currently little documentation with regard to its effect in commercial suborbital spaceflight, despite flight profiles suggesting a period of microgravity immediately preceding an increased-G re-entry phase. **METHODS:** A thorough literature search was conducted to review the push-pull effect in healthy physiology and pathophysiological states, which might affect an individual's experience of the effect. These literature reviews were used to form the basis of a protocol of medical screening for commercial spaceflight participants (CSPs) and a novel seat design for CSPs on board, in combination with open access documents from spaceflight providers Virgin Galactic and Blue Origin, provided by the Student Aerospace Challenge. **RESULTS:** Literature showed that the push-pull effect has been implicated in aviation safety concerns for many years. There are several disease states discovered which might limit either a CSP's +Gz tolerance (such as cardiovascular complications), or impair mitigation strategies such as anti-G straining manoeuvres (which can be affected by any neurological condition which limits movement or control of the lower limbs). It was established in the literature search that +Gx is generally better tolerated than +Gz in untrained individuals. This was integrated into the novel seat design, having CSPs seated horizontally so that +Gx was experienced on re-entry. This however was deemed implausible in crew, and therefore other mitigation strategies have been suggested. **DISCUSSION:** It is evident that the push-pull effect is not yet thoroughly documented in commercial suborbital spaceflight; this is likely due to the lack of data available given the small number of flights that have yet taken place. The integration of physiological monitoring to standard training protocols for such flights will allow a greater volume of data to be collected, further informing on the consequences of push-pull acceleration and the efficacy of any mitigations put in place.

Learning Objectives

1. For participants to understand the impact of push-pull acceleration on normal human physiology and pathophysiological states.
2. Participants to identify mitigation strategies appropriate for commercial spaceflight participants and safety-critical crew roles used in commercial spaceflight to prevent incidents directly relating to push-pull acceleration.

[476] THE EFFECT OF MICROGRAVITY ON THE HEPATOBILIARY SYSTEM AND IMPLICATIONS FOR LONG DURATION SPACE TRAVEL

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(Original Research)

INTRODUCTION: Microgravity induces changes to the nature of fluid flow and biochemistry within the body. The changes to the hepatobiliary system are less known but have significant implications for long duration space flight in the effort to maintain healthy human physiology. This literature review aims to highlight the research undertaken of the hepatobiliary system in microgravity and identify the implications for long duration space flight and where potential mitigation strategies could be developed. **METHODS:** A literature review was performed of medical, engineering and physical sciences databases (PubMed, Embase, Medline, Google Scholar) using search terms of 'Microgravity, Biliary, Liver, Pancreas'. **RESULTS:** A total of 63 articles were included

in the final review (N=6 human, N=39 animal, N=15 cell culture, N=2 review), including a combination of space flight studies (shuttle, ISS and satellite), bed rest, tilt table and simulated microgravity cell culture experiments. Biochemical changes within cell culture and animal studies found: significant changes of cholestasis within the liver with activation of lipotoxic pathways; reduction in hepatocyte metabolic activity; increase in ALT and AST and reduction in Kupffer cell population. These changes can be seen after just 13 days. Human bed rest studies have shown a decrease in gallbladder excretion and reduction in blood flow through the liver. The findings show reversibility after return to a gravity state. **DISCUSSION:** With the advent of long duration space flight, the implications of the changes in the hepatobiliary system is paramount in terms of considering prophylactic intervention and having strategies on board for flight. The changes in fluid flow, lipid absorption, immunotherapy changes – all can lead to an increased risk of hepatobiliary diseases in space flight including the formation of gallstones, cholecystitis, risk of pancreatitis and an increase in non-alcoholic fatty liver disease (NAFLD). Consideration needs to be given to diet modification with reduced fat during flight as well as technology available to deal with complications of biliary disease such as ultrasound training for Astronauts of the biliary tree and availability of percutaneous drains to treat septic complications.

Learning Objectives

1. The audience will learn about the effect of microgravity on the hepatobiliary system.
2. The audience will be able to consider mitigation strategies to reduce the occurrence of pathology in the hepatobiliary system during long-duration spaceflight.

[477] THE EFFECT OF SHORT DURATION BED REST ON POPLITEAL ARTERY STRUCTURE, FUNCTION, AND FLOW-MEDIATED DILATION IN OLDER ADULTS WITH TYPE 2 DIABETES

Kseniya Masterova¹, Jiefei Wang¹, Tatiana Moro², Elena Volpi¹

¹UTMB, Galveston, TX, United States; ²University of Padova, Padua, Italy

(Original Research)

INTRODUCTION: As spaceflight becomes commercialized, those of older age and with common health conditions such as diabetes will be flying, creating unprecedented challenges in space health. Type 2 diabetes mellitus (T2DM) and inactivity individually accelerate changes related to vascular aging. These changes increase cardiovascular risk and contribute to morbidity and mortality in the elderly. It is unknown if T2DM and bed rest have an additive, deleterious effect on vascular structure and function in older adults. The objective of this study is to determine the magnitude of the effect of bed rest on vascular structure and function in older adults with T2DM compared to healthy controls and determine if resistance exercise is protective of this effect. **METHODS:** So far, we have recruited T2DM (n=11) and healthy control (n=18) subjects (age: 67.4 ± 5.6 years) to undergo five days of bed rest. During bed rest, subjects were randomized to receive intensive bedside resistance exercise physical therapy or standard of care in-bed passive physical therapy. On bed rest days 1 and 5, popliteal artery diameter, blood velocity, blood flow, and flow-mediated dilation were measured using Doppler ultrasonography. **RESULTS:** Our preliminary data shows decreased popliteal artery diameter in all groups. Resistance exercise did not prevent artery size changes in controls nor diabetics. Resistance exercise showed a trend in preventing blood velocity and blood flow reduction in both diabetic and control groups. **DISCUSSION:** This preliminary data suggests that older adults with T2DM show similar arterial structure responses to healthy controls. Resistance exercise appears to help maintain blood flow by maintaining/increasing popliteal artery blood velocity, not size.

Learning Objectives

1. Participants will be able to describe how bed rest inactivity in the older adult and diabetic population may affect vascular structure and function.

2. Participants will be able to describe mechanisms by which resistance exercise may be preventative of vascular changes due to inactivity.

Thursday, 05/25/2023

3:30 PM

Grand Ballroom D-E

[S-84]: PANEL: AEROSPACE AND THE NEXT GENERATION OF CARDIAC TECHNOLOGY - USING NEW TECHNIQUES AND KNOWLEDGE TO SUPPORT AVIATION

Chair: Joanna d'Arcy

Co-Chair: Eddie Davenport

PANEL OVERVIEW: This panel will look at new techniques and knowledge in the field of cardiology which offer opportunities to improve the care and support of aviators. The field of clinical medicine is constantly evolving, and as new technologies and practices emerge, they may offer the potential to alter the way in which aircrew are treated for their condition. Whether it is offering a new treatment option that makes a return to the cockpit possible for the first time or providing an alternative way to risk stratify aircrew to enhance flight safety, these are all exciting additions to the armament of aviation medicine. Also, as new techniques are adopted in wider clinical medicine, we must carefully consider whether there is enough evidence to support their use in aviators, or whether we cannot yet consider them suitable for a return to the cockpit. This panel will look at how new techniques and technology may support decision making and treatment for aircrew with a range of cardiac conditions. Trans-catheter techniques for valve disease present different considerations in aircrew, compared with other methods of valve intervention. Valve surgery has also continued to evolve, and the emergence of new technologies that might be more suited to aviation and space than previously is a very exciting proposition. Assessing our aviators using newer techniques will also be discussed, highlighting how they can be used to aid decision-making by AMEs and specialists alike. They may offer the potential to keep aviators flying for longer without compromising flight safety, whilst increasing our confidence that we will correctly identify those at greatest risk. This international panel of aviation-orientated cardiologists will discuss the next generation of cardiology in aerospace medicine, and how it offers the potential to open up new avenues of treatment and assessment for our aircrew.

[478] AEROSPACE CARDIOLOGY BREAKTHROUGHS FOR THE NEXT GENERATION

Eddie Davenport¹, Norbert Guttler², Thomas Syburra³, Olivier Manen⁴, Dennis Bron⁵, Lysette Broekhuizen⁶, David Holdsworth⁷⁻⁸, Joanna d'Arcy⁸

¹U.S. Air Force, Wright-Patterson AFB, OH, United States; ²German Air Force, Cologne, Germany; ³Switzerland Air Force, Luzern, Switzerland; ⁴French Air Force, Paris, France; ⁵Switzerland Air Force, Dubendorf, Switzerland; ⁶Netherlands Air Force, Utrecht, Netherlands; ⁷Royal Army, Henlow, United Kingdom; ⁸RAF, Henlow, United Kingdom

(Education - Program/Process Review)

BACKGROUND: Prior to the year 2003 there was not a single military pilot flying with known coronary artery disease, bicuspid aortic valve, mitral valve prolapse, atrial fibrillation, or congenital heart disease. However, thanks to surgical and medical advances along with evidence-based data, in the year 2023, we now have pilots flying after coronary revascularization, valve repairs/replacements, pacemakers, and even congenital heart disease. **OVERVIEW:** Recent breakthroughs in aerospace cardiology have paved the way for evidence based aeromedical disposition. This collaborative effort has allowed more aircrew than ever back to flying while increasing the safety of flight. Advances in all three realms of

cardiology will be discussed to include electrical, structural, and vascular heart disease. Specific examples include atrial fibrillation, mitral valve repair, aortic valve replacement, multiple repaired congenital defects, and obstructive coronary artery disease returned to high-performance flight.

DISCUSSION: Using aerospace cardiology as a guide, we can increase return to flight in all areas of the aerospace environment. With ongoing international collaboration between the military and civilian institutions and evidence-based practices, the future is very bright for future generations of aerospace medicine.

Learning Objectives

1. Understand the history and advancement of cardiology disposition in aircrew.
2. Learn to apply evidence-based principles in all areas of aeromedical disposition.
3. Promote and develop a sense of collaboration between aircrew and the AME/flight surgeon and medical specialist to allow return to flight for aircrew using evidence-based medicine principles.

[479] BREAKING NEWS FROM THE CARDIAC SURGERY THEATRE: THE BIONIC PILOT AND THE HOLY GRAIL IN VALVE SURGERY

Thomas Syburra¹, Eddie Davenport², Norbert Güttler³, David Holdsworth⁴, Denis Bron⁵, Olivier Manen⁶, Lysette Broekhuizen⁷, Joanna D'Arcy⁴

¹Luzerner Kantonsspital and Swiss Air Force, Luzern, Switzerland; ²U.S. Air Force, Wright-Patterson AFB, OH, United States; ³German Air Force, Cologne, Germany; ⁴RAF, Oxford, United Kingdom; ⁵Swiss Air Force, Dübendorf, Switzerland; ⁶French Air Force, Paris, France; ⁷Dutch Air Force, Amsterdam, Netherlands

(Education - Tutorial/Review)

Is cardiac surgery the death knell for aircrew's career? As we learnt during the past meetings, it is not. Still, limitations will apply. Why so often, why so many: more often than not, we just don't really know at the level of evidence-based science. Thus, the principles of precaution apply and consequently we may end up banning aircrew from flying on a rather eminence-based ponderation. Fortunately, cardiac surgery does not stand still, nor do the aircrafts, the envelopes of deployment, the flight crew licensing regulations, and the occupational profiles. More evidence is gathered after revascularization of coronary artery disease, using preferably total arterial grafting. Minimal invasive direct coronary artery bypass (MIDCAB) surgery does not require a full sternotomy anymore, therefore not impairing the stability of the thorax more than a chest tube insertion. Mitral valve repair, in trained hands, has a repair rate above 80% with outstanding long-term results, including the exclusion of the left atrial appendage at the same time, opening the doors to unrestricted licensing. Mini-thoracotomy is increasingly the standard-of-care in most cardiothoracic units for mitral valve repair. Fully implantable wireless batteryless vascular electronics with printed soft sensors for multiplex sensing of hemodynamics are tested today in USA laboratories, a promising way of obtaining real-time telemetry data from blood flow, oxygenation, and pressure [1]. We had ECG and EEG for our astronauts and aircrew in the past, we will tomorrow gather the whole cardiovascular online telemetry data, biochemical markers and many more included. Aircrew needing an aortic valve operation had the choice of aortic valve repair (in few ideal cases, in few ideal hands). For aortic valve replacement we only had mechanical prostheses (lifelong longevity but Warfarin dependent) in young age, or tissue prostheses (no Warfarin but limited longevity). Two sub-optimal options indeed, despite the latest progresses in prostheses' construction and preservation. Finally comes the Holy Grail in aortic valve surgery: the prosthesis that shall last for ever without need for oral anticoagulation. Sievers' novel trileaflet mechanical heart valve developed at Lübeck University shows ideal hemodynamics, no hemolysis at all and a thrombotic rate well below the 1% safety rule [2]. Do we stand at the doors of a game changer in cardiothoracic surgery? Future will certainly tell!

Learning Objectives

1. Understand the feasibility of established key cardiac surgery procedures in the light of flight crew licensing.
2. Learn about the latest developments in cardiac surgery and their novel lesser impact on flight crew licensing limitations.

[480] FLYING AFTER TRANSCATHETER AORTIC VALVE REPLACEMENT – CURRENT POSITION AND FUTURE PERSPECTIVES

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¹German Air Force Centre of Aerospace Medicine, Cologne, Germany;

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⁴Luzerner Kantonsspital, Luzern, Switzerland;

⁵Aeromedical Centre Swiss Air Force, Dübendorf, Switzerland;

⁶Percy Military Hospital - Aeromedical Centre, Clamart, France;

⁷RAF, Henlow, United Kingdom

(Education - Tutorial/Review)

INTRODUCTION: Surgical aortic valve replacement (SAVR) has been an established procedure for those with severe aortic stenosis for decades and flying after SAVR is accepted by licensing authorities in Northern America and Europe. About twenty years ago, transcatheter aortic valve replacement (TAVR), also called transcatheter aortic valve implantation (TAVI), has been developed, originally for inoperable patients with high periprocedural risk. As the indication for TAVR has now expanded to intermediate- and lower-risk patients, it is discussed whether TAVR could be a suitable method for pilots and if flying after TAVR could be possible in the future. **TOPIC:** TAVR is a minimally invasive procedure, during which a new valve is inserted without removing the old, damaged valve. Mostly, a transfemoral access is used, a transapical access is also possible. **APPLICATION:** TAVR is not yet mentioned in the European aeromedical regulations. But according to the current Guide for Aviation Medical Examiners by the Federal Aviation Administration, TAVR may be considered for any flying class. It has to be specifically explained by the cardiologist why this procedure was chosen. First- and second-class applicants may be reviewed by the Federal Air Surgeon's Cardiology Panel or Consultant after a 6-month recovery period. Randomized trials have shown noninferiority in high- and intermediate risk patients, and more recently even in low-risk patients (PARTNER 3 and EVOLUT Low Risk trials) compared with SAVR. But there are still some open questions to be answered. There are no long-term data about the durability of the prosthetic material used for TAVR. Typical unresolved issues of TAVR are paravalvular leakage and permanent pacemaker implantation. Patients with bicuspid aortic valves have been excluded from most trials. Currently, TAVR is usually recommended according to US Guidelines for patients over 65 years of age, according to European Guidelines it is recommended over 75 years of age. Between 70 and 75 years of age, TAVR can be recommended individually by the Heart Team. Although the average age of pilots has increased, TAVR is currently not the appropriate procedure for most of them. But this may change in the future, when better prostheses and more data about their durability will be available.

