Mindful Application of Aviation Practices in Healthcare

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INTRODUCTION: Evidence supports the efficacy of incorporating select recognized aviation practices and procedures into healthcare. Incident analysis, debrief, safety brief, and crew resource management (CRM) have all been assessed for implementation within the UK healthcare system, a world leader in aviation-based patient safety initiatives. Mindful application, in which aviation practices are specifically tailored to the unique healthcare setting, show promise in terms of acceptance and long-term sustainment.

METHODS: In order to establish British healthcare applications of aviation practices, a PubMed search of UK authored manuscripts published between 2005–2016 was undertaken using search terms 'aviation,' 'healthcare,' 'checklist,' and 'CRM.' A convenience sample of UK-authored aviation medical conference presentations and UK-authored patient safety manuscripts were also reviewed.

RESULTS: A total of 11 of 94 papers with UK academic affiliations published between 2005–2016 and relevant to aviation modeled healthcare delivery were found. The debrief process, incident analysis, and CRM are the primary practices incorporated into UK healthcare, with success dependent on cultural acceptance and mindful application. CRM training has gained significant acceptance in UK healthcare environments.

DISCUSSION: Aviation modeled incident analysis, debrief, safety brief, and CRM training are increasingly undertaken within the UK healthcare system. Nuanced application, in which the unique aspects of the healthcare setting are addressed as part of a comprehensive safety approach, shows promise for long-term success. The patient safety brief and aviation modeled incident analysis are in earlier phases of implementation, and warrant further analysis.

KEYWORDS: aviation, healthcare, checklist, patient safety, crew resource management, investigation.

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Aviation, once known as a hazardous industry, attained high levels of safety after establishing the primacy of safety as a cultural norm. Many aviation practices have been successfully applied to healthcare, an industry which is also complex and potentially high risk. The application of aviation practices has drawn widespread attention due to its benefits in patient survival, particularly with regards to the use of the checklist[36,49,68] and crew resource management (CRM).[33,65,68] Additional benefits such as reduction in postoperative complication,[36] serious medical complication,[33] and infection rates[69] have also been achieved following the adoption of aviation modeled practices.

The UK National Health Service is a healthcare system that could be considered ideal for the implementation and analysis of aviation practices. Early recognition of the importance of learning from adverse events resulted in an aviation modeled National Reporting and Learning System. Recently the United Kingdom also established the Healthcare Safety Investigation Branch (HSIB); the world's first nationalized aviation modeled incident investigation organization[40,51,52] with significant literature regarding the adoption of aviation investigation practices underpinning its legislation.[50,53] The presence in this new organization of a key national patient safety leader from within the airline industry itself has further empowered the application of aviation modeled efforts to improve safety in UK healthcare.[45] Aviation modeled practices can rapidly scale up in the United Kingdom given that all healthcare organizations operate within the same structure and are regulated by the same or similar authorities.

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The application of an aviation model to incident analysis,[7,52,86] debrief,[2,3,38] team communication training,[55,56,75] and several other patient safety practices[34,42,47] within the UK National Health Service have been well described in the literature. Thorough assessments of aviation modeled practices in the United Kingdom have determined that a nuanced, mindful approach is warranted, and the blanket application of aviation practices can be ineffective or counterproductive.[27,42,71,84] The aim of this paper was to establish the scope and review the evidence base underpinning UK healthcare applications of aviation practices, as well as to ascertain key enablers, barriers, and resource requirements for the implementation of such practices.

METHODS

A PubMed search of UK authored manuscripts published between 2005–2016 was undertaken using the search terms 'aviation,' 'healthcare,' 'checklist,' and 'CRM.' Additional search terms 'incident analysis,' 'sterile cockpit,' and 'debrief' did not yield any further publications apart from those identified through the primary search terms. Convenience sample UK authored aviation medical conference presentations and UK authored patient safety manuscripts were also reviewed in addition to secondary references within the primary manuscripts of the literature search.

RESULTS

Of 146 papers obtained using the search terms, 94 were published between 2005–2016. There were 12 manuscripts which met UK author and/or academic affiliation criteria and appeared to be relevant to the incorporation of aviation based practices into the healthcare system. After full review of the manuscripts, 1 of the 12 was excluded as it addressed air ambulance training rather than the express adoption of aviation based practices into healthcare delivery. Additional data sources were obtained through convenience sample UK authored aviation medical conference presentations, UK authored patient safety manuscripts, subject matter experts, and secondary references from within the reviewed literature. Based on the results of the literature search, the debrief process, incident analysis, and CRM were determined to be the primary aviation practices incorporated into UK healthcare from 2005–2016. Other aviation modeled practices such as the daily patient safety checklist, patient safety brief, and sterile cockpit have also been described in the literature. Each of these aviation modeled areas of application will be discussed in further detail. **Table I**, **Table II**, and **Table III** describe a summary of contemplated practices, investigations regarding specific practices, and an analysis of each of the transferred practices.

