Incidental Findings in Head and Brain MRI of Military Pilots and Applicants: Consequences for Medical Flight Fitness

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INTRODUCTION: With improved imaging technology, the number of incidental findings detected in cerebral MRI is increasing. This is a challenge that the German Air Force has to deal with in the context of standardized MRI examinations of young pilot candidates and pilots.

METHODS: The German Air Force Centre of Aerospace Medicine hosted a 2-d conference to develop recommendations and procedures for the handling of some of the most frequently encountered cerebral incidental findings.

RESULTS: Radiological MRI findings from a total of 2724 routine examinations of the skull of pilots and pilot applicants (26.8 ± 10.6 yr old; range from 16 to 62; over 80% range from 17 to 33; 96% men) revealed that in 28.1% of the examinations, one or more incidental findings were discovered. For seven of the following categories of incidental findings, decision guidelines could be established: white matter hyperintensities (*N* = 393; prevalence 14.4%; 95% CI 13.11–15.75), pinealis cysts (317; 11.6%; 10.43–12.84), developmental venous anomalies (64; 2.3%; 1.78–2.92), cavernomas (15; 0.6%; 0.27–0.83), aneurysms (14; 0.5%; 0.25–0.78), cholesterol granulomas (22; 0.8%; 0.47–1.14), and heterotopias of the gray matter (6; 0.2%; 0.04–0.4).

CONCLUSION: Considering pilots health and aviation safety, a waiver decision is often possible after thorough discussion, depending on the specific criteria of the incidental finding and of the type of license.

KEYWORDS: incidental finding, MRI, flight fitness.

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In neuroimaging, incidental findings are of particular importance. There are fine lines between a normal variant, an abnormal finding, and a pathological result. While some findings remain asymptomatic throughout a lifetime, others can lead to severe clinical conditions. If these incidental findings are found in the course of a military flight fitness evaluation, the critical distinction of these fine lines becomes particularly important, both for aviation safety and pilot career implications.

During a flight immense physical stresses can occur. Changes in intracranial pressure due to G forces put the skull and its intracranial structures under severe stress. Hypovolemia and hypoxia are other examples of physiological processes pilots have to cope with.[24] If a hitherto unknown brain lesion does suddenly deteriorate, potentially catastrophic consequences could ensue for pilot, crew, and mission.

In this context, the idea of general prevention plays an important role in aerospace medicine. The German Air Force Centre of Aerospace Medicine (GAF CAM), responsible for routine examinations for military flight duties in Germany, therefore started to include a routine MRI examination of the

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head and spine during the medical check-up of every pilot applicant more than 20 yr ago. This was introduced not only for flight safety, but also in the interest of the health of pilots and pilot applicants.

In May 2016, the former 1 Tesla MRI device at the GAF CAM was replaced by a 3 Tesla high-field MRI. As shown recently, this exchange led to a significant increase in detected asymptomatic incidental findings, followed by an increase of the proportion of applicants who were initially classified as not fit for flying.[2] However, both flight accident and incident rates, as well as pilot health in general, remained stable since the implementation of the new MRI technology. The clinical significance or relevance remains unclear for the individual pilot, the employer, and especially aviation safety. In particular, the very specific kind of stress in military aviation and its possible effects on cerebral incidental findings can often not be predicted. Considering that manifestation of these findings are often variable, their evaluation becomes even more difficult. While national and international guidelines regarding flight fitness evaluations can only serve as a general framework, in our opinion the assessment of specific incidental findings in terms of their hazardous nature for military flying duties needs individual strategies. In order to provide a basis for decision-making, the GAF CAM invited military and civilian experts in the fields of military aerospace medicine, pathology, neurology, neurosurgery, and neuroradiology to a conference. The aim was to establish precise procedural instructions and recommendations for the management of incidental findings with respect to the exams of active military personnel for eight typical and prevalent selected neurocranial incidental findings.

Therefore, each category of one of the selected incidental findings was first presented by an expert in the field. In the ensuing discussion, several aspects had to be agreed upon: does or will the incidental finding pose a hazard to flying? Does this apply to all aircraft? Can the incidental finding be aggravated by the stresses of flying? What are the exact criteria to assess the finding? How can they be assessed most accurately and reproducibly? Are further examinations or follow-ups necessary? Evidence-based data from current scientific literature and the expert opinion from a consensus panel of clinicians served as a basis for discussion.