Learning Objectives

1. Learn that novel cardiac devices which are primarily incompatible with flying may be considered for aircrew in the future, when safety and complication rates have improved, and indications have broadened.
2. Learn that the indication for transcatheter aortic valve replacement has extended to intermediate and low-risk patients.
3. Learn that transcatheter aortic valve replacement is currently recommended for older people.

[481] CORONARY CT ANGIOGRAPHY (CCTA) FOR CARDIOVASCULAR RISK ASSESSMENT IN AIRCREW

Lysette Broekhuizen¹, Joanna d'Arcy², David Holdsworth², Norbert Güttler³, Thomas Syburra⁴, Olivier Manen⁵, Denis Bron⁶, Eddie Davenport⁷

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(Education - Tutorial/Review)

INTRODUCTION: Screening for cardiovascular disease is of great importance in aircrew personnel and knowledge about the latest developments and recommendations on this topic is necessary for a good evaluation. CCTA has a high accuracy for the assessment of coronary artery disease (CAD) and is emerging as a valuable technique for cardiovascular risk assessment. **TOPIC:** Adverse cardiac events related to CAD can cause sudden in-flight incapacitation of aircrew which can result in extensive consequences. Therefore clarity about health hazards is desirable in aeromedicine. As CCTA has a high negative predictive value for CAD in low-risk populations this imaging technique can be used to determine who is at increased risk even before clinical suspicion arises. The predictive value for CAD of CCTA in this population is superior compared to exercise testing. The latter is no longer recommended as a diagnostic tool for CAD in the guidelines for cardiologists but data in aircrew is lacking. Exercise testing is often still used in periodic cardiac screening of aircrew despite of the low pre-test probability in this group. The ACC/AHA guidelines does recommend screening with invasive coronary angiography (CAG) in asymptomatic individuals in case of multiple cardiovascular risk factors or a borderline abnormal stress test results when performing in high risk occupations. Of course, CCTA has the benefit of a very low complication rate and can often be done with limited exposure to radiation. In recent years, the Royal Netherlands Air Force (RNLAF) has experienced a higher demand for additional screening in pilots who are older or have cardiovascular risk factors. Therefore the RNLAF is investigating whether the use of CCTA as a primary screening modality for military aircrew is more suitable than the current approach using only exercise testing (SUSPECT trial). **APPLICATION:** CCTA should be easily accessible in air crew personnel for cardiovascular risk assessment, especially if they are older (men ≥40 years) or have risk factors for cardiovascular disease (including family history). Early detection of atherosclerosis can improve individual prevention strategies.

Learning Objectives

1. Diagnostic benefits and draw backs of CCTA compared to other screening modalities.
2. When to use CCTA for primary screening purposes in aircrew, which is a population at low risk for cardiovascular disease.
3. Value of CCTA for improving preventive measures

[482] GREY ZONE APPEARANCE OF THE HEART – SUPERFIT OR PORTENT OF DISASTER?

David Holdsworth¹, Lysette Broekhuizen², Norbert Güttler³, Thomas Syburra⁴, Denis Bron⁵, Olivier Manen⁶, Eddie Davenport⁷, Joanna d'Arcy⁸

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(Education - Tutorial/Review)

INTRODUCTION: Currently, there is no accepted clinical method to differentiate early heart muscle disease (dilated cardiomyopathy (DCM)) from athletic adaptation when anatomical imaging of the heart reveals borderline dilatation or borderline reduced contractile function (ejection fraction). **TOPIC:** Periodic medical evaluation, typically including 12-lead ECG recording, is a common, routine part of safety assessment for aircrew and space crew. The finding of anomalies on 12-lead ECG, or of murmurs on physical examination, often leads to further cardiac investigation including echocardiography and sometimes cardiac MRI. When imaging demonstrates either that the cardiac chambers are mildly dilated or that the contractile function at rest is mildly reduced there are two possible diagnoses. This phenotype is seen in exercise adaptation¹ or in early heart muscle disease². In UK military aviation practice, the only clinical cases to remain undiagnosed after cardiovascular assessment of >500 aircrew were all borderline dilated hearts with borderline reduced contractile function. This phenotype has been termed the 'grey zone'³. Surprisingly, there exists no reliable method to differentiate the two extremely different clinical entities. The only suggested technique to date is exercise echocardiography. An exercise induced increase of at least 12% in the left ventricle ejection fraction (LV EF) or reaching a peak exercise LV EF of >63% has been reported to provide 77-83% sensitivity respectively for identifying DCM⁴. **APPLICATION:** The UK military aviation medical service now routinely uses cardiopulmonary exercise testing as an integral part of cardiovascular assessment for grey zone cases. In this session, a summary of the clinical exercise test findings of the first consecutive 30 cases will be presented.

Learning Objectives

1. The audience will learn about the frequency and challenge of the 'grey zone' left ventricle finding in aircrew (borderline dilatation and reduced contractile function). This common problem currently leads to the occupational restriction of extremely fit pilots and non-pilot aircrew whose adaptation to exercise includes physiological cardiac enlargement.
2. The audience will learn about the current limitations to diagnosis in this common and challenging clinical scenario and some approaches of exercise-based clinical tests.
3. The audience will learn about the promising initial findings of UK Defence Aviation medicine clinicians performing cardiopulmonary exercise testing to discriminate early heart muscle disease from athletic adaptation.

[483] A HIGH-PERFORMANCE PILOT WITH AN INTERESTING ELECTROCARDIOGRAM

Denis Bron¹, Joanna d'Arcy², David Holdsworth², Norbert Güttler³, Thomas Syburra⁴, Olivier Manen⁵, Eddie Davenport⁶, Lysette Broekhuizen⁷

¹Aeromedical Centre Swiss Air Force, Dübendorf, Switzerland; ²RAF, Henlow, United Kingdom; ³Air Force Centre of Aerospace Medicine, Fürstentfeldbruck, Germany; ⁴Luzerner Kantonsspital, Luzern, Switzerland; ⁵Percy Military Hospital Aeromedical Centre, Clamart, France; ⁶Wright-Patterson AFB, OH, United States; ⁷Central Military Hospital and University Medical Centre-Utrecht, Utrecht, Netherlands

(Education - Case Study)

INTRODUCTION: Aeromedical cardiology examination is a challenging process. New medical findings may play an important role in the relationship between the Aeromedical examiner and Aircrew member. **BACKGROUND:** In the routine annual medical examination process at the Swiss Air Force Aeromedical Centre in Dübendorf an ECG is required at regular intervals. **CASE PRESENTATION:** A 49-year-old F/A 18 pilot was found to have a new bifascicular block (left anterior hemi-block (LAHB) and Right Bundle Branch Block (RBBB)) on screening ECG during an aeromedical examination in 2016. The previous medical history was

uneventful except for lumbar discal hernia. He did have history of G-lock with crash. The pilot was made temporarily unfit to fly while cardiac examination was done. Echocardiography demonstrated normal structure, function and ejection fraction. He had normal exercise ergometry and unremarkable cardiac MRI. Electrophysiological investigation showed discrete prolonged HV interval. The pilot also showed normal performance in the centrifuge with no cardiac abnormalities. After six months of temporary unfit, solo fitness to fly was granted with a waiver. No new cardiac abnormalities have been observed since 2016 during annual cardiac re-evaluations. **DISCUSSION:** Our case shows the alertness of the Aeromedical examiner in finding new ECG-abnormalities. Specific clinical warning symptoms were absent and further examinations could find any cause for a the bifascicular block. This case demonstrates another successful application of the risk calculation matrix used through the occupational cardiology working group NATO WG HFM-316.

Learning Objectives

1. Professional relation to Aircrew is an important factor for aeromedical examination.
2. Frequent ECG recording during aeromedical examination is necessary and useful.
3. Following procedures HFM-316 recommendation is useful.

Thursday, 05/25/2023
Napoleon Ballroom C1-C2

3:30 PM

[S-85]: PANEL: CARDIAC ARREST IN THE AIR TRANSPORT ENVIRONMENT: WHAT'S NEW?

Sponsored by Aerospace Human Performance Committee

Chair: Keith Ruskin
Co-Chair: Carlos Salicrup

PANEL OVERVIEW: Eight million passengers fly on a commercial airline flight every day, and approximately 130 will experience a cardiac arrest during that flight. Rapid recognition of the event and high-quality cardiopulmonary resuscitation (CPR) are critical to survival after cardiac arrest. Factors that can affect this outcome include the availability of rescuers, application of an automated external defibrillator, and possibly diversion after successful resuscitation to provide access to a higher level of care. In some cases, the first responders to in-flight cardiac arrest may be a medical student or resident, and at least one study suggests that skills with a demonstrated impact on the survival, including depth of chest compressions, and performance of shocks using an AED were retained 42 months after CPR training. This educational panel will provide an overview of the management of in-flight cardiac arrest. After a review of the relevant physiology and the available resources, additional presentations will discuss the development of cognitive aids for volunteer rescuers, how medical students and residents can respond to a call for medical assistance, and offer insights into how flight crews respond to medical emergencies during flight. The panel will also discuss the incidence of cardiac arrest in airports and the use of automated external defibrillators in that environment.

[484] A PASSENGER JUST ARRESTED! WHAT DO I DO?

Keith Ruskin
University of Chicago, Chicago, IL, United States

(Education - Tutorial/Review)

INTRODUCTION: The average incidence of out-of-hospital cardiac arrest (OHCA) among adults is 55 per 100,000 person-years. Although overall survival after OHCA is poor, early recognition, high quality CPR, and use of automated external defibrillators (AED) have improved survival and long-term outcomes. Although cardiac arrest during commercial airline flights is relatively uncommon, the unusual setting, limited

resources, and variability of volunteer rescuers' skills present unique challenges. **TOPIC:** Volunteer rescuers and cabin crew should perform CPR in accordance with the most recent guidelines as published by the American Heart Association. Survival after a witnessed arrest with a shockable rhythm has improved in patients who are treated promptly. After starting CPR, an AED should therefore be applied as quickly as possible, and rescuers should follow the instructions given by the device. After return of spontaneous circulation (ROSC) is obtained, the AED should remain attached to the patient for the duration of flight to monitor the cardiac rhythm and to deliver additional shocks should another cardiac arrest occur. Because chest compressions cannot be continued during an emergency descent, AsMA guidelines recommend that the flight be continued until either ROSC has been obtained or attempts at resuscitation have been terminated. At least one study has shown that more effective chest compressions are delivered when volunteer rescuers breathe supplemental oxygen to mitigate hypoxia caused by reduced cabin pressure during cruise flight. Attempts at cardiac resuscitation should continue for as long as the AED detects a shockable rhythm or until the Universal Termination of Resuscitation Guidelines recommend discontinuation of CPR. **APPLICATION:** Early recognition and treatment of cardiac arrest during an in-flight cardiac arrest can improve the likelihood of survival. Successful resuscitation is possible if volunteer rescuers are flexible and can adapt to the unique environment and limited resources in a commercial airline cabin. **RESOURCES:** 1. Ruskin KJ, Ricaurte EM, Alves PM. Medical Guidelines for Airline Travel: Management of In-Flight Cardiac Arrest. *Aerosp Med Hum Perform*. 2018 Aug 1;89(8):754-759. 2. Clebone A, Reis K, Tung A, O'Connor M, Ruskin KJ. Chest Compression Duration May Be Improved When Rescuers Breathe Supplemental Oxygen. *Aerosp Med Hum Perform*. 2020 Dec 1;91(12):918-922.

Learning Objectives

1. Participants will understand how the unique environment of a commercial aircraft cabin affects their ability to provide CPR during flight.
2. Participants will be able to make effective use of the resources on board a commercial aircraft when acting as a volunteer rescuer.
3. Participants will be able to educate and develop research projects on the topic of in-flight cardiac arrest for the next generation of aerospace professionals.

[485] COGNITIVE AIDS FOR VOLUNTEER RESCUERS IN THE NEXT GENERATION RESPONDING TO CRITICAL EVENTS

Anna Ruskin
University of Chicago, Chicago, IL, United States

(Education - Tutorial/Review)

INTRODUCTION: Cardiac arrest during commercial flight is a rare event that requires immediate intervention by cabin crew or volunteer rescuers. Because cardiac arrest is an extremely rare event and occurs suddenly, rescuers may not be cognitively prepared to manage it. After initiating CPR, the likelihood of successful resuscitation may be improved if the volunteer or cabin crew access a cognitive aid. **TOPIC:** Cognitive aids that use human factors principles may help rescuers to manage a passenger who suffers an in-flight cardiac arrest or other in-flight medical emergencies such as hypoglycemia, dehydration, or major cardiac events. Critical event cognitive aids must be carefully tailored, iteratively tested, and regularly reviewed to ensure that they are meeting the needs of the next generation. When creating a new cognitive aid for a critical event, the first step is to determine the 'scope' of the cognitive aid as specifically as possible. A cognitive aid designed for too broad of a scope will contain non-relevant information will take extra time and require a greater cognitive workload to use, especially in an emergency. The next step is to carefully look at the reasons why and timing with which the rescuers will access the aid. These factors must be kept in mind when designing the aid. Beta-testing of the aid should occur during mini-simulations with actual users. Finally, the aid must be tested in the real-world, and changed frequently to meet user needs. **APPLICATION:** The meeting attendees will be taken through a detailed, step-by-step discussion on

how to develop cognitive aids for an in-flight medical emergency. The framework of ensuring that the next generation of volunteer rescuers has human-factors informed cognitive aids for their use will be highlighted.

