Operating Room and Flight Deck: What Do These Places Have in Common?

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ABSTRACT

This review article grounds itself into the advent of aviation safety concepts that share some aspects into healthcare industry, practically and theoretically. These concepts are originally invented for aviation-related operation to ensure safety in flight but there are some aspects that can be related to healthcare context especially in surgery. Because aviation and healthcare are high reliability industries and neither patients nor passenger safety are compromised, safety concepts from aviation may prove useful for healthcare. The objective of this review was to scrutinize the concepts of aviation safety that may be applicable to healthcare. Data collection was based upon a review of literatures. This review article contributes to a broader knowledge from both fields of work regarding operational safety. The review shows that there are several practical concepts including Crew Resource Management, checklists and readbacks, sterile cockpit, and human factors of fatigue and stress that healthcare professionals can adopt and adapt them into their daily operation. Moreover, theoretical concepts such as Swiss cheese model and Threat and Error Management can be applied into healthcare context. This review invokes scenarios of each concept from both industries. The results show that communication is the key to promote safer operation and those concepts can be adopted to promote better safety at work. Future studies should extend the concepts of this review into an experimental research to analyze the effect of concepts on actual healthcare settings or utilize qualitative study to investigate the application of concepts in healthcare environment.

Keywords: Aviation; patient safety; pilot; safety; surgeon; surgery (Siriraj Med J 2021; 73: 710-720)

INTRODUCTION

Safety is essential and considered an utmost goal in aviation. The problem is that aviation accidents always result in enormous loss of life and assets, attracting worldwide attention as well as huge financial costs for all stakeholders. Therefore, the aviation industry is rigorously determined to learn from past lessons from incidents and accidents to prompt better safety procedures and practices. In terms of the rules in pilots' standard operating procedures, there is always someone who has paid for it with their life. In an honest, sincere and truthful way, pilots' standard operating procedures are written in blood. Thereby, pilots have an interest in conforming to the rigorous safety policies and procedures they must follow as the probability exists that they would pay for any shortcomings of the safety procedures with their own lives as well. These are the reasons why the aviation industry has instigated a dominant

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safety culture. However, pilot error seems to remain the primary cause of aviation accidents.[1] On the other hand, medical errors in the healthcare industry provide a serious threat to patient safety as they are estimated to be accountable for 3% of all hospital admissions.[2] Toward the goal of reducing the risk of patient harm, the notion of aviation safety policies and practices may be adopted for the medical field, especially for surgeons. Both the operating room in a hospital and the cockpit in an aircraft, surgeons and flight crews, share a lot of things in common in terms of rigorous training, in-depth technical knowledge, keen eye-hand coordination, and responsibility for operational safety. Moreover, these intangible components of professionalism in both professions are commodified and considered valuable capital for an organization.[3,4]

The objective of this review article is to scrutinize the advent concepts of aviation safety that may be applicable to the healthcare industry. Data collection was based upon a systematic review of related literature including texts, research papers, practitioner papers, academic manuscripts, and other relevant online resources from both academic and practitioner perspectives. This review article contributes to a broader knowledge from both fields of work regarding operational safety.

Described below are reviews of several aviation safety concepts, practically and theoretically, that have been introduced and could possibly be adapted into medical practices. This review article also aims to incorporate existing safety-related literature, pointing towards reported aviation safety philosophy and providing examples related to daily surgical practices.

Practical Concepts

Crew Resource Management (CRM)

Hazard industries, namely healthcare and aviation, rely mostly on effective teamwork exercise owing to the complicate, dynamic and critical safety nature context of their industries. It is inadequate that these teams are built upon individual experts, but the team itself must be high expertise team in order to practice high level of technical performance and team attitudes and behaviors to function safely and adaptively to achieve goals. An expert team is defined as a set of interdependent team members, each of whom possesses unique and expert-level knowledge, skills and experience related to task performance, and who adapt, coordinate and cooperate as a team, thereby producing sustainable and repeatable team functioning at superior or at least near optimal level of performance.[5] Team working on surgical operation share similar characteristic to those in aviation in that they operate in high-risk environments where situation between life and death of patient involves. Moreover, team members always change and surgical operation team are built upon skillful individuals such as surgeons, anesthesiologists, anesthetists, nurses and medical technicians who might or might not know each other and might not have been working together before. Members need assurance that their teammates know and understand their duties and can use their abilities and knowledge collaboratively to intervene or recover operation. This can be built over time as members feel familiar with each other and improve personal working relationships. When there is the possibility for things to go wrong or rapidly deteriorate at work such as midflight engine failure in aviation or a patient blood pressure rapidly drop during operation, there is even more reliance on the teamwork capability to respond quickly to manage the unforeseen situations.[6]

Apart from those CRM factors aforementioned, there are several crucial elements regarding CRM practices that describe safer operation among aviation and medical practitioners alike. These are situation awareness, decision making and SHELL Model.