METHODS

Subjects

All examinations were performed at the GAF CAM. Standardized MRI scans were part of a detailed medical check-up to assess medical fitness for military flying duties.[6] The majority of the subjects ($N = 1722$) were pilot applicants. A smaller part ($N = 1002$) of the examinations involved active pilots undergoing an examination in the newly implemented 3 Tesla MRI (Siemens Magnetom Prisma, Erlangen, Germany; 64-channel head and neck coil) for the first time. All findings in this paper were incidental, i.e., without any symptoms.

Due to the anonymized and retrospective design of this analysis, no explicit permission of the Institutional Review Board was required in accordance with the guidelines of the Bavarian chamber of physicians. All subjects had given their written consent in advance according to the Declaration of Helsinki in its current version.

Procedure

In a recently published study, we presented the German Air Force Imaging Screening Protocol, which was designed to detect and evaluate topographic pathologies in first-time military applicants to minimize potential human factor-related hazards to flight safety.[28] Briefly, for brain imaging, we use multiplanar T2 weighted, partially fluid attenuated, and T1 weighted sequences. Diffusion and susceptibility weighted sequences along with native time-of-flight angiography extend the protocol to detect vascular malformations, microhemorrhages, cavernomas, and actively inflammatory processes.

Each MRI was analyzed by one of two senior radiologists. Both radiologists have over 25 yr of clinical experience in radiology and aerospace medicine. Both assessment and the structure of the written report were standardized. Debatable cases were discussed once more internally to achieve a consent decision; moreover, all findings were routinely discussed with in-house neurological specialists and presented in a daily conference. Thus, detection bias is very unlikely.

Before we reviewed our criteria, the findings to be discussed were selected based on the following items: frequency, unspecific etiology, uncertain prognosis, or danger to flight safety. We conducted an anonymized keyword analysis of the MRI reports from May 2016 (i.e., after the implementation of

Table I. Overview of Total Numbers of Incidental Findings.

INCIDENTAL FINDING	2016 $N = 434$	2017 $N = 724$	2018 $N = 681$	2019 $N = 657$	2020 $N = 228$	TOTAL $N = 2724$	
			NUMBER			NUMBER / PREVALENCE	95% CI
Pineal cyst	26	51	92	118	30	317/11.6%	10.43–12.84
Aneurysm	1	2	1	9	1	14/0.5%	0.25–0.78
DVA	4	9	19	23	9	64/2.3%	1.78–2.92
Heterotopia/FCD	2	2	0	2	0	6/0.2%	0.04–0.4
Cholesterolgranuloma	5	1	8	3	5	22/0.8%	0.47–1.14
WMH	52	79	90	131	41	393/14.4%	13.11–15.75
Cavernoma	1	4	4	5	1	15/0.6%	0.27–0.83
Arachnoid cyst	11	13	9	11	10	54/2.0%	1.46–2.51

DVA: developmental venous anomaly; FCD: focal cortical displaysia; WMH: white matter hyperintensities.

the 3 T MRI) till June 2020. We focused on the following eight diagnostic categories: arterial aneurysms, white matter hyperintensities (WMH), pineal cyst, developmental venous anomaly (DVA), cavernoma, cholesterol granuloma, arachnoid cyst, heterotopia, and focal cortical dysplasia.

In order to develop standardized procedures for the evaluation of certain incidental findings, we invited experts in the respective fields to a conference. The aim of the conference was to define procedural guidelines and decision-making frameworks for flight fitness in cranial incidental findings.

RESULTS

The GAF CAM performed brain MRI examinations on 2724 active pilots and pilot applicants between May 2016 and June 2020. On average, they were 26.8 ± 10.6 yr old (range from 16 to 62; over 80% range from 17 to 33) and over 96% of them were men. In 765 (28.1%) of 2724 examinations, a total of 885 incidental findings (32.5%) were identified. **Table I** and **Table II** show the prevalence of the incidental findings over the individual years. The most frequent were WMH, which were observed in 14.4% of the examinations, and pineal cysts in 11.6%. The prevalence of DVA over the whole period was 2.3%.

Table II. Overview of Age, Sex and Status of Incidental Findings (SD = Standard Deviation).