RESOURCES: 1. Circulation. 2020;142(suppl 2):S580–S604. DOI: 10.1161/CIR.0000000000000899

Learning Objectives

1. To explore cognitive aids during in-flight cardiac arrest for volunteer rescuers in the next generation.
2. To look at ways to design cognitive aids for the future to meet the scope, environment, and user needs.

[486] IN-FLIGHT CARDIAC ARREST: THE FLIGHT CREW PERSPECTIVE

Carlos Salicrup

Medicina Aeroespacial, Mexico City, Mexico

(Education - Case Study)

We have in our flight plans en route alternate airports, largest length of time for an en route alternate is one hour from any critical point, for extended range flights varies from 2 to 4 hours. These “alternates” are normally used in case of a critical system failure that obligates to “land at the nearest suitable airport”. These alternates comply with dispatch requirements, but in case of a medical emergency some of these may not be suitable for a passenger with a medical emergency needing a specific hospital treatment. Most of the flight crews are not aware about this situation. A medical deviation may mean to land the airplane in a non-familiarized airport, in limited or weather conditions and hitting unfamiliar approaches, factors that may lead to a mishap. For the passenger best outcome, medical deviation should be considered to places that along with meeting the technical requirements for “suitable airport” should have the best “suitable medical facility” for the type of illness. An inflight cardiac arrest is a challenge to the cabin and flight crew competencies (Communication, situational awareness, leadership, team work, workload managing, knowledge, etc...). Cabin crew with updated BLS training for these situations is a must, also AEDs/EDs with updated protocols software, and If you have the luck to find a medical volunteer on board, and if is trained and experienced managing these situations. Also if the equipment contained in the medical kits is at the minimum required (No IV lines, No IV fluids, No O2 meters, no Dextrose meters, etc.) the managing, outcome and need to deviate may be different when there's at least the minimum “goodies” that we use in EMS “attack kits” when we make first contact at the scene with a critical patient, by far-away the humanitarian and medical responsibility/quality Vs money savings for airlines have to be considered. If as pilots, should we issue a MAYDAY (Emergency) or PANPAN (Urgency) for a medical emergency on board is also something that have to be considered, since the safety of the airplane is not compromised but there's a life-threatening situation, acting quick but keeping the safety of all the other passengers and aircraft is always the priority. Training in mock-ups or in airplanes about how to extract an unresponsive passenger or crew member from their seat is also a must. We should have all the chance and training to offer the best medical and aviation practices to these passengers.

Learning Objectives

1. The attendee will learn about aviation alternate airports Vs Medical Alternates.
2. The attendee will learn about the implications of a medical deviation.
3. The attendee will learn about the importance of an appropriate medical kit.

[487] SHOULD MEDICAL STUDENTS AND RESIDENTS RESPOND TO AN IN-FLIGHT CALL FOR HELP?

Jaclyn Edelson

University of Chicago, Chicago, IL, United States

(Education - Tutorial/Review)

INTRODUCTION: High quality CPR and medical care in an emergency can save lives, especially when resources are limited, as during flight

on a commercial airplane. This presentation will discuss who ‘should’ provide that care—specifically, this panel section will discuss the ethics, capability, and legal consequences of medical students and medical residents providing medical care on an airplane. **TOPIC:** During in-flight medical emergencies, resources including personnel, drugs, and equipment are limited. A medical student or resident may be the most qualified and knowledgeable person to offer assistance during an in-flight cardiac arrest. Acting as a sole provider on the ground would, however, generally be considered outside of their scope of practice, which typically requires direct supervision from a board-certified physician. This point will be explored further in consideration of the role of the ground-based medical consultation service, who may be able to supervise a medical trainee via telecommunication. The current generation of medical trainees is in a unique position to take advantage of the ground support physician because most have had formal training in and from telehealth due to the Covid-19 pandemic. Physicians-in-training may feel a personal, ethical obligation to help a fellow passenger in need, but later find that their actions are subject to legal consequences. The Aviation Medical Assistance Act of 1998 protects some healthcare professionals who volunteer to help a passenger during an in-flight medical emergency but does not protect them from the financial expense that may lead up to a ‘not guilty’ verdict. This point is especially relevant to medical residents/students who typically do not carry individual medical malpractice insurance and rely on their training institutions’ policies. **APPLICATION:** This presentation will be directly applicable to the “Next Generation” of aerospace medicine physicians and will serve to spur discussion about medical students’ and residents’ roles in an in-flight cardiac arrest. **REFERENCES:** 1. Commercial Airline In-Flight Emergency: Medical Student Response and Review of Medicolegal Issues. J Emerg Med. 2016 Jan; 50(1):74-8. Bukowski JH, Richards JR. PMID: 26514306. 2. Davies M. How should I respond to an in-flight emergency? BMJ 2019; 364: j5151 doi:10.1136/sbmj.j5151

Learning Objectives

1. Debate medical student and residents’ role in an in-flight emergency.
2. Examine changes in medical training due to the Covid-19 pandemic that could affect medical trainee response to an in-flight emergency; specifically changed expectations of responsibility and increased experience with telehealth.

[488] SUDDEN CARDIAC ARREST AND PUBLIC ACCESS DEFIBRILLATION AT COMMERCIAL AIRPORTS

Aditya Shekhar

Icahn School of Medicine at Mount Sinai, New York City, NY, United States

(Education - Tutorial/Review)

INTRODUCTION: Cardiac arrest results in fatal injury if effective resuscitation is not quickly initiated. Early defibrillation is associated with favorable outcomes and is uniformly emphasized in resuscitation guidelines. For many years, commercial airports have been models for public-access defibrillation and are associated with exemplary cardiac arrest outcomes when compared with other public venues. **TOPIC:** Key components of the “Chain of Survival” include timely recognition, early access to high quality CPR and defibrillation, and expedient arrival of professional rescuers. Public-access defibrillation with automated external defibrillators (AEDs) has been highly successful. Commercial airports have been described as “laboratories” for testing public health interventions designed to improve cardiac arrest survival. Airports with have been associated with significantly higher rates of bystander defibrillation and cardiac arrest survival when compared with other public venues. Other contributing factors for favorable cardiac arrest outcomes at airports include an improved likelihood of an arrest being witnessed, a large number of CPR-trained individuals willing to assist, and on-site public safety personnel and emergency medical services (EMS). **APPLICATION:** The efficacy of public access defibrillation has been validated in airports, and these lessons are currently being cross-applied to other public venues, including shopping malls and resorts. Improving access to AEDs and increasing rates of bystander AED use is a current focus of the resuscitation science community. **RESOURCES:** Shekhar AC, Ruskin KJ. Sudden cardiac

arrest in commercial airports: Incidence, responses, and implications. *Am J Emerg Med.* 2022 Sep; 59:118-120. doi: 10.1016/j.ajem.2022.07.006.

Learning Objectives

1. The participant will be able to describe the major components of the "Chain of Survival" in out-of-hospital cardiac arrest as applied to commercial airports.
2. The participant will be able to describe some of the unique factors that lead to favorable cardiac arrest outcomes at commercial airports.
3. The participant will be able to describe how airports have been used to validate public-access defibrillation for other public venues.

Thursday, 05/25/2023
Napoleon Ballroom D1-D2

3:30 PM

[S-86]: PANEL: US AIR FORCE ACCESSION MEDICAL WAIVER DIVISION (AMWD) OUTCOMES EVIDENCE PANEL: US AIR FORCE SCHOOL OF AEROSPACE MEDICINE (USAFSAM) PILOT PROJECT

Chair: Ian Gregory

PANEL OVERVIEW: *Militaries over the millennia have had to determine who is "fit to serve." Military medical standards, even in antiquity, were controversial. Medical standards for entering the US military branches have been established for over two centuries. Medical standards manuals from WWII era stated that "to be effective in military service, an individual must have the capacity for sustained duty in the face of separation from home, regimentation, lack of privacy, extremes of climate, hunger, exhaustion, and threat of bodily harm." Today's Department of Defense Instruction (DODI) 6130.03 Volume 1 directs the principles behind current standards: free of contagious disease, minimal lost duty time or early separation, ability to complete military training, adaptable to all military environments worldwide, and ability to perform duties without worsening medical condition(s). The US Air Force (USAF) enlists and trains approximately 30,000 new airmen yearly. Each must meet Department of Defense medical standards, or receive a medical waiver, to attend Basic Military Training. Recruiting data indicate there are fewer qualified applicants currently present in the general US population, leading to pressure on the medical standards to meet force demands. Senior leaders want medical accession waiver staff to "take more risk" with incoming applicants. However, the level of risk currently being taken has not been fully quantified. Historically, standards have been "surrogates" for assessing health and performance. Usually, medical experience, prognosis and judgement were primary inputs to the conditions listed in the standards and waiver decisions. The Accession Medical Waiver Division (AMWD) has been focused on gaining more evidence from outcome data to inform waiver threshold determination and accession medical standards. The AMWD is also focused on quantifying the level of risk that fully qualified individuals bring to key operational measures versus those with medical waivers, utilizing data harvested from an expanding suite of outcome evidence. This 2023 panel will discuss AMWD's "pilot" project with the USAF School of Aerospace Medicine (USAFSAM) in baseline risk quantification for a first set of outcome measures, discuss the extent of the USAF's new Exception to Policy Process, and outline plans for future improvements and additions to the outcomes evidence portfolio.*

[489] DEPARTMENT OF THE AIR FORCE MEDICAL EXCEPTION TO POLICY PROCESS

Robert York, Christopher Grussendorf
U.S. Air Force, San Antonio, TX, United States

(Education - Program/Process Review)

BACKGROUND: The United States Air Force (USAF) assesses approximately 70% all applicants for accession as fully qualified and an

additional 10% of all applicants as medically acceptable with waiver. Of the remaining population, 10% are medically disqualified, and 15% did not complete the application process. Despite not meeting medical standards, the line of the Air Force (i.e., non-medical senior leadership) is willing to accept additional risk in order to access exceptional individuals into the Air Force by selectively approving exceptions to policy (ETPs, specifically line exception to medical policy) requests. In 2020, the process for review of ETP requests was delegated by the Secretary of the Air Force for Manpower and Reserve Affairs (SAF/MR) to the Commander of the Air Force Air Education and Training Command, serving as the Air Force's Force Development Commander. Some ETP decision authority was also delegated to the AETC Commander; authority for some case types was retained to SAF/MR. **OVERVIEW:** The ETP board process is part of the Air Force's Talent Management process and operates to access or retain highly qualified and exceptional service members while minimizing the risk to mission and health. This session will discuss the history, authorities, current risk assessment process and known outcomes. Since the advent of the current ETP board process, 117 cases have been reviewed by the Air Education and Training Command (AETC) commander (AETC/CC). The most common case types include: vision, asthma, spinal, dermatologic, and mental health diagnoses. **DISCUSSION:** Medical standards are the intersection of evidence-based medicine and the risk tolerance of the line leadership. The ETP process allows the line of the Air Force to make decisions to access or continue service for certain exceptional service members. The current ETP board process involves dialogue about medical and operational risk, Air Force career field personnel requirements, and commander advocacy for members with desirable skills and leadership potential. The objective of these boards is to provide the AETC Commander with data and perspectives to render ETP decisions. Discussion and decisions from these boards fuel areas for future medical standards policy review, and with the increased awareness of line risk tolerance/acceptance, provide data for future medical standards decision making. Speakers on this panel will present further details on the AF ETP board process.

Learning Objectives

1. The Department of the Air Force has a process to access or continue service for aviators and others in special duties following medical disqualification. This includes review of medical risk to the mission and to the member.
2. ETP process data and trends in line of the Air Force senior leader assumption of risk is used to inform future reviews of medical standards policies.

[490] EVOLUTION OF US AIR FORCE ACCESSION MEDICAL WAIVER DIVISION DECISION MAKING PROCESSES.

Ian Gregory

U.S. Air Force, Joint Base San Antonio-Randolph, TX, United States

(Education - Program/Process Review)

BACKGROUND: The US Air Force Accession Medical Waiver Division (AMWD) was created to ensure consistent, timely, data driven accession and initial flying medical waiver decisions across the total force. For the AMWD to meet its mission, it needs to use updated data to base future decisions from. Specifically, data on the outcomes of prior waiver decisions will drive decision making for future waiver considerations. While the AMWD has always used up to date medical information to drive decisions, further understanding outcomes data will help improve the quality of occupational suitability decisions. **OVERVIEW:** The AMWD's mission is to "conduct comprehensive entrance and initial special duty occupational suitability analyses and rapidly deliver consistent evidence-based decisions to the Total Air and Space Force." The challenge presented to the AMWD so it can meet its mission while using outcomes data, is that the information systems that collect data on accession medical waivers do not naturally communicate with systems that collect outcomes data that is relevant to the operational Air Force. Desired operational outcomes include retention in the service for 1 operational tour, restrictions in ability to deploy, restrictions in ability to perform

one's job, utilization of medical care, and more. A contract was funded to get people to link the data within the different systems to analyze the likelihood of desired outcomes from those who started off with a medical waiver. **DISCUSSION:** Significant data is present showing the workload the AMWD has done over the past 3 years of its existence. Diagnoses, percent of waiver approvals, types of applicants are all well documented by the organization. Some changes in waiver practices have been made based off those numbers, and other influences. With the new information about operational outcomes from members who accessed with medical waivers, decisions can be made about future waiver practices. The project is early in the implementation phase, but increased fidelity when looking at the data will help to know if people with specific diagnoses are more or less likely to have specific outcomes that the US Air Force is interested in. Extending the project to include more outcomes and more years of cohort participants will ensure greater success moving forward.

Learning Objectives

1. Understand the mission and processes of the US Air Force Accession Medical Waiver Division when making occupational suitability decisions for members who do not meet accession and initial flying standards.
2. To learn about the different data the Accession Medical Waiver Division uses to track decisions and help inform future decisions.
3. Understand the fundamentals of incorporating operational outcome data to prior medical accession waiver decisions.