Important gaps between the way aviation and medical incidents are analyzed and managed have been identified in the literature.[42,53,86] While human nature often seems to apportion blame to an individual rather than an organization, a blame and shame culture is recognized to harmfully reduce the reporting of medical error and hamper organizational learning.[23] Rather than assessing for blame, the aviation industry habitually ascertains the latent factors contributing to incidents using Reason's model of accident causation.[70] The aviation model of incident analysis furthermore recognizes and accounts for human factors such as fatigue, personal stress, and work environment[25,48] and establishes the primacy of incident prevention over attribution of blame.[76] Furthermore, the aviation industry is committed to ensuring the widest possible dissemination of lessons learned sharing, whereas medical researchers have determined little to no discussion of lessons learned sharing on analysis of medical investigations.[86]

The importance of recognizing latent factors in medical incident analysis through the adoption of an aviation model has been recognized by patient safety advocates,[42,84,86] with the application of Reason's model of causation[84] and the application of the human factors analysis and classification system (HFACS) determined to be particularly useful.[20] Additional aspects of incident analysis considered for application into the healthcare system include data capture through confidential reporting systems,[28] a structured investigative process,[50,86] an independent safety investigation agency,[47,53] the use of behavioral health specialists to elucidate relevant underpinnings of adverse medical outcomes,[42,48] the use of a 'black box' in the operative theater,[27,42] collaborative analysis among government and industry stakeholders,[42] and the provision of timely corrective actions—all inherent in the aviation safety feedback cycle.[7] A summary of proposed applications of aviation modeled incident management and investigation are listed in Table I. Those which have been implemented will be discussed in greater detail.

To a limited extent, aviation-modeled incident analysis has been indirectly studied in the UK healthcare environment. Konieckzny et al.[43] undertook a survey regarding the degree to which surgical staff accept the aviation-based HFACS[85] that is based on Reason's model of accident causation.[70] Acceptance of such a model is poor, especially in terms of junior staff vocalizing concerns about unsafe acts and unsafe supervision.[43] The authors were unable to identify any to date directly evaluating aviation modeled investigation and/or management of incident techniques in any country. Despite this, the rise in the value of the aviation model is evident and mounting due to significant public advocacy.

There has been meaningful adoption of aviation practices within the UK regarding the investigation and management of error, in no small part due to tragic medical error. Healthcare adoption of training and lessons learned sharing following serious incidents is poignantly advocated by commercial airline pilot and patient safety advocate and chair Martin Bromiley, OBE. His wife died from hypoxia in the operating room in what has been described as a preventable death.[35] While having to deal with the personal tragedy involved, he was also dismayed that this would not be investigated, depriving other healthcare workers the opportunity to learn from the mistake. He also recognized similarities from the circumstances of his wife's death to an accident report he had learned about during pilot

Table I. Proposed Applications of Aviation Practices into UK Healthcare.

APPLICATION	AUTHOR	FINDINGS/OBSERVATIONS/RECOMMENDATIONS
Incident Management/Investigation	Flin & Paterson-Brown[28]	Recognize latent conditions through the deep data capture of confidential reporting systems
	Woloshynowych et al.[86] and Macrae[50]	Structured investigation process; use of trained investigators, use of accident causation model and follow up on outcomes
	Benn et al.[7]	Recommendation for permanent not temporary safety feedback cycle; timely, visible, and repeatable response to error
	Elliot[27] and Kapur et al.[42]	Use of 'black box' in the operative theater
	Lewis[46] and Macrae & Vincent[53]	Establish Independent patient safety investigation agency using Air Accident Investigation Branch model
	Kapur et al.[42]	Incorporation of behavioral health subject matter expert into organization's incident management
	Kapur et al.[42]	CAST* modeled collaboration between government and industry stakeholders—develop high stakes interventions based on collective incident analysis
Brief/Debrief	Kapur et al.[42]	Brief/debrief in order to appraise procedures, encourage mutual respect and team bonding
Crew Resource Management	Seager et al.[74] and Martin et al.[54]	Institutionalize cooperation, leadership, workload management, situational awareness, and decision making into healthcare
	Kapur et al.[42]	First name only rule for team procedures, cross-checks, read-back, 'two challenge rule*'; use direct eye contact, introductions prior to procedures
Checklists	Kapur et al.[42]	Specific use of checklists during transitions of care
Check rides	Seager et al.[74] and Elliot[27]	Requirement for observation of clinician skill performance at regular intervals
Line operations safety audit*	Elliot[27] and Kapur et al.[42]	Evaluation of procedures by SMEs who collect error/threat management data, to drive safe practices and refine training
Pilot risk profile development	Mitchell[57] and Kapur et al.[42]	Aptitude, personality testing for healthcare personnel
Risk free reporting	Kapur et al.[42]	Immunity from disciplinary action if reporting an incident (apart from gross or willful negligence)
Sterile Cockpit	Kapur et al.[42]	Create a distraction free environment at critical points of healthcare delivery