	AGE (± SD)	MALE / FEMALE	APPLICANTS / PILOTS
Pineal cyst	25 (± 6.3)	291/26	288/29
Aneurysm	25.4 (± 5.9)	14/0	14/0
DVA	25 (± 7.1)	58/6	62/2
Heterotopia/FCD	23.2 (± 2.6)	6/0	6/0
Cholesterol granuloma	22.6 (± 4.8)	22/0	22/0
WMH	27.2 (± 9.2)	375/18	310/83
Cavernoma	27.5 (± 9.3)	15/0	14/1*
Arachnoid cyst	24.9 (± 4.4)	49/5	49/5
Total	26.8 (± 10.6)	2628/96	1722/1002

DVA: developmental venous anomaly; FCD: focal cortical displaysia; WMH: white matter hyperintensities.
*Incidentally found cavernoma in an active pilot, who had undergone MRI for a different reason. Afterwards he needed to be declared unfit.

Arachnoid cysts were found in 2%. Incidental findings with a frequency less than 1% include cholesterol granuloma (0.8%), cavernoma (0.6%), aneurysm (0.5%), and heterotopia (0.2%). The management of arachnoid cysts is not discussed in this paper and will be presented separately.

At the end of the conference, the expert panel produced standardized guidelines to assess fitness for flying duties in cases for aircrew identified with seven types of common neurological incidental findings. **Table III** summarizes the basic elements of the decisions in abbreviated form. It is striking that only incidental findings with low prevalences of < 1% lead to an initial classification as unfit to fly.

This classification is based on their increased risk of sudden incapacitation. The exception is cholesterol granuloma, which initially leads to complete unfitness despite low prevalence and low risk of sudden incapacitation. However, a medical waiver is usually granted in this case if bony erosion can be ruled out by means of a high-resolution CT scan.

The most often occurring incidental findings in these examples carry an extremely low to no risk of sudden incapacitation. Accordingly, these findings do not require limitations on fitness for flying duties. There are rare, but critically important exceptions for most of the low-risk incidental findings which require further scrutiny and/or flight limiting restrictions. This demonstrates the importance of reviewing the specific clinical circumstances of each individual case.

DISCUSSION

During flight, aircrew may be subjected to immense physiological stresses. An extreme example occurs in modern military fighter aircraft, which can exert up to 9 Gs of force on pilots during certain maneuvers. Centrifugal force-induced blood shifts along the body axis lead to rapid blood pressure fluctuations. Positive forces lead to a drop in hydrostatic pressure of the head, resulting in reduced perfusion of the brain. The effect is amplified by a drop in venous pressure at head level, which causes blood to be drawn out of the skull to the venous side. In contrast, negative G-forces lead to an increase in hydrostatic intracranial pressure. Pressure on the cerebral blood vessels

Table III. Conference Resolution for Guidelines for Flight Fitness.

	PREVALENCE	RISK FOR SUDDEN INCAPACITATION	WAIVER DECISION	EXCEPTIONS
WML	High	Low	Fit	• Specific pathological distribution (i.e., MS) • Significantly high number or large area (i.e., Fazekas II) • Underlying noncurable disease
Pineal cyst	High	Low	Fit	• Aqueductal stenosis • Tumorous transformation
DVA	Intermed.	Low	Fit	• Surrounding parenchymal abnormalities • Coincidence with cavernomas
Cholesterol granuloma	Low	Low	Unfit	• Intact bone shell
Cavernoma	Low	High	Unfit	–
Aneurysm	Low	High	Unfit	• Extradural location • Very low risk of rupture in individual cases
Heterotopia / FCD	Low	High	Unfit	–

WMH: white matter hyperintensities; DVA: developmental venous anomaly; FCD: focal cortical displaysia.

increases significantly and may cause rupture. Even transverse acceleration forces cause blood shifts within the skull from, for instance, frontal to occipital. In addition to the effects of this hypovolemic hypoxia, the danger of hypoxic hypoxia, occurring as a result of the drop in oxygen partial pressure with increasing altitude, affects flying personnel even more.[1]

It is the responsibility of aviation medicine to consider these and other stresses on the heads and brains of aircrew and to evaluate them in the context of flight safety. The screening of military pilot applicants should help to protect the candidates from sudden incapacitation, long-term illness, and loss of their flying license.[3] Explicitly, the evaluation of incidental cerebral findings often poses challenges even for the experienced flight surgeon or aeromedical examiner. What is the risk of aneurysm rupture under the influence of centrifugal force-based shifts in intracranial blood volume? Can even common venous incidental findings that belong to the low-pressure system, such as developmental venous anomalies or cavernomas bleed under G forces? Uncommon risks like these are difficult for the aeromedical assessor alone to quantify and validate, but must be addressed as part of the process of certifying safety of flight for aircrew. Study designs that specifically examine the effects of in-flight forces and mechanisms on individual incidental findings are difficult to implement.