[491] OUTCOMES AND EVIDENCE – FUTURE INQUIRIES AND ANALYSES

Rodger Vanderbeek, Hernando Ortega

Accession Medical Waiver Division, Air Force Recruiting Service, Randolph AFB, TX, United States

(Education - Program/Process Review)

BACKGROUND: Occupational suitability assessments and subsequent decisions for entrance and initial special duty accessions depend upon predictive models of disease/injury progression, risk of recurrence or exacerbation, and response to occupational exposures. Suitability decisions further depend upon a robust understanding of the operational mission task requirements and environmental challenges, their performance requirements, and the required and desired human performance attributes and capabilities across the entire Air Force and Space Force Specialty Codes (AFSCs) spectrum. Gaps in knowledge across this entire spectrum remain. **OVERVIEW:** In pursuit of closing these knowledge gaps, the Accession Medical Waiver Division (AMWD) needs a larger suite of operational outcomes to accompany condition/disease outcomes, and then incorporate that larger outcome suite within ongoing studies and analyses. Evidence from those studies across a larger data set/larger outcome set will allow comparison of cohorts for both clinical outcomes of their waived condition or disease and operational outcomes in the context of the cohort's condition/diagnoses. This larger body of outcomes (operational availability, human performance, and clinical) will provide an even larger critical evidence-base for deeper enlightenment of the impact of occupational suitability decisions across a larger number of occupations (AFSCs). **DISCUSSION:** Targeted future operational and human performance outcomes will be described along with presently utilized outcomes. Networks/data systems that are the home for some of these outcomes will be described. Ongoing work to establish new validated performance outcomes will be described. Future studies and analyses will be described along with their anticipated utilization in occupational suitability analysis and their potential to inform service and DoD policy for medical standards.

Learning Objectives

1. The audience will learn about potential operational human performance outcomes of interest to support evidence-based outcomes for occupational suitability determinations in USAF/USSF accession waivers.
2. The audience will learn about future cohorts to be submitted to an operational analysis agency for studies and analyses on those cohorts,

to compare clinical, occupational and operational outcomes for cohorts and control populations.

[492] TITLE: OPERATIONAL OUTCOMES ANALYSIS: DIAGNOSTIC SUBGROUP ANALYSIS

Eduardo Rizo¹, Benjamin Clapp², Hernando Ortega³, David Coulliette⁴, Atheer Jaffar⁴

¹U.S. Air Force, San Antonio, TX, United States; ²U.S. Air Force, Wright-Patterson

AFB, OH, United States; ³U.S. Air Force, Randolph AFB, TX, United States;

⁴U.S. Air Force Materiel Command, Wright-Patterson AFB, OH, United States

(Original Research)

INTRODUCTION: USAFSAM Studies and Analysis pilot project proof of concept analysis linked qualified (QUAL) and waived (WAVR) enlisted accessions to outcomes of interest; 4-year retention (RET), mobility restrictions (MR), duty restrictions (DR) and medical visit counts (MVC). USAFSAM further stratified the WAVR cohort into diagnosis groups.

METHODS: All active duty (AD) enlisted accessions from FY15 – FY18 and their waiver status, were cross referenced with AF personnel data and AF medical data to measure RET, DR, MR and medical utilization. The WAVR cohort was further divided, based on ICD code, into a MH group (ADHD, anxiety, and mood disorders), an Ophthalmic/Otic group (astigmatism, myopia, binocular vision disorders, and hearing loss), and an Atopic group (asthma, atopic dermatitis, and allergy or anaphylaxis). RET was measured at 1, 6, 12, 24, 36 and 48 months. DR were measured as days on profile and compared to total days in service, as were MR. MVC per Airman year calculated by sponsor identification divided by time in service. **RESULTS:** The 4-year QUAL group had 104,4970 individuals and had RET rates at 1, 6, 12, 24, 36, and 72 months of 96.1%, 92.7%, 90.9%, 87.7%, 84.0%, and 72.1%. The WAVR subgroups ranged from 50 to just over 1250 individuals. All subgroups had unique RET rates that were equal to or greater than the QUAL group except for hearing loss (lower). MR for the QUAL group was 9.5% of time in service with a mean 35 days. Anxiety disorders and hearing loss subgroups had lower MR rates than the QUAL group; the rest were higher. DR days were 5.9% of time in service for the QUAL group. Anxiety disorders myopia astigmatism, and atopic dermatitis had lower DR rates. The QUAL cohort had an average of 12.8 MVC per year; all WAVR subgroups were higher in MVC except for hearing loss and atopic dermatitis. **DISCUSSION:** Mood disorders (207) the highest RET, 73% higher MR, 37% higher DR, 30% higher annual MVC. Anxiety disorders had 101 individuals but similar to the baseline QUAL population. ADHD (1,253) had increase of 15% for MR, 13.5% DR, and 3% for MVC. Astigmatism and binocular vision were similar to the QUAL baseline. Myopia had higher RET and had MR/DR rates similar to astigmatism. The allergy or anaphylaxis subgroup (628) had similar RET to the QUAL group but had 28% higher DR/MR rates and 20% increase in MVC. Atopic dermatitis had 13% lower DR and a 4% higher MR while asthma had a 20% increase DR and 16% increased MR.

Learning Objectives

1. Understand which conditions have represent higher medical risk and suggest the waiver threshold is appropriate.
2. Understand which conditions might be appropriate for accepting increased risk in waiver determination based on outcomes in the first term of service.

[493] OPERATIONAL OUTCOMES ANALYSIS: BASELINE FULLY QUALIFIED VS WAIVER

Benjamin Clapp¹, David Coulliette², Atheer Jaffar², Hernando Ortega³, Rodger Vanderbeek³, Eduardo Rizo³

¹USAFSAM, Wright-Patterson AFB, OH, United States; ²U.S. Air Force, Dayton, OH, United States; ³U.S. Air Force, San Antonio, TX, United States

(Original Research)

INTRODUCTION: Medical standards have been "surrogates" for assessing health and performance. The medical literature has data on

medical outcomes. The Accession Medical Waiver Division has been focused on gaining more evidence from operational outcome data to inform waiver thresholds and accession medical standards. This proof of concept looks at an initial set of operational outcomes to establish base-lines for the current application of DOD medical standards. **METHODS:** AMWD provided a list of active duty (AD) enlisted accessions from FY15 – FY18 and their medical waiver status, either qualified (without medical waiver or QUAL) or with medical waiver (WAVR). This list was cross referenced with AF personnel data and AF medical data to measure retention rate on AD, days on duty restrictions, days on mobility restrictions and medical service utilization. Retention was measured at 1, 6, 12, 24, 36 and 48 months. Duty restrictions (DR) and mobility restrictions (MR) measured as days on profile were compared to total days in service. Visits per Airman year were calculated by sponsor identification divided by time in service. **RESULTS:** The 4-year QUAL group had 104,4970 individuals while the WAVR cohort had 10,953. The QUAL cohort had retention rates at 1, 6, 12, 24, 36, and 72 months of 96.1%, 92.7%, 90.9%, 87.7%, 84.0%, and 72.1%. The WAVR cohort retention rates were 96.7%, 93.9%, 92.2%, 89.2%, 85.8%, and 75.1% respectively. MR for the QUAL group was 9.5% of time in service with a mean 35 days while the WAVR group had 11.0% time on MR with a mean of 38 days. DR days were 5.9% of time in service (mean 21 days) for the QUAL group, and the WAVR group had DR days of 6.6% of time in service (mean 24 days). The QUAL cohort averaged 12.8 medical visits per year; WAVR was 13.7 visits per year. **DISCUSSION:** A baseline for these 4 outcomes was established for the QUAL cohort and compared to the WAVR cohort. WAVR had slightly higher retention rates across the board, slightly increasing over the 4-year study period. The QUAL had average MR rate, above the SECDEF goal of 95% deployability. The WAVR group was 22% higher at 11% overall MR. DR for the WAVR group were also higher than the QUAL group (17% increase). However, this study did not link waiver diagnosis to the diagnoses that produced MR or DR. The finding of 12.8 medical visits per airman per year was high for all airmen and should be further investigated, but the WAVR group had a 7% higher medical visit rate.

Learning Objectives

1. Know that observed retention rates are higher among the waived than the unwaived population.
2. Identify a significant (validated) concern with the admission of persons diagnosed with mood disorders prior to admission into the USAF.

Thursday, 05/25/2023

3:30 PM

Napoleon C3

[S-87]: PANEL: AEROSPACE MEDICINE: ADAPT OR PERISH REDUX: CHALLENGES AND OPPORTUNITIES FOR THE AEROSPACE MEDICAL PROFESSIONAL IN THE NEXT DECADE

Chair: Stephen Altchuler

Co-Chairs: Gitika Gorthi, Paul Nelson

PANEL OVERVIEW: This panel presents a series of views of where the practice of Aerospace Medicine is and where it is going. Much of this change is being driven external to the specialty of Aerospace Medicine, and the pressures driving change are accelerating. These include, but are not limited to, the advancement of operational missions supported, including enhanced focus on the Space Medicine mission; military and civilian. Concurrently, the practice of clinical medicine is rapidly evolving, and includes factors such as a demand for care anytime and anywhere, democratization of medical knowledge, emphasis on team collaboration, an enhanced role of precision medicine, artificial intelligence and biocybernetics, while experiencing a continued emphasis on cost containment. Additionally, the United States Military Health System (MHS) has long been the institution that disproportionately supported the specialty of Aerospace Medicine in the United

States for both military and civilian domains. The MHS is undergoing the most dramatic realignment of medical support functions since the early 1950's as both operational missions and approaches to clinical medicine present increasing challenges. The profession of Aerospace Medicine must successfully demonstrate and communicate a clear Value Added Proposition (VAP) to policy makers in order to compete successfully for increasingly scarce resources, regardless of whether in the military or civilian domains. This panel will review some of these challenges, suggest best practices, new models of engagement and education to maintain relevance, and describe what the requirements of the specialty will demand if we are to not only survive but to prosper. In keeping with the theme of this year's scientific program, the panel will close with a look to the future from those young people who will carry our specialty forward. The icons of Aerospace Medicine delivered to us a proud legacy to run our lap of a never ending race. The future will be built on a proud legacy of those who have come before us. As we hand off the baton to our emerging aerospace leaders, it is now up to us to engage with the remarkable young people who will soon take our place, helping set them up for success in creating an exciting future that few of us have even dreamed of.

[494] THE FUTURE IS NOW: CHALLENGES AND CHANGES THAT WILL DRIVE CHANGES FOR THE AEROSPACE MEDICINE SPECIALISTS

Jacob Berry¹, Lawrence Steinkraus²

¹Harvard University, Cambridge, MA, United States; ²Mayo Clinic (emeritus), Rochester, MN, United States

(Original Research)

INTRODUCTION: Operations in the Air and Space domains drive support requirements, including requirements for Air and Space Medicine. Only by understanding where operations are today, and where they will be over the next several decades, can we position the specialty of Aerospace Medicine to meet the support demands of these rapidly changing air and space operations. **METHODS:** This panel will provide a review of trends in the air and space domains. It will cover current civilian and military operations, connecting policy, business trends, public and private investments, and forecasts predicting what operations may look like in the future. **DISCUSSION:** As supported operations in the air and space domains rapidly evolve, the requirements placed on aerospace medical professionals will change quickly too. Some things will change incrementally, such as the approach to aerospace medical standards or mitigation strategies for the traditionally stressors or air and space flight. Other changes will be more dramatic, including changes in health monitoring systems, biocybernetics, integration of artificial intelligence and machine learning into operational medical support, and the challenges of providing medical support for distant operations as complex networked operations drive missions far beyond the reach of traditional air and space medical support.

Learning Objectives

1. Understand some of the macro trends that will drive medical support for Air and Space Operations of the future.
2. Consider how some of the current and emerging technologies may change the way that medical support for Air and Space Operations are accomplished.

[495] RISK IDENTIFICATION, MANAGEMENT, COMMUNICATIONS: MULTI-DISCIPLINE AND MULTI-DOMAIN ENGAGEMENT DRIVE KEY AEROSPACE MEDICAL PROFESSIONAL PROFICIENCIES

Paul Nelson¹, Lawrence Steinkraus²

¹USAFSAM, Wright-Patterson AFB, OH, United States; ²Mayo Clinic (emeritus), Rochester, MN, United States

(Original Research)

INTRODUCTION: Complex systems, as discussed by Perrow, Reason, Dekker, and others, are often under-appreciated relative to

safety and mission success. To be effective, risk mitigation requires not only constant attention amidst real-world friction and demands, but also effective management and communication skills. While constructs such as the Human Factors Analysis Classification System (HFACS) aid in understanding error chains, they are insufficient in providing a global understanding of how to recognize and address complex systems prior to accidents, ensuring the pre-conditions for safer air and space operations. **METHODS:** The speakers will briefly review lessons from a high-profile failure costing many lives and millions of dollars. They will then integrate concepts such as High Reliability Organizations (HRO) theory and the Failure Mode Effect Analysis (FMEA) construct and propose a model for effective relationships and horizontal and vertical communication strategies to improve both safety and mission effectiveness. **DISCUSSION:** Many of the concepts proposed by the authors are familiar. However, as previous speakers have discussed, the domains within which the Aerospace Medicine Specialist will practice are rapidly changing. The proposed model for effective relationships and communication strategy will build upon concepts and practices that have worked well in the past but will incorporate requirements for the specialty to remain relevant and effective in the rapidly evolving future that is upon us. This talk will review options to enhance the Value-Added Proposition (VAP) for the next generation of Aerospace Medical Specialists leading and participating in a cross functional multidisciplinary team of specialists. These will drive requirements for education and training that are currently being set by the American Board of Preventive Medicine (ABPM).

Learning Objectives

1. Understand the concepts of the HRO and FMEA models, and how they may apply to the future practice of Aerospace Medicine.
2. Critically evaluate the model proposed by the authors to effectively engage with Air and Space Operations at all levels.
3. Understand that effectively communicating scientific recommendations as the Aerospace Medical Specialist will become far more challenging in an increasingly linked world where information is democratized.