Situation awareness comprises three stages which are, the perception of the elements in the environment in a matter of current time and space orientation, the comprehension of their meaning and the projection of their status in the near future and thus, proper decision making is made to mitigate risks.[7] With these three components combined, situation awareness may support better choice of action as this involves cognition and short-term memory or working memory. Moreover, situation awareness is relevant to dynamic working environment such as flight deck and operating room and hence is not the same as the still knowledge of long-term memory under static working condition.[8] Flight crew and surgeons, who are always situationally aware, have an ability to access to a precise mental representation of the dynamic environment that is broader than that which can be upheld in the restricted capacity of working memory. For instance, in aviation context, during final approach stage, there is a sudden conflict of aircraft traffic during final approach path, but if the good situation-aware pilot can call on suddenly to respond accordingly to this situation, the pilot will decide accordingly to maneuver aircraft so rapidly and accurately that the flight path is safe from air traffic collision during final approach due to the ability to rapidly access the information from working memory.[9] In healthcare context, during perfusion and cardioplegia management, after an administration of a bolus of cardioplegia solution, the surgeon notifies

that the heart is filling up with blood or full heart. The good situation-aware surgeon can recall to root cause suddenly to respond to this situation that there might be an improper operation of heart-lung bypass circuits. The surgeon suddenly makes a decision to fully isolate the heart's profusion circuit by adjusting the aortic cross-clamp and bolus of cardioplegia will later on be re-administrated.[10] Situation awareness helps support the response to the unexpected events that may arise anytime during their flight mission or operating procedure.[11]

According to SHELL model in Fig 1, this model can help understand human factor element in CRM concept. The SHELL model is a conceptual model of human factors that helps clarify the human factor relationships between resource, system, environment and human.[12] The model represents several wavy squares to illustrate different elements of imperfect interacting components which are Software (policies, procedures, practices), Hardware (machines, aircraft), Environment (working context) and Liveware (man). The core component of this model is the man (Liveware), flight crew or operating room crew in this case, and this is considered as the most sensitive system component as human is subject to great variation in performance and limitation and all other components ought to be adapted to fit with this centered Liveware such as Liveware-Hardware (man and machine), Liveware-Software (man and procedure), Liveware-Environment (man and working environment). According to CRM concept, Liveware-Liveware (man and man) is the most essential interaction term as this interface is about interpersonal interaction; moreover, the human is the weakest point in safety operation and considered as the major cause of an accident.[13,14] Liveware-Liveware (L-L) interaction encompasses the interrelationships among the individuals within operator groups. In aviation context, pilots are the centered liveware that interacts with engineers, ground crew, cabin crew, air traffic controller and passengers. In healthcare context, surgeons are the centered liveware that interacts with anesthesiologists, anesthetists, perfusionist, medical interns and patients. Human interaction can influence work behavior and performance. Thereby, the L-L interface is mostly concerned with interpersonal relationship, crew cooperation, communication and leadership. Poor L-L interface can be result in a risky working situation. For example, bad interpersonal relationship between captain and first officer can lead to an undesirable cockpit environment and this can also lead to an accident as seen in Korean Air Flight 801. First officer and flight engineer failed to challenge captain for the wrong ground base radio navigation aid approach and captain did not listen to his subordinates then the aircraft crashed into the hill about 3 nautical miles short of the runway.[15] To mitigate L-L interface risk, appropriate CRM training can be applied to those flight crew and operating room crew that always assigned to work together as a team.[16]

Fig 1. SHELL Model Adapted from ICAO

Both healthcare and aviation are high reliable industries and specific training is necessary. Crew Resource Management (CRM) concept is introduced to support and enhance teamwork exercise and team performance. CRM is the effective use of all available resources for flight crew personnel to assure a safe and efficient operation, reducing error, avoiding stress and increasing efficiency.[17] This type of training incorporates simulator-based scenarios and on the job training (OJT) to allow team members to practice both technical skill and soft skill and attain feedback on their performance from instructors. CRM ensures that team members responsibilities are clearly defined and properly delegated when a sudden change in workload occurs. In summary, it helps team members to solve unforeseen problem.[18] In aviation, problem solving is more efficient when the immediate corrective actions of designated crew members are clearly defined. In operating room, the need for close cooperation and intensive communication between members may be slightly deviant from aviation as many surgeons, anesthesiologists, technicians and nurses tend to focus on their own work and only consult with each other whenever they need.[19,20] However, cardiac surgeons represents a close CRM practice to pilots seeing that they are accustomed to frequently communicate with perfusion technicians, anesthetist and anesthesiologist at their mission.[21] Less cooperation between medical staff in operating room tends to rise due to distinct and delimit competencies and responsibilities of surgeons and anesthesiologist compared to flight crews. Disagreement