As of today, there is no standardized international approach on how to manage the aeromedical disposition for radiological incidental finding. While aviation authorities, such as the European Union Aviation Safety Agency or the U.S. Federal Aviation Administration, generally agree that conditions that jeopardize flight safety or can be expected to do so will result in disqualification from flight fitness,[8,10] they do not yet provide guidance on how to proceed in individual cases of incidental findings. This makes sense, because the wide range of incidental findings and their different manifestations is difficult to cover in a single regulation.

Nevertheless, in times of growing widespread use and application of high-resolution MR scanners, the proportion of detected incidental findings increases. Sönksen et al.[28] compared the prevalences of incidental findings in brain MRI before and after the introduction of a 3T versus a 1T scanner. They observed that the prevalence of cerebral vessel malformations (1T: 0.28% vs. 3T: 1.67%) and abnormal central nervous system incidental findings (1T: 5.12% vs 3T: 9.8%) increased significantly, ultimately attributed to the technical upgrade.[28]

A comparable study population of young adults in our institution was examined by Weber and Knopf[35] using a 1-T scanner in 2006. They detected 24.25% incidental findings in 2536 examinations, listing over 20 different forms and entities.[35] Our analysis has shown that, using a high-resolution 3T MRI scanner, 32.5% incidental findings were found, categorized into seven types. At least one of the findings was detected in 28.1% of the examinations. Thus, more than every fourth pilot or flight applicant is nowadays affected when examined with a state-of-the-art scanner and an adapted protocol. With the continued evolution of technology, aerospace medicine will increasingly be confronted with this issue in the future.

Crucial in the management of an incidental finding is the assessment of the risk for sudden incapacitation. The probability must be very low, which is difficult to determine given the high degree of individuality and the paucity of data. It is often not possible to define threshold values for individual incidental findings. A frequently used international consensus is that the probability must be less than 1%. However, considering the potential consequences of sudden incapacitation, in our opinion even 1% seems too high: The “1% rule” was originally developed for a two-pilot cockpit under the conditions of civil aviation without considering the additional risk for complications due to the special stresses of flying. In addition, the consequences for the health of the pilot and his/her claim to fly must also be considered. For these reasons, our philosophy of risk stratification is to work through each individual case as thoroughly as possible. Part of the workup is to conduct a detailed and high-quality screening. This includes an MRI examination of the head and spine. For a targeted assessment of the incidental findings, knowledge of the current scientific literature as well as the reviews of clinical and aeromedical experts is needed. On this basis, criteria and guiding characteristics can be defined which assist the aeromedical examiner in his/her decision. For example, a frequently used approach in military aviation to address potential sudden limitations in full performance is the restriction to dual control.

In the daily routine of aeromedical assessments at the GAF CAM, the evaluation of cranial incidental findings is designed as a two-step process. First, all findings were discussed in a daily meeting of department directors to decide on flight fitness and possible further diagnostic procedures and limitations. In a second step, exceptionally complex findings were presented in a weekly meeting of an expert group of neurologists, neuroradiologists, and neurosurgeons at the Bundeswehr Central Hospital in Koblenz. In this group the findings were reevaluated in respect to the clinical assessment regarding disease severity and prognosis. Subsequently a physician of the respective department of the GAF CAM informed the applicant about the diagnosis and its clinical relevance from both an aeromedical and a clinical perspective and gave advice on further clinical care. This daily process requires standardized decision guidelines.

To address these needs, the GAF CAM held a conference to determine procedures and decision bases for incidental findings from MRI examinations of the head for the assessment of military flight fitness. We failed to develop a common guideline for the management of intracranial arachnoid cysts due to difficulty in quantifying the possible risk of incapacitation. Research in this area is limited and consists mainly of case reports. While there are several reports ranging from coincidental hemorrhage to associated epileptic seizures and psychiatric disorders, a clearly established chain of causality is usually lacking. Moreover, considering the frequency of arachnoid cysts in the general population, these cases are very rare.