[496] FOOTBALL OR FUTBOL? UPDATES FROM THE AIR UNIVERSITY: EDUCATING AN AIRMAN OR SPACE GUARDIAN FOR THE 21ST CENTURY

David Manrique¹, Paul Nelson²

¹Air University, Maxwell AFB, AL, United States; ²USAFSAM, Wright-Patterson AFB, OH, United States

(Original Research)

INTRODUCTION: As Air and Space missions rapidly evolve, the Air University embarked upon a transformation effort in 2015 to ensure that the education system of the Air Force produced Airmen (and now Guardians) capable of leading in increasingly complex environments. Building upon educational theory, the authors will propose a sports analogy as a starting point to better understand the education requirements to produce such leaders. **METHODS:** This presentation is built upon several prior presentations delivered at the Aerospace Medical Association annual meeting on the rapid curriculum evolution at the Air University. These changes were necessary to keep pace with the requirements of producing professional Airmen and Space Guardians in the dynamic environment of the 21st century. The authors will review existing educational models including the Continuum of Learning and Bloom's taxonomy and describe recent significant changes to the curriculum at the Air University. Finally, the authors will propose an analogy of education and training requirements to build world class athletes in two quite different games, American and European Football (Soccer). **DISCUSSION:** Certainly, to become an elite athlete in either American or European football requires a basic athletic ability, discipline, intelligence, and a commitment to excellence. While the path to becoming an elite athlete in either sport requires a sustained commitment to

excellence, the way the game is played and coached is different. Both are complex games to play, especially at the elite level, but the way players are developed before they reach the elite level shares both similarities and differences. The authors will describe recent experiences at the Air University with wargaming as an educational tool demonstrating the strengths, but also weaknesses of both types of education. They argue that the pathway for development of a professional relevant for the 21st century is more like European football/soccer and less like the development process for American football. They will discuss the implications of this model for the development of Aerospace Medical professionals.

Learning Objectives

1. Understand Bloom's taxonomy and the Continuum of Learning, two existing educational models employed by both civilian and military educators.
2. Integrate concepts and lessons from coaching and developing talent in professional athletes across two different sports into existing educational models.
3. Consider if these concepts may be relevant as we strive to develop Aerospace Medical professionals with the skills to effectively lead in the 21st century.

[497] THE FUTURE IS OURS: LET'S CREATE IT TOGETHER!

Gitika Gorthi

Columbia University, New York, NY, United States

(Original Research)

INTRODUCTION: The generations that gave us medical support for two world wars, the Cold War, the Apollo program, Precision and Stealth and now into a new frontier of Space will soon be led by a younger generation. Young people will create the future of the Aerospace Medicine Specialty, yet very few of these young people who will soon take our places are represented at this conference. Senior Aerospace Medical professionals must engage with the youth today that will soon be in charge to ensure viability for our profession for the future. **DISCUSSION:** The author will provide an overview of the macro-trends that are influencing a younger generation and fueling their passions, connecting the content with the material presented by the previous speakers on the panel. She will integrate her experiences creating an international community of young people connected with experienced and diverse professionals across the globe to provide clues for the audience to ensure that what is built today is not only sustainable and meets the needs of future operations but is accessible and engaging to attract and retain the talent that is necessary for the viability of our specialty going forward.

Learning Objectives

1. Understand some of the macro trends that are shaping the views of young people today.
2. Understand some of the factors that are driving interest in the specialty of Aerospace Medicine in young people today.

Thursday, 05/25/2023

Napoleon Ballroom A1-B3

3:30 PM

[S-88]: PANEL: NAWCAD HUMAN SYSTEMS ENGINEERING UPDATES ON IMPROVING HUMAN PERFORMANCE AND PROTECTION

Chair: Micah Kinney

Co-Chair: Chris Foster

PANEL OVERVIEW: TITLE: NAWCAD Human Systems Engineering Updates on Improving Human Performance and Protection **BODY:** This panel will present ongoing and future efforts in improving human performance

and protection within the aviation environment from engineers and scientists at the Naval Air Warfare Center Aircraft Division (NAWCAD) Human Systems Engineering Department. The first presentation will discuss the development of a Naval Aviation Operational Injury Database (NAVOID) linking operational factors with aeromedical waivers. Second, a presentation on the need for meta-analysis and machine learning to identify future air platform physiological monitoring requirements. Third, a discussion on the ongoing efforts of technology test and evaluation to improve hearing protection and performance in flight. Finally, the fourth topic will discuss ongoing efforts in developing digital human models to predict and prevent injuries in aviation mishaps.

[498] DEVELOPMENT OF A NAVAL AVIATION OPERATIONAL INJURY DATABASE (NAVOID) GUIDING SOLUTIONS AND INTERVENTIONS TO ONGOING MUSCULOSKELETAL PAIN AND INJURY

Travis Doggett, Bethany Shivers, Juan Diaz-Rijos
Naval Air Warfare Center Aircraft Division, Patuxent River, MD, United States

(Education - Program/Process Review)

BACKGROUND: Musculoskeletal injuries associated with naval flight environment directly impact flight personnel, readiness, and cost. Acute and chronic injury data relative to operational exposures are critical to providing focused solutions to the fleet and is a well-established knowledge gap. Aeromedical researchers and human systems engineers, currently depend largely on survey data and anecdotal reports to identify relationships between aviation operational exposures and medical outcomes and/or waivers to develop and prioritize research and materiel/non-materiel solutions to commonly reported aircrew issues. These relationships lack verifiable supporting data or are limited in accuracy and application necessary for critical analysis of data and relationship determination. Access to individually-linked operational and medical data would allow researchers to identify exposure/outcome trends across a broad range of commonly reported issues such as neck and back pain/injury, better enabling focused solution development that can be rapidly implemented to the fleet. **OBJECTIVE:**

1. Demonstrate the critical capability provided by an aggregated database linking individual operational and medical readiness data providing data specificity critical to advancing aeromedical research efforts and solution development. 2. Develop a cost effective strategy to establish a full-scope aggregate operational and medical database as a core capability within NAWCAD. **APPROACH:** Aviation-specific operational and medical readiness data are reported independently removing the critical context needed to capture the full magnitude of the impact on readiness. The external databases identified for initial inclusion are the Navy's Sierra Hotel Aviation Readiness Program (SHARP) and Aeromedical Electronic Resource Office (AERO) flight waiver adjudication system. **OUTCOME:** Access to aggregated medical and operational data through a usable database will focus and define research of mitigation/prevention strategies, prediction tools, and treatment parameters. The result would be improved warfighter short/long-term health and medical readiness while decreasing chronic injury-related costs. Conducting a proof-of-concept data query and providing a cost-effective development strategy will strengthen appeals for program-level joint funding to support the immediately beneficial and broadly applicable capability provided by a full-scale aggregated operational and medical database.

Learning Objectives

1. Understand the critical need in linking operational exposures with medical conditions in order to streamline treatment and focus preventive research efforts.
2. Demonstrate SHARP and AERO as viable options for collecting data, aggregating, aligning, and collating into a centralize, queryable database discovering trends between operational factors and medical problems.

[499] USING MACHINE LEARNING TO IDENTIFY KEY PHYSIOLOGICAL MONITORING REQUIREMENTS FOR FLIGHT OPERATIONS

Travis Doggett, Micah Kinney
Naval Air Warfare Center Aircraft Division, Patuxent River, MD, United States

(Education - Program/Process Review)

BACKGROUND: The Department of Defense (DoD) has invested a significant resources into the investigation of unexplained physiological episodes within the flight environment. As part of this effort, devices to monitor the physiological state of aircrew during operational exposures have been tested in a variety of environments and in some cases in flight. Devices evaluated include functional near-infrared spectroscopy (fNIR), heart rate and respiratory sensors, eye-trackers, and electroencephalography. These studies have generated large data sets to better understand human physiology, validate hardware/sensors, and demonstrate how flight environments affect physiology. However, despite the large investment, there remains a significant knowledge gap in platform requirements and go/no-go criteria. **OBJECTIVE:** A systematic review will be conducted of existing DoD data obtained during validation of physiological hardware testing, human performance in environmental extremes, and investigations of individual differences on human physiology. Using these data sources will enable the use of machine learning algorithms to identify key physiological markers for impairment or reduced performance. With the identification of these key physiological markers, requirements for future aircraft platform integration of physiological monitoring hardware and command go/no-go criteria can be developed. **APPROACH:** NAWCAD and Naval Medical Research Unit-Dayton will perform a systematic literature review to identify relevant physiological monitoring efforts. Down-selection will guide machine learning "binning" including reduced oxygenation, impaired cognition, or elevated heart rate and allow meaningful connections of unrelated metrics. The Naval Air Warfare Center Training and Simulation Division recently developed machine learning algorithms to enhance aircraft maintenance. A multitude of sensors collecting data including gravitational forces and engine temperatures is collected as part of routine maintenance cycles. Employing machine learning and data analytics, potential failures of components can be identified beforehand. We propose using this approach with physiological data to identify deviations from baseline prior to impairment or loss of performance. We hypothesize that machine learning can be applied to the existing multi-variate data sets to identify key physiological measures, then validated and verified to ensure reasonable and intelligible outputs.

Learning Objectives

1. Understand the physiological endpoints of importance in monitoring aircrew during operations.
2. Understand the need for performing meta-analysis of physiological data in order to determine tolerance trends that can guide requirements on future aircraft design.

[500] EMERGING TECHNOLOGIES TO IMPROVE HEARING CONSERVATION MANAGEMENT AND ENHANCE WARFIGHTER PERFORMANCE

Kyle Shepard
Naval Air Warfare Center Aircraft Division, Patuxent River, MD, United States

(Education - Tutorial/Review)

Effective hearing and balance is imperative to mission success in all military operations. Situational awareness and communication capability are the most important mechanisms for military members to operate safely and competently as a team in dynamic environments. Temporary or permanent disruption to these abilities account for a large portion of physiologic events (PE's) throughout the Naval Aviation Enterprise. Disruptions can be caused by hazardous noise, vibration, pressure changes, significant motion and other factors. Unfortunately, these stressors are very common

throughout Naval Aviation. Fortunately, they can often be mitigated when properly understood and appropriate controls are applied. Audiologists are subject matter experts of the assessment and management of hearing and balance systems. Therefore, this specialty became a primary component of the new Aeromedical Monitoring and Analysis Branch of the Human Systems Engineering Department when it was created in 2021 at Naval Air Warfare Center Aircraft Division (NAWCAD) of NAVAR at Naval Air Station Patuxent River in Maryland. Operational Audiologists in the Navy offer clinical expertise in both hearing and balance, field knowledge of sustaining or enhancing these systems in unique environments and physiologic knowledge to be synergized with the wealth of engineering expertise already present at NAWCAD. This presentation is intended to discuss audiologic concepts and emerging technologies demonstrating promise to improve hearing conservation management and/or enhance warfighter performance in extreme environments.

Learning Objectives

1. Following participation in this session the learner will be able to name one of the primary facilities in the Navy that conducts research on current and emerging hearing protection and communication systems.
2. Following participation in this session the learner will be able to name at least 1 emerging technology that will impact hearing protection and communication systems in the future.
3. Following participation in this session the learner will be able to be able to describe the difference between talk through and active noise reduction technology.

[501] USING ANALYTICAL HUMAN MODELS FOR ACCURATE PREDICTION OF INJURIES

Lindley Bark, Aamir Jafri

Naval Air Warfare Center Aircraft Division, Patuxent River, MD, United States

(Education - Program/Process Review)

INTRODUCTION: Human analytical models were developed two decades ago to assess injuries accurately. These models are regularly applied in modeling and simulation to analyze injuries in automobile accidents. The OEMs (Original Equipment Manufacturers) like Toyota, General Motors, Ford Motor Company etc., have led many of these developments. Presently, simulation of the kinematics of and prediction of injuries within the entire human body is possible including the brain and internal organs with and without muscle activation. Recently, NAWCAD acquired a set of models: Total Human Models for Safety (THUMS) from Toyota Labs. The purpose is for research toward reducing human harm in aviation mishaps.

TOPIC: The THUMS model is currently used by NAWCAD to assess highly dynamic loading that naval personnel experience during aviation mishap events. It provides unprecedented fidelity with respect to potential injuries (including lower extremities) that are not fully captured by current physical or virtual anthropomorphic test devices (ATDs). Since each body organ and tissue model was developed using polygon scanner to capture accurate geometry along with verified/validated material properties with non-linear stress-strain curves, bone fracture, organ failures like bladder rupture, injury on the kidneys, liver, heart etc., can be determined.

APPLICATION: The applications includes development of expanded injury criteria by comparing ATDs and THUMS in terms of predicted injury under specified dynamic conditions and identify how to bridge the standard ATDs with human body models. The return on investment is in allowing specific injury mechanisms to be investigated with countermeasures developed and assessed for efficacy. This enables targeting acute injuries for mitigation, injury criteria development, crashworthy system design and development, and rapid evaluation of airworthiness concerns. Internally, at NAWCAD, chronic injury prediction is underway to identify countermeasures. These models are also being adapted for conditions where warfighters experience mine blast or other transient dynamic events. The model results are accumulating into a database with spot tests against cadaveric testing or anecdotal mishap results are spot checked. Additional data from physical testing for different human specimens pertaining organs, tissues, muscle will be gathered and incorporated to the materials defined in these models.

Learning Objectives

1. Application of analytical human body models to injury prediction for aviation mishaps.
2. Correlation of human model vs. mechanical surrogate models for aviation mishap applications.
3. Potential used of analytical models to improve survivability in aviation mishaps.

Thursday, 05/25/2023

Nottoway & Oak Alley

3:30 PM

[S-89]: POSTERS: HUMAN PERFORMANCE 2 AND OTHER POSTERS

[502] ESTABLISHING MECHANISMS THROUGH WHICH SYSTEMIC INFLAMMATORY PROCESSES NEGATIVELY IMPACT BRAIN STRUCTURE, FUNCTION, AND ULTIMATELY, AIRCREW READINESS

Koyal Ansingkar¹, Kui Xu¹, Joseph Piktet¹, Adrienne Dennis², Elizabeth Damato¹, Michael Decker¹

¹Case Western Reserve University, Cleveland, OH, United States; ²MetroHealth Medical Center, Cleveland, OH, United States

(Original Research)

INTRODUCTION: Cognitive fatigue represents a constant threat to tactical aviator safety. We have recently found increased serum levels of proinflammatory cytokines are associated with fatigue in a cohort of T-6A instructor pilots. Hypobaria, ever present in tactical aviation, may be one contributor to the synthesis and release of those cytokines. We hypothesize exposure to proinflammatory cytokines perturbs levels of connexin-43, a key protein responsible for blood-brain barrier integrity, promoting the onset of neuroinflammation as cytokines leak into neuronal tissues. This manifests as cognitive fatigue. Our objective was to assess neuronal connexin-43 levels in a murine model following hypobaric exposure. **METHODS:** Following approval by the Institutional Animal Care and Use Committee, 15 C57BL/6J mice purchased from Jackson Labs were divided into three groups of five, each placed in a rodent hypobaric chamber at different altitudes to simulate different atmospheric pressures: 760 mmHg (sea level), 564 mmHg (8,000 feet of elevation), and 429 mmHg (15,000 feet of elevation). Each exposure consisted of an alternating cycle of 60 minutes at the experimental altitude followed by 60 minutes at sea level, three times per day over five consecutive days. Following all exposures, mice were sacrificed, and their brains extracted and preserved. The brains were processed for Western blot analysis to determine quantitative changes in connexin-43. **RESULTS:** Using Western blot analysis, connexin-43 protein levels were normalized to the total protein levels and calculated by dividing the target band signal by a determined lane normalization factor. This yielded normalized signals of 319092.7 ± 148238.1 (sea level n=3), 381111.9 ± 165984.5 (8,000 feet n=3), and 160805.1 ± 27104.5 (15,000 feet n=3). A relative decrease was observed in connexin-43 protein in the brains of mice exposed to 15,000 feet of altitude. **DISCUSSION:** The decrease in connexin-43 levels suggests an alteration in blood-brain barrier integrity following hypobaric exposure. Due to the small sample size in this preliminary study, statistical analyses could not achieve a minimum power of 0.80 at an alpha < 0.05. Experimental manipulations in upcoming months will include increasing sample sizes as well as the infusion of oxygen into the hypobaric chamber to maintain normoxia, similar to the cockpit environment experienced by tactical aviators.