* Key aviation safety definitions: CAST: Commercial Aviation Safety Team, an aviation safety body; Two challenge rule: A team member is allowed to overrule another person if that person has been challenged twice without responding; Line operations safety audit: team of experts within the cockpit record errors, threats, and safety related behaviors in order to provide anonymous non-punitive data to support accident prevention, CRM, and other training (reference: http://aviationknowledge.wikidot.com/aviation:losa).

training, which described the hazard of task fixation in a fatal low fuel air accident. Recognizing this deficiency in medical incident investigation and lessons learned sharing, he pushed for an investigation and ensured the findings were publicly available[35] in order to ensure nationwide organizational learning. Subsequently he established a nonprofit organization which has been instrumental in bringing the aviation aspects of simulation and incident management into the healthcare industry.[10,45,78] Similarly, tragic preventable deaths have served as a rallying cry for aviation based investigative reform in the United Kingdom.[53]

Recognizing that healthcare incident analysis benefits from the same structured and human factor approach that guides the aviation industry, Vincent and Amalberi published a standardized LONDON/ALARME (Association of Litigation and Risk Managers-Europe) model of medical investigation which takes human factors greatly into account, but its implementation has not been described in the literature to date.[84] The Yorkshire Contributory Factors framework[44] is a promising human factors based model which has been used in the investigation of isolated incidents in the British healthcare system, but has not been adopted on a national level.[8] In the wake of such preliminary efforts and outcries for an aviation modeled investigation authority,[53] the United Kingdom recently legislated a nationalized HSIB.[40] Modeled on the Air Accident Investigation Branch and led by the immediate outgoing Chief Inspector of Air Accidents,[1] the HSIB makes the United Kingdom the first nation in the world to nationalize an investigative organization across its entire healthcare system.[51,52] Importantly, this organization establishes a distinct separation between regulatory and investigative organizations, such as that existing between the Federal Aviation Authority and the National Transportation Safety Board. Efforts to develop a similar organization for healthcare were previously contemplated, but not realized in the United States.[24]

In another gain for standardization of the investigative process, 'Investigating human performance' courses now teach aviation and healthcare professionals concurrently.[22] Staff instructors, including an Air Accident Investigation Branch investigator and a prior UK military Apache pilot, are human factors specialists who deliver incident analysis training to aviation modeled HSIB investigators, many of whom have been drawn from within the aviation and aviation medicine communities themselves.

Another approach to incident analysis employing an aviation model includes the provision of timely information and

Table II. Investigations of Aviation Practices Applied in UK Healthcare.