Nevertheless, a differentiated analysis and extended research is needed to provide a solid basis for decision making with respect to the specificities of aviation. In order to address the complexity of this topic adequately, we will elaborate this in a consecutive publication. The conference members did reach consensus on procedures for seven types of neurological incidental findings which we describe in the following sections.

WMH are among the most frequent findings in the brain detected in MRI examinations (**Fig. 1**). WMHs have been associated with a wide variety of infectious and inflammatory processes, including microangiopathic diseases, migraine headaches, inflammatory processes, and infectious diseases. Most often, they accompany normal aging. Consequently, every case needs to be examined individually.[20,31,34] Especially for active flying personnel, clarification of the underlying disease is crucial and a comprehensive clinical examination for possible underlying diseases indispensable.

For decisions on flight fitness of pilot applicants, we look at the age, clinical data, and history for a possible underlying disease. If none can be identified, the incidentally found WMH still remain to be evaluated for flight fitness. Therefore, we take into account the number, the distribution pattern, and morphology of the WMH. To date, there is no consensus in the scientific literature on how many WMH are acceptable for a given age. Especially in healthy young adults without any disease, they are expected to carry no WMH. However, our data and experience show that WMH can be detected in a significant proportion of young adults. Since the number of WMH is an important indicator for extent and etiology, we have agreed on an artificially chosen cutoff value of 10 WMH based on experience over the years to differentiate between still acceptable and suspicious findings. Nevertheless, it must be noted again that radiologically the number represents only one decision factor besides morphology and distribution pattern. **Table IV** gives an overview of the decision scheme regarding WMH. For example, a small number of less than 10 WMH with mainly point-shaped, isolated, or speckled formations and with an unspecific distribution pattern is presumed to be benign. In cases where an underlying disease process is suspected, follow-up MRI examinations after an adequate period of time help to evaluate for progression. If, however, the number of WMH is significantly high, i.e., more than 10 lesions, the distribution pattern indicates a specific disease (e.g., multiple sclerosis), or the WMH are atypically formed or cover large areas, the pilot in question has to be declared unfit for service unless an underlying disorder is defined and cured or ruled out. For quantitation, we use the most widely used FAZEKAS scale, although most of our cases are in the lowest category.[11]

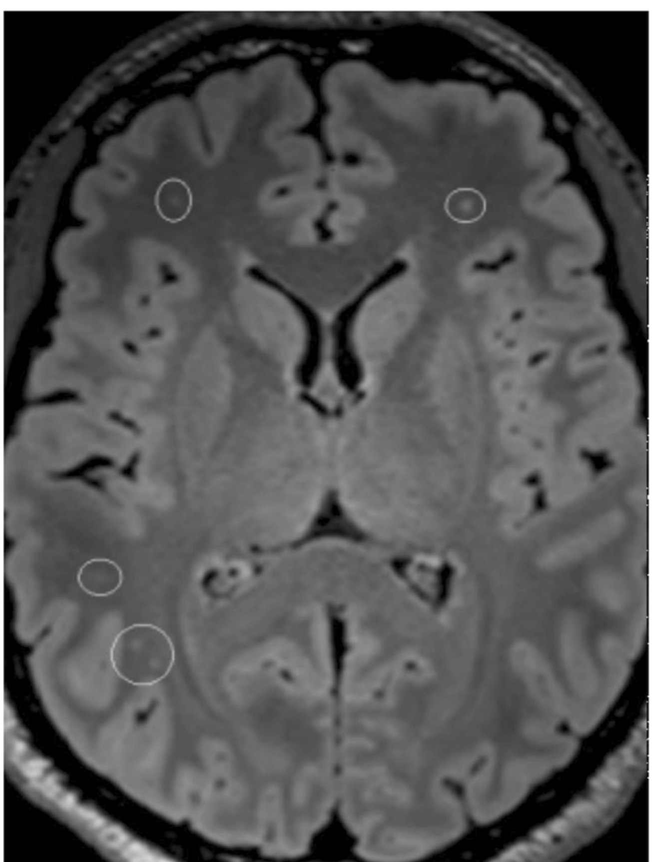

Fig. 1. White matter hyperintensities (in a 23-yr-old male applicant). Axial fluid attenuated inversion recovery (FLAIR). The small punctiform hyperintensities (circled) are found in the white matter of the frontal and parietal lobes. A cause is often not identifiable.