Learning Objectives

1. Confirm a decrease in connexin-43 expression in the brain following exposure to hypobaria.
2. Isolate hypobaria from hypobaric hypoxia through infusion of oxygen into the hypobaric chamber to determine whether the decrease in

connexin-43 expression in brains is due to hypobaric alone or hypobaric hypoxia.

3. Understand whether hyperoxia, through excess infusion of oxygen into the hypobaric chamber, exacerbates the decrease in connexin-43 expression after exposure to hypobaria.

[503] INFLUENCE OF BAROMETRIC PRESSURE ON CARBON DIOXIDE ELIMINATION DURING NORMOXIC VOLUNTARY HYPERVENTILATION

Victoria Edwards, Alec Stevenson, Henry Tank, Rachel Firth, Vivienne Lee, Des Connolly
QinetiQ, Farnborough, United Kingdom

(Original Research)

INTRODUCTION: Aircrew are trained to recognise in-flight symptoms of hypoxia. However similar symptoms may result from hypocapnia due to hyperventilation in the absence of underlying hypoxia. Reports suggest that ambient pressure influences carbon dioxide elimination, therefore this study aimed to determine whether hyperventilation in the absence of hypoxia is more or less likely to occur at altitude than at ground level. **METHODS:** Fourteen participants undertook 15 minutes of normal restful breathing followed by 15 minutes of controlled voluntary hyperventilation (lowering end-tidal partial pressure of carbon dioxide to ~21 mmHg) in a hypobaric chamber. This was repeated on separate occasions at ground level (GL) and at 17,000 ft pressure altitude (PA). Cardio-respiratory data were analysed using two-way ANOVA to evaluate the influence of *Altitude* (GL vs PA) and hyperventilation *Duration* (5, 10, 15 minutes). **RESULTS:** *Altitude* influenced baseline restful breathing such that minute ventilation increased at PA (9.1 ± 2.1 vs. 10.3 ± 1.9 L·min⁻¹, $p=0.001$), however there was no difference in *Altitude* on minute ventilation during hyperventilation (21.5 ± 4.0 vs 22.4 ± 3.4 L·min⁻¹, $p=0.219$). There was no effect of *Altitude* on any measures during hyperventilation ($p>0.05$), however *Duration* from five to 15 minutes influenced minute ventilation (26.1 ± 3.5 to 20.0 ± 3.1 L·min⁻¹, $p=0.001$), respiratory exchange ratio (1.10 ± 0.31 to 0.82 ± 0.17 , $p<0.001$) and heart rate (87 ± 14 to 76 ± 10 bpm, $p<0.001$), which all decreased over the 15-minute period. Brain blood flow velocity was initially decreased with hyperventilation by 35% but increased over the 15-minute period (35.8 ± 8.7 to 40.6 ± 9.8 cm s⁻¹, $p=0.001$). There were no differences in physiological or subjective measures during hyperventilation conducted at PA relative to GL. **CONCLUSION:** Under normoxic conditions, decreased ambient pressure does not predispose towards hyperventilation. The difference in ventilation during restful breathing likely resulted from the Haldane effect due to the requirement for the participant to breathe hyperoxic gas (43% oxygen) prior to ascent. In fast jet aircraft the breathing gas is often hyperoxic as a precaution against hypoxia, which could explain a tendency towards increased ventilation during fast jet flight at routine cabin altitudes.

Learning Objectives

1. The audience will understand the influence hyperventilation has on physiological variables at altitude compared to ground level.
2. The audience will learn if there is any difference in the lung ventilation required at altitude and at ground level to achieve an equivalent severity of hypocapnia.

[504] EFFECTS OF HYPOCAPNIA ON POSTURAL STANDING BALANCE MEASURED BY SHARPENED ROMBERG TESTING (SRT) IN HEALTHY SUBJECTS

Richard Eboka, Jan Stepanek, Gaurav Pradhan
Mayo Clinic Alix School of Medicine, Scottsdale, AZ, United States

(Original Research)

INTRODUCTION: The effects of hypocapnia on the postural system have not previously been adequately investigated. The specific aim of this study is to evaluate the effects of hypocapnia on postural standing balance using the sharpened Romberg test (SRT). Hypocapnia arises in

many significant and common clinical conditions affecting ventilation such as bronchial asthma, high progesterone states, sepsis and more. We hypothesized that participants would have decreased time to step out on SRT in the hypocapnic condition. **METHODS:** 22 healthy subjects (7 M, 15 F) at 500m elevation were timed on SRT before and after they deliberately lowered their carbon dioxide levels by increased ventilation over 2min. End-tidal CO₂ (ETCO₂) measured by an EMMA capnometer was used to approximate the blood carbon dioxide level during the experimental procedures. The standing times were then compared to the baseline pre-hypocapnic SRT using a one-tailed, paired-samples t-test in order to assess how hypocapnia affects standing balance. The participants subsequently returned to normocapnic status through regular, quiet breathing and CO₂ supplementation. After returning to subjective normocapnia, the participant performed the SRT once more, followed by a final measurement of ETCO₂. Approval for human subjects research was granted by the Mayo Clinic Institutional Review Board and Ethics Committee for Human Studies. **RESULTS:** Mean times to step out on SRT were 101.324 ± 116.52 seconds at baseline ETCO₂, 47.67 ± 68.03 seconds post-maximum voluntary ventilation for 2 min, and 120.553 ± 132.09 seconds post-normocapnic recovery. Statistical tests comparing baseline SRT to post-hyperventilation SRT was $p = .0128$ indicating rejection of the null hypothesis. When comparing post-hyperventilation SRT to post-normocapnic recovery SRT $p = .0002$, again indicating a rejection of the null hypothesis. **DISCUSSION:** Our findings demonstrate that hypocapnia at 500m altitude is sufficient to cause clinically and statistically significant decreases in time to step out on SRT. These results in normobaric settings reveal that carbon dioxide homeostasis is integral to cerebral functioning that governs postural control. Thus, clinical assessment of capnic status is important in the evaluation of altitude-related illnesses, notably when trying to differentiate acute mountain sickness (AMS) and high altitude cerebral edema (HACE) as the latter is clinically associated with truncal ataxia.

Learning Objectives

1. The participant will learn about the effect of hypocapnia on postural standing balance in normobaric conditions at 500m elevation (equivalent to barometric pressure of 716 mm Hg or .94 atm).
2. The participant will appreciate the importance of capnic status assessment in the differentiation of acute mountain sickness and high altitude cerebral edema.

[505] A PILOT-STUDY TO INVESTIGATE NON-INVASIVE POSITIVE PRESSURE VENTILATION ON OXYGEN SATURATIONS WITHOUT SUPPLEMENTAL OXYGEN AT ALTITUDE

Crystal Marshall¹, Elias Smirlis¹, Jenna Taylor², Peter Larsen¹, J. Hunter Downs III², Douglas Rozendaal¹, Joshua Donkor², Aidan Downs², Jessica Johnston², Bruce Johnson², Douglas Summerfield¹

¹MercyOne North Iowa Medical Center, Mason City, IA, United States;

²Mayo Clinic, Rochester, MN, United States

(Original Research)

INTRODUCTION: Flying between 12,500 feet mean sea level (MSL) and 14,000 feet (MSL) for more than 30 minutes or any duration above 14,000 feet (MSL) requires the use of supplemental oxygen per the Federal Aviation Administration (FAA), however hypoxia can develop in pilots of general aviation (GA) aircraft below these levels. In an effort to offer an alternative method to supplemental oxygen for hypoxia prevention and increase safety of GA, we hypothesized that the use of noninvasive positive pressure ventilation (NIPPV) in the form of bilevel positive airway pressure (BPAP) would improve subjective overall well-being and cognition while at altitude. **METHODS:** Five males and five females between the ages of 18 to 89 with experience flying at 8,000 feet (MSL) or higher were recruited for a standardized flight profile consisting of four 15 minute segments, two at 8,000 feet (MSL) and two at 12,500 feet (MSL). The participants were randomly assigned

to either BPAP or ambient air and switched halfway. Environmental conditions during the two-day experiment were consistent. The Lake Louise scoring system for acute mountain sickness and a questionnaire were used to assess participant outcomes. Cohen's D for effect size and Wilcoxon Signed-Ranks tests were computed. All subjects participated voluntarily without compensation and written informed consent was obtained. The study was approved by the Mayo Clinic Institutional Review Board (protocol number 22-003189). **RESULTS:** We safely collected data on physiologic changes in subjects while on BPAP as compared to baseline ambient air. There were no injuries or acute medical complications. The majority of subjects felt that BPAP had a positive impact on their high altitude experience. Cohen's D = 1.1 suggestive of a large effect size was computed. Owing to small sample size and self-reported nature of this data, these effects are presented descriptively. Our study demonstrates subjective improvement both overall well-being and cognitive abilities while utilizing BPAP. **DISCUSSION:** Our focus was to prevent potentially dangerous effects of hypoxemia. The results from this study suggest that the use of BPAP subjectively improves well-being and cognitive abilities at and above 8,000 feet (MSL), as reported by the majority of our participants. Further research into the use of BPAP as an alternative to supplemental oxygen for the GA community is warranted.

Learning Objectives

1. The feasibility and practicality of inflight human research in general aviation.
2. The effectiveness of noninvasive positive pressure to alleviate symptoms of hypoxia.

[506] A CASE OF HYPERCAPNIA UNDER CONDITIONS REPRESENTATIVE OF FLIGHT

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(Original Research)

INTRODUCTION: Unexplained physiological impairment is a leading safety concern among tactical aircrew. Hyper- or hypocapnia have been proposed as potential causal factors for some physiological symptoms, but no in-flight data exist to evaluate such hypotheses. The present case report describes an instance of hypercapnia in a single study participant for whom the breathing circuit was fully monitored. **CASE PRESENTATION:** This event occurred during a study evaluating effects of repeated activations of an automated backup oxygen system (ABOS). The research participant was a 35y/o male active-duty United States Air Force Medical Technician with approximately 100 hours of hypobaric chamber experience. The participant experienced the following profile in a hypobaric chamber: 15 min at ground level with three simulated ABOS activations, followed by ascent to 9,000 feet for 45 min. Gas was supplied through a CRU-103 regulator and MBU-23/P flight mask. Delivered oxygen was 50% at ground level, 100% during simulated ABOS activations, and 95% at 9,000 feet. Beginning 32 minutes into the profile, the participant reported sudden severe symptoms, including tingling in his fingers, heart palpitations/increased heart rate, anxiety, sweating, and lightheadedness. The experimenter monitoring the signals in real time noted that the end-tidal CO₂ was just below the hypercapnic abort level of 65 torr. The profile was aborted, and the participant was given 100% O₂ for 25 min with no benefit. He was evaluated at the emergency room, discharged, and reported feeling better the next day. Subsequent data examination confirmed end-tidal CO₂ levels fluctuating around 9%. There was no evidence of equipment malfunction, and no indication of rebreathing expired gas. The participant's minute ventilation was noted to be approximately 23% less than his previous visits for the study. We hypothesize that the elevated oxygen suppressed the participant's carotid body CO₂ receptors while he was breathing on a somewhat resistive circuit, leading to lower

minute ventilation. **DISCUSSION:** Physiological symptoms may occur in the absence of any fault or irregularity in the breathing system. One potential cause is acute hypercapnia, possibly influenced by the hyperoxic cockpit environment. In cases of hypercapnia, the standard response to in-flight events of activating an emergency supply of 100% oxygen may be counterproductive.

Learning Objectives

1. Describe possible causes of physiological symptoms in a cockpit environment.
2. Identify possible issues with using 100% oxygen as a default countermeasure.

[507] HYPOXIA AWARENESS TRAINING: PILOTS' EXPERIENCE OF HYPOXIA PARTICIPATING IN FIVE AVIATION PHYSIOLOGY COURSES OVER A TIME PERIOD OF 16 YEARS

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(Original Research)

INTRODUCTION: The German Air Force Centre of Aerospace Medicine provides Hypoxia Awareness Training for flight personnel in a hypobaric chamber at intervals of four years. Refresher training in aviation medicine is required throughout the careers of the flight personnel. This raises the question whether these personal hypoxia experiences have changed over time. **METHODS:** 70 male military aircrews attended five aviation medicine training courses every four years between 2002 (age 33 +/- 4 yr.) and 2019. Each pilot underwent 5 exposures to reduced pressure in a hypobaric chamber to a simulated altitude of 25,000 feet to experience change of pressure and hypoxia (hypoxia recognition training). Heart frequency, oxygen saturation, hypoxia recognition time (HRT) and hypoxia symptoms were recorded. After a modification of the hypobaric chamber a remote controlled oxygen-separation was introduced in 2003. **RESULTS:** There was a significant difference regarding the hypoxia recognition time in the first and the following courses. In the first course the students disconnect themselves from 100% oxygen and the HRT was 72 sec. After the modification in 2003 the students were disconnected unperceivedly by the instructor from outside the chamber. The HRT under this condition were at least 99 sec (99 sec – 104 sec). The oxygen saturation when feeling the first hypoxia symptom averaged to 87%. The students reconnect to 100% oxygen at an average oxygen saturation of 70%. The most frequent 1st symptom was sensation of heat (44%) followed by dizziness (18%). Only 8 pilots (11%) had the same first symptom during all five courses. 13 (19%) aircrews didn't experience any hypoxia symptoms at least one time during the aeromedical training courses and 2 aircrews didn't feel any symptoms during three hypoxia demonstrations. **DISCUSSION:** The difference regarding the HRT between the first and the other courses could be an effect of the different disconnection methods from 100% oxygen. In the first course the disconnection from oxygen was conducted by the students but not in the following courses. So this could be the explanation why they felt the hypoxia symptoms 27 sec earlier. The recognition of hypoxia symptoms is not very reliable and therefore it makes sense to train it during a pilot's career. Medical monitoring is helpful for the safety crew to realize health problems of trainees in time and enables students to compare subjective feelings with objective data.