APPLICATION	AUTHOR	DESCRIPTION	FINDINGS/RECOMMENDATION
Incident Management	Konieczny et al.[43]	Survey/*N* = 112	Organizational influences on error causation (i.e., Departmental staff listening to concerns, adequate training) are perceived as positive by only 28%, 27%, and 15% of consultants, trainees, and support staff, respectively.
Brief/Debrief	Allard et al.[3]	Survey/*N* = 118	Surgeons have differing perceptions on meanings and value of briefing. Of operative staff, 78% agree that briefing improves teamwork and 82% feel that briefing improves safety; surgeons were the most likely group to disagree. Of staff, 94% want to see more briefing, 14% of surgeons do not want to see increased briefing. Reasons for briefing not being adopted were 'potential waste of time' (73% of staff), difficulty in coordination (70%), 'lack of enthusiasm' (60%). A total of 48% engage in informal briefing in any week. Surgeons who employed briefs rated them favorably.
	Mishra et al.[56]	Observational (26 procedures)	Recommendation for incorporation of intraoperative briefings to increase situational awareness/non-technical teamwork skill of 'situational awareness' negatively correlates with technical error (rho: −0.718; $P < 0.001$).
	Allard et al.[2]	Survey/*N* = 597	Individual practitioners who endorse briefings as common in the operating theater also report a better safety climate.
	Konieczny et al.[43]	Survey/*N* = 112	Pre-session team brief was viewed as important for safety and effective team management by almost all consultants, with junior staff less supportive.
	Hynes et al.[38]	Survey/*N* = 18	Of those surveyed, 100% perceived briefings with an 'emergency of the day review' improved team cohesion and communication, 58% thought modification to the process could provide benefit on a ward and enhanced training experience, 17% believed that incorporating the practice would interfere with a normal working day.
Crew resource management	Martin et al.[54]	Survey (Unreported *N*)	An evaluation of a 2-d team resource management education program determined that aviation concepts must be rooted in healthcare for training to be understandable and relevant to staff. Reporting of clinical adverse events increased from 40 to 350 per month after 2 yr of implementation. Training increased awareness of workload management, need for self-awareness, effects of changes in leadership style. Support of senior staff in implementing training is critical. Competing statutory/required training makes implementation difficult.
	Flin et al.[29]	Survey/*N* = 352	Staff attitudes are favorable toward safety and teamwork; surgical theater staff perceive personal invulnerability to stress/fatigue and are uncertain of managerial prioritization of safety over other business objectives.
	Mishra et al.[56]	Observational (26 procedures)	Non-technical teamwork skill of 'situational awareness' negatively correlates with technical error (rho: −0.718, $P < 0.001$).
	McCulloch et al.[55]	Observational (103 procedures)	Following a 9-h CRM class with twice weekly CRM coaching, non-technical skills/attitudes improved, teamwork climate increased, operative technical errors decreased from 1.73 to 0.98 (u = 1071; $P = 0.009$), and nonoperative procedure errors decreased from 8.48 to 5.16 per operation ($t = 4.383$; $P < 0.001$). Non-significant reduction in length of stay, no change in operative time. Intervention subjectively assessed as welcomed by nursing staff, passively and reluctantly undertaken by some senior medical staff. Hierarchical inhibition of open communication evident in several observed team interactions. Live practice with expert mentor viewed as helpful.
	Konieczny et al.[43]	Survey/*N* = 112	Of those surveyed, 56% of trainees, 72% of support staff, and 94% of consultants felt positively about questioning the decisions or actions of senior staff; 33% of consultants, 15% of trainees, and 15% of support staff felt positively about team members monitoring one another for signs of stress or tiredness.
	Timmons et al.[79]	Interviews/*N* = 20	Following a 6-d human factors course, 20 participants and teaching faculty underwent semistructured interviews. Participants rated the training highly, but report significant barriers to implementation: time resourcing, competing demands, resistance to change.
Sterile Cockpit*	Svetz and Jenkins[77]	Survey/Audits (48 audits)	Significant reductions in healthcare worker interruption following implementation of the medication safety zone 'Seeing Red' initiative, modeled after the sterile cockpit rule.
Ward round checklist	Hale & McNab[34]	Observational	Increased compliance with documentation of patient safety outcome measures (45–89%).

* Aviation Safety Definitions: HFACS: Human Factors Analysis and Classification System, a general human error framework originally developed and tested within the U.S. military as a tool for investigating and analyzing the human causes of aviation accidents. Based on Reason's[70] model of latent and active failures, HFACS addresses human error at all levels of the system, including the condition of aircrew and organizational factors (Wiegman & Shappell[85]). Sterile Cockpit Rule: FAA regulation requiring pilots to refrain from nonessential activities during critical phases of flight, normally below 10,000 ft. Reference: CFR 121.542 and CFR 135.100, "Flight Crewmember Duties."

support to families following a serious incident, as outlined in the updated UK National Health Service Serious Incident Framework.[60] This practice routinely occurs following a fatal air accident[62,64] and is a longstanding statutory requirement for U.S. National Transportation Safety Board and U.S. commercial carriers.[18,19,63] Additional aspects of aviation modeled practices

Table III. Analysis of Investigations of Aviation Practices Applied in UK Healthcare.