Cerebral heterotopia and disorders of cortical formation are congenital malformations, rather than acquired cerebral lesions (**Fig. 2**). They are the result of an arrested migration of neurons from the subependymal layer during development of the cerebral cortex. Heterotopias and focal cortical dysplasia generally increase the risk of epileptic seizures.[1] Accordingly, these inherent cerebral dysplasias result in an unfitness for flying duty, regardless of the aspirant's and pilot's medical history.

A pineal cyst usually presents as a unilocular cystic transformation of the pineal gland and is one of the most frequent incidental findings on CT or MRI scans as the pineal gland degenerates in adulthood.[13,25] The vast majority of these cysts present with a diameter of less than 1 cm and are asymptomatic (**Fig. 3**).[25] The problem is that they cannot be reliably distinguished from cystic tumors such as pinealocytomas. Tumorous growth of the cyst may compress midbrain tectum, leading to aqueduct stenosis.[29] In this case, special attention must be paid to changes in MRI and clinical signs indicating disturbed cerebrospinal fluid circulation or even increased intracranial pressure. Conducting an extremely thin-sliced MRI sequence to assess aqueduct stenosis may help in this regard. Due to this very low risk of a clinically dangerous, symptomatic incident, typical pineal gland cysts are not disqualifying. Nevertheless, since there is a potential, albeit small, probability for the cyst to increase in size, we monitor cyst size by MRI before pilot candidates take up their flying duties as well as every 5 yr until they have reached the age of 30. In case of unexpected alterations and growth, we perform a contrast-enhanced examination for better differentiation from cystic tumors of the pineal region.[30]

Cholesterol granulomas represent the most common cystic lesion of the petrous apex; however, they can occur in any

Table IV. Summary of the Decision Basis for White Matter Hyperintensities.

DECISION	NUMBER	DISTRIBUTION PATTERN	MORPHOLOGY	MEASURES
Fit	Small	Nonspecific	Punctate / small / solitary	Follow-up in a 5-yr interval
Unfit with special waiver option	Increased	Nonspecific	Punctate / small / solitary	Exclusion from fighter aircraft Examination for underlying diseases Follow-up
Unfit	Significantly confluent areas/increased OR Specific OR atypically formed/large spots			Recommendation for further neurological clarification

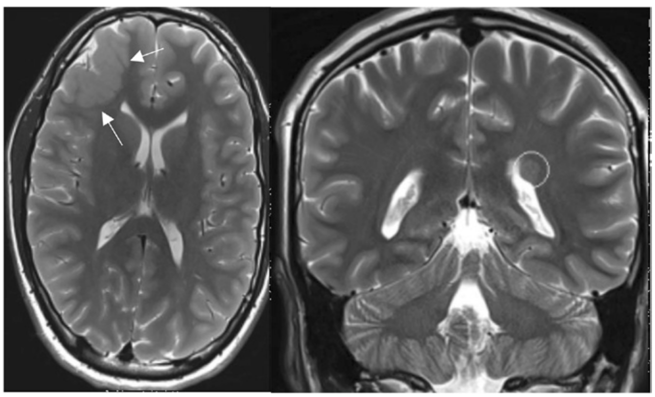

Fig. 2. Left: focal cortical dysplasia of a frontal gyrus (in a 19-yr-old male applicant). A transversal T2 weighted image. Focal thickened gyral cortex with an abnormal gyral and sulcal pattern (arrows). The difference is particularly apparent when comparing the gyrus to the other side. Right: a nodular heterotopia next to the left lateral ventricle (in an 18-yr-old male applicant). A coronal T2 weighted image. Unilateral focal nodule periventricular to the left lateral ventricle (circle). Signal intensity of heterotopias follow gray matter in all sequences.