Learning Objectives

1. To understand the benefit of hypoxia training in a hypobaric chamber.
2. to understand the most frequent hypoxia symptoms and the benefit of medical monitoring.

[508] RELIABILITY OF TWO CLINICALLY ORIENTED EYE TRACKING PROTOCOLS

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(Original Research)

INTRODUCTION: Smooth pursuit eye movements, when the eyes continuously track a moving target, can be used to quantify an individual's general oculomotor and neurological health. Two commercially available eye tracking systems, the neuroFit ONE and RightEye Sensorimotor, measure smooth pursuit as a predictor of operational or athletic performance and biomarker of neurological health. However, to be useful for either, the same individual should score similarly on successive iterations of the same test. This study evaluates the test-retest reliability of both systems and their usefulness in aeromedical screening applications. **METHODS:** Intrasection test-retest data were collected from 43 participants (34.5 ± 7.8 years). Each session included the neuroFit ONE protocol, which consists of a radial Rashbass step-ramp smooth pursuit task, and the RightEye horizontal and vertical smooth pursuit protocols, which consist of a sinusoidal tracking task. Participants ran each protocol twice within the same session. Bland-Altman analyses were used to assess the repeatability of reported output metrics. Metrics from both devices were considered reliable if internal variance (95% limits of agreement) was less than external variance (95% range). **RESULTS:** Five of the neuroFit ONE metrics had acceptable test-retest reliability: latency (ms): mean difference = $+2.05$ (95% LOA: $+10.28$ to $+15.82$); response acceleration ($\text{deg} \cdot \text{s}^{-2}$): mean difference = -5.45 (95% LOA: $+35.33$ to $+65.73$); direction noise (deg): mean difference = $+0.68$ (95% LOA: $+4.33$ to $+7.77$); smooth pursuit gain: mean difference = $+0.00$ (95% LOA: $+0.24$ to $+0.16$); and smooth pursuit proportion: mean difference = -0.01 (95% LOA: $+0.13$ to $+0.20$). The RightEye produced 8 different metrics of interest for each smooth pursuit direction, many of which were found to be reliable metrics, including horizontal disconjugacy, saccade percentage, and smooth pursuit gain. **DISCUSSION:** These results suggest several quantifiable components of smooth pursuit tasks can be measured reliably with commercial protocols. For the neuroFit ONE, metrics such as saccadic latency, response acceleration, direction noise, steady-state tracking gain and smooth pursuit proportion showed adequate test-retest reliability. Likewise, for the RightEye Sensorimotor, disconjugacy, gain, and saccade percentage demonstrated reliability. Some (but not all) elements of both devices could therefore be used in further studies to investigate aeromedical applications.

Learning Objectives

1. The audience will understand the reliability of two commercially available eye tracking systems, the neuroFit ONE and RightEye Sensorimotor.
2. The audience will understand which metrics produced by the neuroFit ONE and RightEye Sensorimotor could be used for further aeromedical testing.

[509] AN EYE-OPENING OUTCOME AFTER ROUTINE VISUAL ACUITY ASSESSMENT

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(Education - Case Study)

INTRODUCTION: This case report describes a 43-year-old military helicopter pilot who was found to have bilateral posterior subcapsular (PSC) cataracts. **BACKGROUND:** Ensuring excellent visual acuity is critical to flight safety. Changes in vision may occur imperceptibly or very rapidly, and any change in a pilot's visual acuity must be thoroughly evaluated. **CASE PRESENTATION:** A 43-year-old United States Air Force (USAF) helicopter pilot was noted to have 20/30 visual acuity bilaterally on annual flight physical. While considered near-normal vision, he did not meet the 20/20 visual acuity standard for required for USAF pilots. Ophthalmologic evaluation revealed decreased visual acuity (20/50 on the right eye and 20/40 on the left eye), and bilateral opacities just in front of the posterior lens capsule consistent with PSC (2-3 mm PSC on the right eye and a 1-2 mm PSC on the left eye). He underwent surgical correction with

implantation of a monovision synthetic intraocular lens with resolution of his right-sided functional vision, and is pending left-sided surgery in the future. **DISCUSSION:** Cataracts are the leading cause of vision loss in the US, with an estimated 24.4 million adults aged 40 years and older having one or both eyes affected. However, the prevalence rate increase with increasing age, affecting only 2.5% of individuals aged 40-49 years. Of the 3 morphological types of cataracts, PSC is the rarest form, comprising only 2.2% of all cataract cases globally. PSC is fast-growing, can progress rapidly, and typically affects individuals at an earlier age than the other types. Most cases occur in people over 60 years old but can occur in younger patients with diabetes mellitus, chronic use of steroids, ocular disease such as retinitis pigmentosa, or a history of eye trauma. Symptoms primarily affect one's reading and night vision, creating halo effects and glare around lights. Regardless of vision correction to 20/20, cataracts pose a significant risk to flight safety. However, visual effects of cataracts can be successfully treated with surgical correction and pilots can return to flying once vision standards are met. PSC should be considered in the differential diagnosis for decreased visual acuity even in young pilots with subtle visual changes.

Learning Objectives

1. The audience will understand the signs and symptoms of posterior subcapsular cataracts.
2. The audience will understand the risk factors for developing posterior subcapsular cataracts.

[510] COOLING OF HELICOPTER FLIGHT CREWS AND GROUND HANDLING PERSONNEL DURING MISSIONS IN COLD REGIONS

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(Original Research)

INTRODUCTION: Military operations can occur worldwide, in all dimensions (land, air, and maritime) and at any time of the year. Often missions arise in extreme environments, including all combinations of heat, cold, wind, precipitation, etc. The acra are most affected in cold weather, so this is where the focus of damage is initially seen. There is always a disparity between optimum cold protection and enough movement as well as comfort to perform operational tasks. Crews in a helicopter with open side door or ramp are particularly affected on the different workstations. Low temperatures, cold wind, and moisture can affect crew members up to hypothermia, local cold injury and permanent tissue damage. **METHODS:** During a 3-week helicopter winter operation in Sweden, flying and ground personnel were examined with the mobPhysioLab® configured precisely to the required physiological parameters during the respective missions. The skin temperatures (T_{skin}) of the fingers and wrists, toes and ankles, as well as in the face (cheekbone) and the neck were considered. In addition, the core body temperature (CBT), as well as the heart (Hf) and respiratory rate (Bf), were synchronized recorded additionally with the environmental parameters (T , Hum, $\text{Pres}_{\text{Envir}}$) in real flight. **RESULTS:** The ground-bound outside temperatures were $\text{AvDT}_{\text{Envir}} -10^\circ\text{C}$ (range: -3 to -25°C) by in-flight activities. From 14 soldiers, 46 records could be generated and evaluated. Of these, 5 were in the cockpit, 24 were on the open side door in flight, and 17 were on the ground personnel during activities at the flying helicopter (e.g., downwash). All in all, a continuous cooling of the T_{skin} fingers ($\text{AvDT} -10^\circ\text{C}$, range -3 to -18°C) and T_{skin} toe ($\text{AvDT} -17^\circ\text{C}$, range -10 to -27°C) could be obtained during flight time only up to 50min. **CONCLUSIONS:** Strong cooling of the extremities means a reduction in blood circulation, leading to a stagnancy. Through this protective mechanism of centralization, the extremities are virtually abandoned in favor of the organism's survival. Depending on the exposure time and the depth of the cold, damage up to necrosis occurs. In parallel, the functionality is increasingly restricted, which means the loss of dexterity when the T_{skin} hand falls below 15°C ; at 8°C , a nerve block is formed (loss of function). The preliminary results

of this study show that despite protection, skin temperatures continuously drop to a critical threshold in a short period of time.

Learning Objectives

1. Cold can affect the extremities of a person extremely quickly and prevent their function, up to irrevocable damage
2. Low protection from the cold can severely affect the person in the military operationality and severely affect the flight safety of all.
3. It is of considerable importance that soldiers on deployment in cold climates are especially protected from the cold so that they can fulfill their mission and return from deployment without suffering personal harm

[511] CARBOHYDRATE INGESTION ATTENUATES COGNITIVE DYSFUNCTION FOLLOWING LONG-DURATION PASSIVE HEAT STRESS IN HUMANS

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WITHDRAWN

[512] EVALUATION OF MORE THAN 20 YEARS AEROMEDICAL EVACUATION – LESSONS LEARNED FOR THE FUTURE BASED ON 2060 TRANSPORTED PATIENTS

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(Original Research)

INTRODUCTION: During military operations abroad, serious illnesses and injuries can occur with the consequence that soldiers have to be flown out to their home countries by fixed-wing aircraft for further medical care. These special equipped aircrafts are also often used for evacuation in the context of humanitarian missions. An ongoing scientific analysis is necessary to improve the medical treatment before, during and after the aeromedical evacuation (AE) flights. **METHODS:** A retrospective analysis of 612 AE-flights of the German Air Force since 2002 were conducted. In total 2,060 patients were evacuated by fixed-wing military aircraft to Germany. 1,337 (65%) of these patients were soldiers, 723 (35%) have been flown as part of humanitarian aid missions. The analysis based on an evaluation of the intensive care transport records used during flight with additional data (patient movement request, clinical data, written report). In 1875 cases (91%) the transport protocol was available. **RESULTS:** In median the age was 34.3 years (min: 4.6, max: 101.0). Patients flown as part of humanitarian aid missions were significantly older than evacuated soldiers (40.4 vs. 32.4 years, $p < 0.001$). 1,641 (80.0%) patients were males, 227 (11.0%) females and in 192 (9.3%) cases the sex/gender was not documented. Most patients ($n = 909$, 44.1%) have been flown due to underlying traumatological/surgical conditions, 732 (35.5%) patients have had an internal medicine underlying disease. This was significantly different between humanitarian missions, where traumatic and surgical reasons were predominated, and evacuated soldiers with internal medicine reasons. Complications requiring invasive measures only occurred in a small number of patients: three (0.2%) patients required a chest drain, four (0.2%) patients had to be intubated, and three (0.2%) patients received a new central venous catheter. **CONCLUSIONS:** AE flights are an integral part of the rescue chain and essential for high-quality medical care for soldiers deployed abroad. Underlying diseases vary significantly between soldiers and patients transported for humanitarian aid missions. However, serious complications are rare. This shows, based on more than 20 years of experience, that the procedures during AE flights have been standardized and integrated into medical care in an optimized manner.

Learning Objectives

1. The audience will learn that the patients transported by aeromedical evacuation differ between evacuation from military mission abroad and humanitarian aid missions.
2. The audience will learn that traumatic/surgical and internal medicine diseases are the most common reason for the need of aeromedical evacuation.
3. The audience will learn that there can be found a broad range of age especially when patients from humanitarian aid missions are transported, this must be taken into consideration when an aeromedical evacuation team plans a flight.

[513] ACUTE CHANGES IN RAT TISSUE AND BLOOD GENE EXPRESSION FOLLOWING EXPOSURE TO FLIGHT-RELEVANT HYPOBARIA

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(Original Research)

INTRODUCTION: Exposure of humans and lab animals to high altitude, e.g. >10,000 ft, results in changes in gene expression in tissues and blood cells that may mediate adaptation to altitude or contribute to altitude sickness. This study tested the hypothesis that exposure of healthy rats to flight-relevant hypobaria (4000-8000 ft) and/or different O₂ concentrations causes acute genotypic changes in the blood, lungs, heart, and brain that help explain the effects of moderate hypobaria on both normal and injured animals. **METHODS:** The protocol was reviewed and approved by the UMB IACUC (1217007) and the U.S. Air Force Surgeon General's Office of Research Oversight and Compliance (FWR-2018-0001A). These studies were conducted in a facility accredited by AAALAC, in accordance with the Guide for the Care and Use of Laboratory Animals (NRC, 2011) and were performed in compliance with DODI 3216.1. Adult male Sprague-Dawley rats were exposed to the "flight" conditions for 5 or 10 hours, after which the rats were euthanized and tissues were flash frozen. RNA was subsequently isolated and used for microarray measurements of differential gene expression (≥ 1.5 -fold change, $p < 0.1$) across 9 experimental groups compared to control animals which were maintained at sea level pressure under room air. **RESULTS:** Microarray analysis detected several hundred differentially expressed transcripts, including several at 4000 ft for only 5 hours. Blood showed the greatest change in gene expression while cardiac tissue showed the least. Canonical pathway enrichment identified several genetic pathways of interest for each tissue, including antioxidant gene expression in the lung, and iron homeostasis in the heart, lung, and brain. **DISCUSSION:** Exposure of rats to mild hypobaria and/or hyperoxia results in acute changes in gene expression in blood and vital organs. Some pathways showed trends over the two treatment durations, such as Nrf2-mediated gene expression in response to 8000 ft hypobaria in the lung. Although no mechanism was identified as a cause of flight-related secondary injury, this study provides a strong foundation for the analysis of gene expression changes after flight in normal animals and eventually in those subjected to trauma. The views expressed are those of the authors and do not reflect the official guidance or position of the United States Government, the Department of Defense or of the United States Air Force. Supported by US Air Force FA8650-18-2-6H15.

Learning Objectives

1. The audience will learn about gene expression changes brought on by aeromedical-evacuation relevant levels of hypobaria. They will see that relatively short exposures to moderate hypobaria and/or hyperoxia significantly affect the expression of many gene transcripts in multiple tissues, which may play a role in precipitating secondary injury.
2. The audience will learn which genetic pathways are most affected by aeromedical-evacuation relevant levels of hypobaria and/or hyperoxia in healthy rats. They will see this as a solid foundation in order to examine the differences in the gene expression between healthy and injured rats when exposed to moderate hypobaria.