APPLICATION	ENABLERS	BARRIERS	EVIDENCE
Debrief	Direct involvement of recognized leaders	Cost/time	2B
	Established as part of broader cultural change	Perception of redundancy	
		Unsupportive leaders	
CRM Training	Dedicated/mandated time	Cost/time	2A
	Train the trainer programs	Availability	
	Structured with healthcare specific context	Lack of national policy	
HFACs based incident analysis	Direct collaboration with industry safety experts	Cost/time	3C
		Fear of negative reflection on organization	
Independent centralized investigation	Political will	Cost/time	3C
	Popular demand	Lack of legal immunity for participants	
	Enforcement of recommendations		
	Safe space for reporting		
	Continual stakeholder feedback		
Patient Safety Brief	Leadership support	Cost/time	3C
	Front line buy-in		
Sterile Cockpit (Seeing Red Initiative)	Leadership support	Cost/time	2B
	Physical indicators ± structural facility modifications		
	Hospital visitor/staff education		

Evidence levels may be greater for the larger international body of literature; the evidence ratings appearing in this table pertain only to the UK body of literature. Original aviation practices have been correlated with decreased accident rates and/or passenger fatality rates. The evidence ratings appearing in this table regard healthcare applications specifically, with respect to decreased incident rates and/or increases in safety culture indicators.

Quality of Evidence: Level 1: Good quality. Systemic review/meta-analysis, multiple RCTs with consistent findings or a single high-quality RCT. Level 2: Limited quality. Systemic review/meta-analysis of lower quality clinical trials or of studies with inconsistent findings, lower quality clinical trial, cohort study, case-control study. Level 3: Other evidence. Consensus guidelines, extrapolations from bench research, usual practice, opinion, case series.

SORT/Strength of Recommendation Taxonomy: A = Consistent, good quality patient oriented evidence; B = Inconsistent or limited quality patient-oriented evidence; C = Consensus, usual practice, expert opinion, or case series.

Reference: Ebell et al.[26]

championed in the updated National Health Service Serious Incident Framework include the dedicated training of investigators, a requirement for the assessment of multiple contributory causes, standardization of the investigation process and reports, and explicit promotion of a 'fair and just culture' over attempts to assign blame.[60]

The importance of establishing latent factors during incident investigation through confidential reporting systems, such as those existing in the aviation industry, has been strongly advocated within the UK surgical community.[28] Local and national aviation modeled reporting systems have subsequently evolved in the United Kingdom. The broad internet availability of U.S. and UK air accident investigation reports[31,62] as well as the UK aviation safety Confidential Human Factors Incident Reporting Program have been mirrored by a nonprofit organization whose surgeon and non-surgeon membership makes lessons learned from anonymously reported surgical incidents publicly available for the promotion of nationwide organizational learning, with discretionary feed of information to the UK National Patient Safety Agency.[21,46] In a similar vein, the purpose of the National Confidential Inquiry into Patient Outcome and Death Progamme is to assist in maintaining and improving standards of care by reviewing the management of patients, by undertaking confidential surveys and research, by maintaining and improving the quality of patient care, and by publishing and generally making available the results of such activities.[59] Finally, the Department of Health in the UK has published results of multiple public inquiries into the standard of care received by patients in some National Health Service trusts with a purpose of building trust with the public by promoting transparency and demonstrating accountability at an organizational level. The UK's national reporting and learning service database, one of the largest in the world and a gem of the UK patient safety movement, has been used for anonymous reporting as well as wide scale analysis of incidents.[9,61] Additional analogies between the national reporting and learning service and practices in aviation include blame free incident reporting, focused patient safety alerts, the publication of organizational safety performance, and the use of incident reports to improve learning on the front line.

Aviation brief and debrief practices have also been considered for implementation within British healthcare. By giving a short synopsis of intended actions, responsibilities, and lines of communication the brief by the individual in charge facilitates safety by creating a common mental model.[58] Particularly in high risk contingency settings such as those confronted by aviation maintenance tests or trauma surgical staff, adherence to pre-established briefing limits is crucial in ensuring safety.[72] Healthcare briefings have been contemplated for use at the start of clinics, ward rounds, handovers, and at the start of operative days.[47] The debrief affords a post hoc opportunity to discuss positive and negative aspects of the care, along with any lessons learned. To date a number of studies have assessed the acceptability and value of the debrief within the UK National Healthcare System[2,3,38] (see Table II).