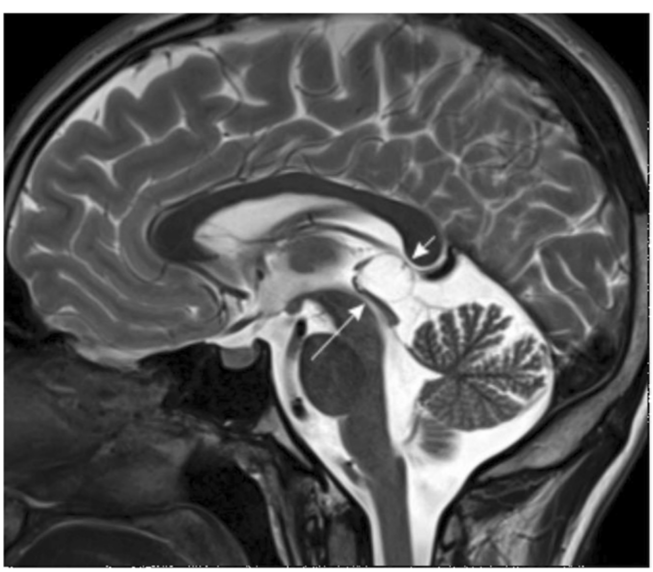

Fig. 3. Cystic formation of the pinealis gland (in an 18-yr-old male applicant). A sagittal T2-weighted image in the median plane. The pinealis gland can be defined as a round, thin-walled cyst (short arrow). The adjacent structures, such as the superior colliculi of the tectum, are initially compressed. However, the cerebral aqueduct is not yet affected (large arrow).

aerated part of the temporal bone. They consist of granulation tissue formed by a vascularized chronic inflammatory process.[36] Should symptoms occur, the most commonly reported associated symptoms were hearing loss (64.7%), vestibular symptoms (56%), tinnitus (50%), and headache (32.3%).[14] When a cholesterol granuloma is detected, the pilot in question is initially declared unfit for service. In order to determine waiver eligibility for continued flying duties, we use a high-resolution CT of the temporal bones to assess the extent of intact overlying bone which functions as a protective shell. If there is adequate osseous coverage, a waiver is usually approved since sudden incapacitation during flight is highly unlikely. We then conduct subsequent follow-up examinations by MRI in 3–5 yr to assess progression.

Spontaneous rupture of an intracranial arterial aneurysm is the most common (85% of all cases) cause of a subarachnoid hemorrhage. Although the reasons for the formation and rupture of aneurysms are still being discussed, it is clear that blood flow and hemodynamic overload play an important role. Consequently, it should be assumed that the strains military pilots must cope with have certain effects on the cerebrovascular system and, thus, also on cerebral aneurysm as a suspected focal weak point. Because of these serious threats to health and flight safety, clinical outweigh aeromedical aspects. While consequently no flight fitness can be granted for applicants, there are two exceptions for active pilots. In very rare cases with a very low calculated risk for growth or rupture of a small aneurysm, a waiver for an active pilot can be granted in a mutual decision. Important factors such as size, shape, and localization of the aneurysm, as well as age, geographical origin of the pilot, and concomitant diseases, play a decisive role in better estimating the risks. For instance, aneurysms of the posterior intracranial circulation have a higher risk of rupture than those of the anterior circulation.[9] Helpful tools to a better estimation of the risk of rupture and growth, such as the PHASES or ELAPPS scores, are based on extensive meta-analyses.[5,12] In addition, stress based on aircraft type and comorbidities must be included as factors in considering whether an active pilot with an incidentally discovered microaneurysm should be allowed to return to active flight duties. The second exception are aneurysms located in the extradural part of the carotid artery. By definition, they do not harbor a risk of subarachnoid hemorrhage. Nevertheless, one should always consider the risk of a cranial nerve dysfunction/palsy (mainly NVI, NIII), which might affect flying capability. Consensus in literature recommends a check-up every 5 yr for small aneurysms.[21] For aircrew we perform routine check-ups at least every 3 yr. Additionally, since intracranial aneurysms mostly develop between the ages of 40 to 60, we recommend annual screening of all pilots from this age on for intracranial aneurysms.[9,33] Fortunately, the incidence of accidentally discovered intracranial aneurysm is very low in those younger than 30 yr. In a meta-analysis, data for patients under 30 yr of age showed a prevalence of 0.01% (95% CI 0.00–0.12) and in patients ages 30–39 a prevalence of 0.4% (95% CI 0.1–1.6) after adjustment for age, sex, and comorbidities. Our increased prevalence of 0.5% (95% CI 0.25–0.78) with a mean age of 27 (± 10.6) might be explained by the high accuracy of the MR angiography used.