[514] LOW OXYGEN TENSION DOWNREGULATES VIRAL ENTRY GENE EXPRESSION AND UPREGULATES THE TLR-IL33-NFKB PATHWAY IN HUMAN BRONCHIAL EPITHELIAL CELLS

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(Original Research)

INTRODUCTION: Given that hypobaric hypoxia and normobaric reoxygenation are commonly associated with air traveling and landing, while ischemia/hypoxia-reperfusion and hypoxemia are both associated with lung transplantation and chronic obstructive pulmonary disease (COPD), it is an interdisciplinary research topic of interest for both epidemics and aerospace medicine to investigate whether exposure to consecutive hypoxia or intermittent hypoxia-reoxygenation may influence the viral transmissibility, antiviral activity and innate immune and inflammatory response of human bronchial epithelial (HBE) cells. **METHODS:** Normal (NHBE) and COPD-diseased (DHBE) human bronchial epithelial cells derived from Caucasian age-matched donors were obtained from Lonza Biotechnology Company and cultured under normoxia (21% O₂) for consecutively 6 days, or cultured under 24/24-hour cycles of H/R (i.e., 1% O₂ and 21% O₂ alternately) for 6 days in total, or cultured under 1% O₂ for consecutively 3 days followed by 21% O₂ for consecutively another 3 days. Total mRNAs were then extracted followed by quantitative real-time PCR analyses. **RESULTS:** Consecutive hypoxia significantly decreased expression of the coronaviral entry genes *ANPEP*, *DPP4* and *TMPRSS2* as well as the influenza viral receptor gene *ST3GAL4* in both NHBE and DHBE cells, whereas intermittent H/R significantly decreased only *ANPEP* and *DPP4* but not *TMPRSS2* and *ST3GAL4* expression in the DHBE cells. Interestingly, both intermittent H/R and consecutive hypoxia significantly increased phospho-NF-κB nuclear localization and expression of the pro-inflammatory cytokine genes *IL6*, *IL8* (*CXCL8*) and *IL33*, and significantly decreased expression of the anti-inflammatory cytokine gene *IL17* in both NHBE and DHBE cells, while consecutive hypoxia significantly decreased expression of the anti-inflammatory *IL4* gene and intermittent H/R significantly increased expression of the pro-inflammatory *IL1B* (*IL-1b*) gene in both NHBE and DHBE cells. **CONCLUSION:** Taken together, our results demonstrate that 1) decreased viral transmissibility may not be associated with decreased cytokine storm; 2) increased nuclear localization of NF-κB is associated with increased expression of pro-inflammatory cytokine genes and increased nuclear localization of the hypoxia-inducible transcription factor HIF1α; 3) whether the *CGRP* expression levels are correlated with the *IL33* mRNA levels still awaits future studies.

Learning Objectives

1. To understand that Low oxygen tension downregulates viral entry gene expression and upregulates the TLR-IL33-NFκB pathway in human bronchial epithelial cells
2. To understand that Consecutive Hypoxia And Intermittent Hypoxia-Reoxygenation Downregulate Expression of Viral Entry Genes And Upregulate The TLR-IL33-NFκB Pathway And Pro-inflammatory Interleukin Genes in Human Bronchial Epithelial Cells
3. 1. Viral transmissibility may not be associated with the cytokine storm
2. Increased nuclear localization of NF-κB is associated with increased expression of pro-inflammatory cytokines and increased nuclear HIF-1α
3. It remains to be studied whether *CGRP* expression is correlated with the *IL-33* mRNA levels

[515] DEVELOPMENT AND FLIGHT TESTING OF PRESSURE BREATHING OXYGEN EQUIPMENT DURING WORLD WAR II BY U. S. ARMY AIR FORCE (USAAF) PHYSIOLOGISTS

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WITHDRAWN

[516] HISTORICAL CASE STUDY: FATAL CRASH OF GEMINI ASTRONAUTS

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(Education - Case Study)

INTRODUCTION: In 1966, two NASA astronauts died in a T-38 crash on the way to train for their upcoming Gemini mission. This historical case study will provide a summary of the accident, the findings of NASA's review board, and conclude by looking at the crash through a modern lens of human factors and aviation safety. **BACKGROUND:** On February 28, 1966, Gemini astronauts Elliot See and Charles Bassett were killed when their T-38 jet, NASA 901, crashed in St. Louis. Thick clouds and poor visibility caused them to take an instrument landing approach. When they flew below the clouds, they were going too fast to make the runway, so See chose to take a visual circling approach. By the time See realized he was heading toward a building, it was too late. Both astronauts were killed on impact within 500 feet of the Gemini IX spacecraft they would have flown into orbit. **CASE PRESENTATION:** The crash was deemed to be caused by pilot error, which was not unusual at the time. However, See's personality and background were different than the other Gemini astronauts, which served to shift blame on him instead of focusing on the wider safety and culture of NASA. Flight Crew Operations chief Deke Slayton later disparaged his flying skills and said it was a "bad call" putting him in command. This tendency to blame the pilot for a crash is contrary to our current approach to aviation safety. Crew Resource Management (CRM) was developed in the 1970s in response to airline crashes in which human error was blamed, rather than getting to the root cause of the system. **DISCUSSION:** The early years of NASA's astronaut corps were idealized in *The Right Stuff* as a "combination of high technical competence, a very rugged individualism, and a very high level of competitiveness". Bob Helmreich, who helped develop CRM, described how this individualism and competitiveness can be destructive to teamwork and a culture of safety, concluding that this may be the "wrong stuff" for aviation safety. Rather than blame individual pilots for error, we should look at the larger system. Viewed this way, there were organizational influences that contributed to the high-risk culture of the astronaut corps. This crash could have been a moment of self-reflection for NASA on lessons learned, instead of blaming See and moving on as if nothing had happened. The crash of NASA 901 serves as a powerful reminder of the importance of developing a culture of safety with implications for aviation and medicine.

Learning Objectives

1. The audience will learn about the fatal crash of NASA 901 in 1966.
2. The audience will learn about the findings of the accident investigation and how blame was placed on an individual's personality and perceived skills rather than on the larger system.
3. The audience will learn about how human factors and crew resource management evolved over the years and how this case may be viewed differently based on our current approach to accident investigation.

[517] A REVIEW OF EVIDENCE-BASED DIVERSITY INITIATIVES IN MEDICAL EDUCATION AND THEIR APPLICABILITY TO TRAINING IN AEROSPACE MEDICINE

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(Education - Tutorial/Review)

INTRODUCTION: The Accreditation Council for Graduate Medical Education (ACGME) specifies the following Core Requirement for residency and fellowship programs: "The program... must engage in practices that focus on mission-driven, ongoing, systematic recruitment and retention of a diverse and inclusive workforce of residents, fellows, faculty members, senior administrative staff members, and other

relevant members of its academic community.” Research has begun to identify approaches that are effective for the recruitment, retention, and development of medical students and residents from underrepresented in medicine (URM) backgrounds. This presentation introduces such strategies and discusses how they might translate to the training of aerospace medicine practitioners in particular. **TOPIC:** Producing a skilled physician is a longitudinal process that begins with early childhood education and continues indefinitely during practice as an attending. While the first years of life are instrumental in shaping the trajectory of one’s future, the preponderance of research on diversity in medical education has focused on training from the pre-medical years to the end of residency. One promising intervention is the “diversity pipeline,” a type of mentorship program that prepares learners from underrepresented demographic groups for a career in medicine. The literature reports many pipelines in which a majority of participants, whether high school, college, or medical students, have successfully advanced to the next stage of education. Complementing these outreach-based approaches are steps to directly mitigate unconscious biases in medical school and graduate medical education admissions procedures, some of which have resulted in significantly increased matriculation of URMs. Finally, graduate programs built around diversity go on to generate diverse leaders for the wider medical profession, as evidenced by certain residency programs that have become models for increasing representation in their respective disciplines. **APPLICATION:** Promoting diversity should be a priority for aerospace medicine education not only because it is an accreditation requirement but also because doing so equips our specialty to better serve an increasingly diverse flying population. Pipeline programs, vetted admissions procedures, and structural representation in graduate-level training are examples of evidence-based methods that have the potential to enrich the aerospace medicine community.

Learning Objectives

1. Learn various evidence-based approaches for improving diversity in medical training programs.
2. Understand how such strategies may be adapted to aerospace medicine training programs.

[518] EFFECTIVENESS OF ROUTINE CARDIAC CATHETERIZATION ON AVIATORS WITH KNOWN CORONARY ARTERY

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(Original Research)

BACKGROUND: There are no universal guidelines recommending coronary angiography in the routine evaluation of asymptomatic military aviators with a history of coronary artery disease (CAD). The purpose of the study was to analyze the efficacy of periodic evaluation of CAD using coronary angiography. Specific timeframes from diagnosis included six months to a year, one to five years, five to ten years, and cumulative time in study. **METHODS:** A retrospective cohort study was conducted on 289 military aviators between 1986 to 2021. These aviators were referred to the Air Force Aeromedical Consultation Service (ACS) for their history of CAD. Each record was reviewed to identify the development of a significant event secondary to their CAD. An event was defined as either death, myocardial infarction, repeat revascularization or disqualification from flight status. Aviators were followed through to that event or the entire length of time within the ACS. Kaplan-Meier curve was constructed to show mean time to event among aviators in the study. Additionally, Chi-Square testing and Cox proportion hazard models were used to analyze the data. **RESULTS:** A total of 50 events were captured during the study, with 72% of the events occurring within the first year of follow-up while 28% occurred during the remaining time period. Additionally, an association was

seen between history of a myocardial infarction or being a current smoker and developing a significant event. **CONCLUSION:** Significant cardiovascular events were detected among asymptomatic aviators using catheterization as a primary means of evaluation. Given the risk associated with flying aircraft and participating in military operations, this study supports the recommendation of periodic angiography in asymptomatic aircrew for evaluation of worsening CAD.

Learning Objectives

1. Analyze the effectiveness of periodic angiography studies in asymptomatic aviators
2. Stratify potential of secondary cardiac event in aviators with known CAD

[519] PROCESS FOR AN USN/USMC AIRCREW ANTHROPOMETRIC SURVEY

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(Education - Program/Process Review)

BACKGROUND: The USN/USMC Aircrew Anthropometric Survey is the first aircrew survey since the mid-1960s, and the first that includes female aircrew. Fleet and industry feedback indicates that addressing this data gap is long overdue. This project provides an opportunity to develop and populate a high-quality database and summary report at a much lower cost than previous military surveys through the use of new 3D scanning technology and analysis methods. **OVERVIEW:** This project is projected to take 2 years to complete, with data collection beginning in FY23. Power analysis and aircrew demographics yielded a sample size of 3765 as a goal. Survey sampling, manually collected measurements, and data analytics are standardized per 2012 US Army Anthropometric Survey and the 2010 USMC Anthropometric Survey. Collaborators include Senior Research Anthropologists and Anthropometrists from across the DOD and University of Michigan Transportation Research Institute (UMTRI). 3D scans are being collected with the UMTRI developed PassFit Body Scanner, Artec Leo (face/neck and hands), and Aetrex Albert II foot scanner. The PassFit system extracts DOD standardized anthropometry from the body scans. Fifteen manual measurements are also be collected. Optionally, range of motion data may be collected with a FaroArm coordinate measuring machine, and/or range-of-motion devices as appropriate. Application of parametric head and hand models that are currently in development for the face/neck and hand scans to create aircrew specific databases will be part of a future effort.

DISCUSSION: The survey will address several current warfighting needs, including: 1) the creation of properly fitting equipment through accurate size design; 2) ensure that the necessary sizes/quantities of personal protective equipment are available in supply through accurate size tariffing; 3) facilitate the development of advanced mission equipment that relies upon accurate conformal fit, e.g., body armor, strength-augmenting or weight-offloading exoskeletons, and physiological monitoring garments; and 4) facilitate appropriate cockpit/workstation layout and seating design. The USN/USMC aircrew survey process can potentially be applied to other US military populations as well. It allows an opportunity for affordable and timely database generation that is beneficial across the DOD and industry.

Learning Objectives

1. Fleet demand signals indicate the need for improved fit, tariffing, and the need to address mission performance and endurance issues. The audience will learn that anthropometry appropriately characterizing the USN/USMC aircrew population is urgently needed and critical to modern aircrew systems design and qualification.
2. The audience will learn that new scanning technology, analysis methods, and survey processes are available to characterize military populations in a timely and affordable manner.

[520] CORONARY ARTERY AGGREGATE STENOSIS FOR CORONARY ARTERY DISEASE RISK STRATIFICATION IN AVIATORS WITH KNOWN DISEASE – CAN WE BROADEN RISK CATEGORIES?

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(Original Research)

BACKGROUND. Cardiovascular disease is a leading cause of morbidity and mortality among the general population as well as aviators. Annualized risk is a stalwart of aerospace medicine, and the traditionally accepted level is less than 1% per year. More recent analysis in asymptomatic aircrew suggests that new, expanded cutoffs for aggregate stenosis can be applied to annualized risk categories. The purpose of this study was to evaluate the new cutoffs, in a study population with symptomatic disease to determine if the cutoffs meet an acceptable level of risk for aviators to maintain flying privileges.

METHODS. Aggregate stenosis was obtained via heart catheterization and reviewed via database search resulting in 384 military aviators

between 1986 and 2021. Individuals were followed to event (cardiac death, repeat myocardial infarction or revascularization, or waiver denial) or study drop out. Analysis for cutoffs was performed utilizing a ROC curve and cumulative incidence graphs. ANOVA, chi-square, and Cox regression hazard ratio were used for additional analyses.

RESULTS. Annualized risk of cardiac event for the experimental groups was (Group 0, 0% stenosis) 0.09%, (Group I, 1-95% aggregate stenosis) 0.67%, (Group II, >95% aggregate stenosis) 22.8%, and (Group III, Single Vessel Stenosis $\geq 70\%$) 3.42%. Revascularization was the event that drove the increased risk of Group II. Groups II, III, and BMI were independent risk factors for cardiac event risk. As aggregate stenosis increased, age, systolic blood pressure, blood glucose did as well. **CONCLUSIONS.** Mild-risk population cutoffs can be broadened without increasing risk of cardiac event above previous established cutoffs among symptomatic aviators. Future evaluation to better define a moderate-risk group may be warranted for those with known coronary artery disease.

Learning Objectives

1. Understand the risk of cardiac event associated with aggregate stenosis groupings in those with previously known disease.
2. Identify and stratify aviators at-risk for cardiac event in clinical practice.