A 2007 survey by Allard et al. established various perceptions of the meaning and value of the brief in the operating theater environment. While broad skepticism about the debrief and resistance to implementing it was evident, those employing it related the debrief as a positive experience which improved morale and shared understanding.[3] A 2008 Oxford study subsequently assessed surgical performance using an aviation

based assessment of social/cognitive skills and determined that lapses in situation awareness directly correlated with error, leading authors to suggest incorporation of a debrief in order to enhance performance.[56] As part of a 4-yr Theater Team Resource Management project, briefing and debriefing were undertaken by over 300 operating theater personnel. Briefing was more readily accepted than the debrief, which was often perceived as superfluous. A correlation was established between safety culture and agreement with the statement that 'briefings are common in the operating theater.' However, uptake of briefings was sporadic and inconsistent, with implementation largely determined by individual surgeon influence.[2] A 2014 process improvement project conducted at the Emergency Department of Addenbrookes Hospital evaluated the experience of 18 doctors of varying grades participating in an aviation modeled brief/debrief cycle, including an 'emergency of the day' discussion, over a 3-wk period. Of the doctors, 100% perceived that such a project improved team cohesion and communication, 58% thought modification to the process could provide benefit on a ward and enhanced training experience, with 17% believing that incorporating the practice would interfere with the normal working day.[38] Briefs and debriefs are now specifically recommended by the Royal College of Surgeons as part of an approach toward improving communication.[30]

CRM includes leadership, decision making, and communication procedures. These procedures are used within high risk environments in order to reduce risk for error, to trap errors committed, and to mitigate the consequences of error.[37] They have been incorporated into healthcare previously with positive impact on mortality and complication rates.[33,65] Five features of CRM have been noted by British healthcare researchers to be especially helpful when incorporated into clinical medicine: cooperation, leadership, workload management, situation awareness, and decision making.[74] Since 2005, six peer reviewed publications have addressed assessments of CRM/non-technical skill applications within the British healthcare system, each of which will be discussed in further detail. Pioneered in 2005 within the United Kingdom, 'Team Resource Management' was fielded as a four stage NHS Trust program geared toward behavior, communication, and leadership. Team Resource Management was positively evaluated by participants and resulted in increased medical incident reporting. Continual evaluation of the program found that although aviation concepts are transferable, nonetheless they have to be rooted in healthcare as well as aviation to make them understandable and relevant to staff.[54] In 2006, researchers from the University of Aberdeen surveyed 352 surgical team staff using the aviation HFACS modeled Operating Room Management Attitudes Questionnaire. Attitudes toward safety and teamwork were favorable, but both surgical and nursing staff reported personal invulnerability to stress and fatigue. Survey respondents were uncertain of managerial prioritization of safety above other business objectives.[29] A subsequent observational study of 26 laparoscopic cholecystectomies was undertaken in conjunction with a retired British commercial airline pilot with extensive experience in airline teamwork training delivery. The specific non-technical teamwork skill of 'situation awareness' was found to negatively correlate with technical error.[56] In a 2008 Oxford 'Aviation-style non-Technical Skills Training' program, self-selected surgeons (65% of available surgeons) completed a 9-h CRM course with 3 mo of follow-on CRM expert coaching. A subsequent assessment of 103 laparoscopic cholecystectomies and carotid endarterectomies found that CRM training was associated with significant increases in teamwork climate score and team non-technical skill rating, significant reductions in error, and a non-significant trend toward decreased length of stay; operating technical error was reduced from 1.73 to 0.98 per procedure and nonoperative procedural error was reduced from 8.48 to 5.16 per procedure in the trained group.[55] In a further assessment of CRM training, Timmons et al. conducted interviews with 20 self-selected participants who underwent a human factors training course led by aviation human factors experts. Training was highly rated; all reported gains in insights and attempted to implement the training into clinical practice. However, participants noted significant organizational structure and cultural barriers to incorporating their training into healthcare delivery.[79] In the most recent of the CRM/non-technical skill studies, Konieczny et al. measured attitudes to human factors in 112 surgical staff using an aviation-based analysis and classification system, specifically with regards to the 'unsafe supervision' and 'preconditions to unsafe acts' domains. Trainees were more likely to agree with the statement that 'Team members should not question the decisions or actions of senior staff except when they threaten the safety of the operation.' Across all staff, the concept of cross-monitoring within the healthcare team for signs of stress or fatigue was poorly accepted.[43]