A DVA is an extreme variation of a normal medullary venous drainage. The etiology of DVAs is explained from an evolutionary perspective as a functional adaptation to the absence of normal ways of drainage (**Fig. 4**).[3,19] They rarely have proliferative potential or (as so called atypical DVA) arteriovenous shunts.[27] With a prevalence of 0.48–2.56% in the general population, they rank among the most frequent vascular incidental findings.[3,32] However, there is a reported coincidence with cavernomas of 13.3%[26] and, in some cases, surrounding parenchymal abnormalities have been reported.[3,23,26] SWI is a crucial sequence to detect these variations because of its high sensitivity for paramagnetic substances such as hemosiderin. A detected simple cerebral DVA does not affect flying fitness. There are no restrictions regarding the type of aircraft. Since DVAs are hypothesized to play a crucial role in development of cavernomas,[15,17] we reasonably recommend follow-ups at intervals of 5 to 6 yr. Exceptions are DVAs with surrounding parenchymal abnormalities, e.g., perifocal white matter alterations or gliosis. These might be associated with microcavernomas and therefore entail some individual risk of complications.[23] They result in an unfitness for flight duty.

Cavernomas are nonencapsulated, well-defined, vascular hamartomatous lesions, representing the only venous malformation of the central nervous system. They are formed by sinusoidal vascular spaces, with no cerebral parenchyma in between,[7,22] the main differentiation to capillary telangiectasia. The endothelium is lined by a thin weak epithelium that lacks elastic and muscular layers, predisposing to hemorrhage. The vascular spaces contain areas of bleeding at different stages and, due to recurrent bleeding, they present a pseudocapsule of gliotic brain stained with hemosiderin. MRI, especially its susceptibility-weighted sequences, is an indispensable component of the MRI protocol to diagnose cavernomas. To differentiate small cavernomas from capillary telangiectasia, the administration of contrast agent is required. Although they often are diagnosed incidentally, cavernoma harbor the risk for clinical symptoms such as seizures (5-yr risk of 4%; 95% CI: 0–10%) or hemorrhage (5-yr risk of 15.8%; 95% CI: 13.7–17.9%).[16] Even in the absence of specific strains, these might lead to a respectable risk for sudden incapacitation.[2,4,18] Therefore, if a pilot candidate is diagnosed with cerebral cavernoma, he is considered as unfit for military flying duties. Generally, an aeromedical waiver will not be granted.

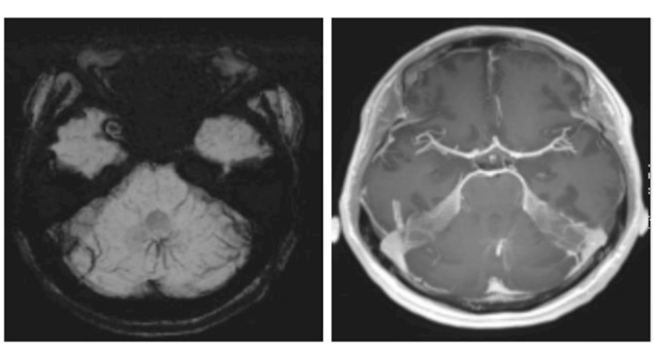

Fig. 4. Developmental venous anomaly (DVA) of the cerebellum (in a 24-yr-old male applicant). Left: axial susceptibility weighted image (SWI); Right: after contrast agent injection. In the cerebellum the typical caput medusae sign of a DVA can be seen. Several small veins drain into a larger collecting vein.

This initial list provides guidance for seven different categories of incidental findings; there are, obviously, various more that the aeromedical assessor may encounter. Accordingly, this can only be considered as a starting point. The medical debate must continue and be constantly updated, always under the aspect of new scientific findings and interdisciplinary dialogue.

The assessment of the fitness of military personnel for flying duties is a subject of national and international regulations. Due to the specific requirements of military aviation and the considerably higher physical demands compared to civil aviation, a more thorough fitness evaluation and assessment of the medical findings are necessary. The listed procedures for evaluating specific incidental findings illustrate how important decision-making on a case-by-case basis is. Clear exclusions of flight fitness, as for example in the case of congenital alterations of the gray matter, are the exception. Even in the case of intracranial aneurysms, restricted flight fitness can be granted in individual cases. On the other hand, in rare cases rather harmless and frequently occurring findings such as pineal cysts may lead to unfitness under certain circumstances.

A thorough discussion within the consultation team is strictly required for waiver decision, depending on the individual license, the tasks, and physical stressors during flight. Guidelines in interdisciplinary and even international exchange can support flight safety and the health of pilots.

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