In the advent of these findings, CRM and simulation classes for healthcare professionals have greatly expanded in the UK. An overseas study of 15 CRM training and healthcare subject matter experts confirmed the five domains determined to be most suitable for inclusion into a 1-d CRM course for healthcare providers (communication, task management, situational awareness, decision-making, and leadership). These domains broadly correlate with the existing content of major CRM programs implemented in healthcare.[14] A number of academic institutionally affiliated programs deliver CRM styled training in the United Kingdom. There are 15 London healthcare organizations which participate in a single university's program that trains students to be CRM instructors within their own local healthcare systems; simulation and debriefing are other aspects of this training.[80] The Royal College of Surgeons offers CRM rooted classes, as well as publicly available online resources.[73] The Anesthesia non-technical skills manual addresses task management, team working, situational awareness, and decision making along with specific examples of positive behaviors and self-assessment schemes.[81] The Non-Technical Skills for Surgeons[82] and Scrub Practitioners List of Intra-Operative Non-Technical Skills Manual[83] manuals also address situation awareness, decision making, communication, teamwork, and leadership. The Observational Teamwork Assessment for Surgery targets the behaviors of communication, coordination,

cooperation/backup, leadership, and team monitoring/situational awareness.[39] Each of the CRM modeled online resources provides rating schemes to enable quantification of these skills for an operative team. Commercial programs offering human factors training for the aviation sector have begun marketing such programs to healthcare professionals. The scope of such training includes the debrief process, incident analysis, and CRM, as well as, in the case of a commercial airline-NHS partnership, simulated flight with immersion into typical flight crew interaction.[4,5,15] Leading patient safety figures strongly champion the widespread adoption of aviation modeled CRM for healthcare professionals across the NHS.[27,45]

While incident management, debrief, and crew resource management comprise the majority of published healthcare applications of aviation practices into the UK healthcare system and remain the focus of this review, a number of other aviation modeled practices have been theoretically contemplated within the literature and warrant mention. Such practices are referenced in Table I, which comprehensively details proposed applications of aviation practices into healthcare. These practices include the establishment of healthcare specific 'minimum safety requirements' such as nationalized minimum nursing ratios and maximal bed occupancy rates,[42] the widespread adoption of black box recording systems to facilitate incident investigation,[42] implementation of a 'first name only rule,'[42] implementation of a 'bottle to throttle' rule for alcohol intake,[42] the habitual incorporation of a behavioral health specialist onto the patient safety team,[42] mandatory competency checks,[27,57] the passenger/patient safety brief,[11,12] the use of a ward round checklist,[32] and the sterile cockpit rule.[77]

Among these theorized aviation practices, the patient safety brief, ward round checklist, and sterile cockpit rule have actually been implemented into the UK healthcare system. The UK-based largest single-site cancer center in Europe initiated an aviation-modeled patient safety brief[11] and information card,[12] providing patients' information on blood clots, falls, and infection prevention, among other measures, to limit preventable complications in a similar fashion to the passenger safety briefs undertaken on commercial airlines. A ward round checklist developed to improve compliance with documentation of patient safety related outcome measures at one NHS Trust improved compliance from 45% at baseline to 89%, with important implications in ensuring proper standards of care are being achieved.[34] The NHS Wales University Health Board recently publicized its 'Seeing Red' Initiative in which 'Medication Safety Zones' are established across medical wards to introduce the 'sterile cockpit rule.' As legally required during critical stages of flight,[16,17] unnecessary distractions and interruptions are kept to a minimum during the management of medication—indicated by the presence of red doors, red floors, or individuals wearing red aprons.[66] Undertaken as an NHS process improvement project, 26 preintervention and 22 postintervention audits revealed a significant reduction in healthcare worker interruptions following the adoption of the sterile cockpit model.[77]

DISCUSSION

A review of the literature surrounding the incorporation of aviation practices into UK healthcare reveals a widespread acknowledgment of the value of safety and teamwork, with various degrees of evidence[26] supporting each transferred aviation practice into the health field. However, there is uneven acceptance of evidence based aviation practices such as the debrief and crew resource management training (Table III). It is important to establish a good understanding of the barriers and enablers of successful transfers.

Mindful rather than broad stroke application of aviation practices is important. Research demonstrates that innovations within service organizations that are compatible with the intended adopter's values, norms, and perceived needs are more readily adopted.[32] The degree to which certain cultural practices, such as assertive communication, have already been normalized must be taken into account before adopting a safety practice from any other industry. The one-off insertion of an aviation practice without consideration of the degree to which an overarching safety culture has already been developed is likely to fail, as did early aviation CRM attempts which were not operationally relevant to the training population.[58] Leaders within the UK patient safety movement have consistently voiced that 'one size does not fit all' when it comes to the application of aviation practices into healthcare.[27,84] Mindfully applied applications of aviation practices address the development of a larger safety culture and engage broadly. For example, the successful sterile cockpit intervention targeted patients as well as healthcare professionals for education, including highly visible posters and materials for the visually impaired, with physical remodeling of building structures undertaken to support efforts.[77] Such substantial support for this undertaking underscores the prioritization of safety as equal to or above the other business goals of management, amplifying a safety message.

The use of incident investigation techniques adopted from aviation is best applied in healthcare with conscious awareness of what makes it work in aviation,[67] such as well-established feedback loops and industry-wide embracement of a "just culture."[23] The HSIB's recruitment of aviation and healthcare investigators and the continual feedback it has sought from key stakeholders throughout its development recognizes the need for a nuanced approach and is thus an exemplary instance of mindful application of an aviation practice.[10] Resistance to individual measures such as the team debrief appears to be less when delivered along with human factors training that aims to change behaviors and communication skills. Inconsistent delivery of CRM training across the NHS, attributed to a lack of national policy and training investment[30] rather than the absence of recognized value for such training, is an unmindful approach. While a remit for flexibility in adapting the CRM training to the healthcare setting is desirable, a lack of universal CRM training has been specifically cited as an obstacle to implementation of human factors based practices.[79] The many academic and patient safety organizations have bridged this gap

through public access publications and by offering no cost, publicly accessible resources. Due to its nationalized system of healthcare delivery, the United Kingdom is far better placed at establishing a national CRM requirement than nations with non-nationalized healthcare such as the United States. The nesting of all adopted aviation practices with training is consistent with a mindful approach. Accordingly, training in assertiveness, communication, and leadership skills has been specifically advocated by the Royal College of Surgeons.[30] In particular, assertiveness training has been demonstrated to be effective in overcoming hierarchical resistance to challenging error within the healthcare system, especially in the context of emergency airway simulation.[6]

Despite the promise of directly applying an aviation model to healthcare through an organizationally supported approach as part of larger cultural change efforts, it is important to also recognize the importance of a nuanced approach toward specific fields of healthcare themselves; aviation modeled practices should be tailored to specific characteristics of the healthcare setting. Highly organized and predictable fields of medicine such as radiotherapy are more capable of attaining the low incident levels that civil aviation achieves than are the less predictable medical fields of trauma or experimental surgery; such healthcare settings more closely resemble the military[13,84] and/or maintenance/experimental test pilot[72] fields of aviation. High-risk aviation safety practices, such as extensive contingency briefing/planning, are better for application within healthcare settings that confront similar degrees of risk.

Several limitations exist in this review. Data regarding the efficacy of CRM training may be limited by the self-selected nature of study participants, who are likely to be inclined toward self-improvement. Studies associating implementation of practices such as the brief and debrief to safety culture would be more powerful if clinical outcomes had also been assessed. There is a paucity of studies assessing specific barriers to the implementation of aviation practices or the rationale for healthcare worker attitudes that are not aligned with a high safety culture. The obstacles discussed within this review may be representative of only a fraction of the barriers that actually exist. The authors were unable to identify any studies regarding the efficacy of implementing aviation modeled medical incident investigation practices, therefore making it impossible to quantify the actual value of this transferred practice.

Should the UK healthcare system mindfully harness a broad scope of aviation applications during this era of unparalleled investment and adoption of such practices, safety could rise to new heights. At the root of the debrief, CRM and aviation based investigation are what a leading UK patient leader asserts to be at the very crux of patient safety: listening to one another.[87] Patient safety efforts which extend beyond those of the aviation industry include the formal assessment of investigative reports against established benchmarks for quality, as occurs in the NHS Serious Incident Framework, and the interorganizational development of investigative recommendations that are conducted through the UK surgeon led confidential reporting program. Expanded efforts which extend beyond the aviation industry safety standard could include a system for investigation of whistleblower treatment.[41] At this time, none of these healthcare practices have a parallel within the aviation industry.

Future efforts should include measurement of objective outcomes in gap areas such as centralized investigation, the implementation of proposed aviation practices which have not yet been undertaken within the healthcare system, and further investigation of novel healthcare safety practices which are not currently established within the aviation industry. Barriers to the adoption of aviation practices must be closely assessed in order to ascertain more mindful ways of applying these practices into healthcare. We must continue striving for zero preventable harm and for the inevitable day that the aviation industry looks to healthcare for ways in which to optimize aviation safety.

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