between surgeons and anesthesiologist needs to be resolved by absolute consensus as these two professions share the same level of responsibility. While in aviation, captain or Pilot-in-Command (PIC) always has ultimate decision.[22] In practice, active communication between operating team members is the key and can help improve a smoother operating process and yield a better result. For example, if anesthetists were briefed in advance regarding patient condition, they would cope with hemodynamic and metabolic changes confidently and then they can mitigate the risk of detrimental impact from aorta-cross clamping.[23]

Checklists and readbacks

In aviation context, checklists have been developed for each phase of the flight mission including taxi, takeoff, climb, level flight, descend, approach and landing as well as for emergency situations that may arise during mission. Pilots are strongly encouraged and committed to abide by these checklists and any deviation from checklists is considered a flight regulation violation. Moreover, checklists are specifically designed to the specific type of aircraft to assure that all safety-related elements are included. In healthcare, back in 2008, the World Health Organization (WHO) released surgical safety checklists to embrace patient safety. WHO surgical safety checklist tries to imitate each phase of the flight mission by dividing each phase of surgical operation including anesthesia, incision and wound closure.[24] Even though WHO did not force medical practitioners to adhere to this checklist but WHO strongly encourages them to edit the proposed checklist to their own operation. In fact, by customizing checklist for their own interests of interventions like aviation checklist that is tailored made for specific type of aircraft, may seem logical.[25] For instance, vascular surgery operation might need different safety checks for endovascular procedures than for orthopaedical surgery. For the most complicated or infrequent performed procedures, even more intervention-specific checklist may be necessary.[26]

Effective, yet efficient communication is determined as a very basic human necessity which is particularly essential to assure safety in high-reliability industries, healthcare and aviation alike. In spite of minor error in communication during operation, damage and loss can be anticipated.[27] A readback, in aviation, is defined as a procedure whereby the receiving station repeats a received transmitted message or an appropriate part thereof back to the transmitting station in order to obtain confirmation of correct reception.[28] In short, the process of readback involves the person receiving information repeating it back verbally to the sender and this will let the sender know the message has been received and provides a chance to correct any discrepancies. Some past air accidents involving poor communication between pilots and air traffic controller and this emphasizes that human errors in communication still occur even in advances technology in aviation. On the contrary, it is essential to develop communication phraseology or standard protocols in high-reliability industries like, marine, aviation and surgery.[29] Past study revealed that a significant source of surgical errors can be contributed to a poor communication before, during and after surgery. Poor verbal communication accounted for approximately 85% of undesired event related to verbal communication but poor written communication only accounted for approximately 4%.[30] According to this result, the patient safety needs formal readback. Readback, in this medical-related case, can be ranging from readbacking orders among team members operating on patient so as to reduce incidence of perioperative complications to readbacking medication orders over the phone when verbal transmission of critical information is inevitable.[31,32] Past study quantified the impact of readback as a communication technique for improving transmission of clinically relevant information during a critical phrase of work. It found that when anesthetists mentioned items of information to anesthesiologists in a simulated emergency situation, the anesthesiologists were much more likely to correctly answer a question about the information after the scenario if they had repeated it back at the time it was mentioned to them and this could promote a better level of patient safety during operation.[33] Moreover, psychology study also suggested that repeating back important information is likely to help improve memory. This is determined as 'production effect', the phenomenon where speaking words improve memory of those spoken words.[34] While aviation checklists is mandatory to mitigate human error risk that might lead to an unsafe situation, in operating room setting, surgeons and team members should consider which scenarios are critical and design their own specific checklist as per scenarios, especially in the critical phrase of the procedure that requires immediate action.

Sterile cockpit

Even though an operating room is literally sterile for sanitary purpose, sterile cockpit, in aviation context, does not mean that the flight deck is sanitized by any disinfection agents. It means that the flight crews in the cockpit keep the environment of a cockpit safe from all

non-pertinent conversation and non-essential activities are disregarded during critical phases of flight especially takeoff and landing. This concept of sterile cockpit has stemmed from the notion that distracting activities cause pilot errors and reduce pilot flight performance.[35] Nonetheless, the working environment of an operating theater is less structured than a cockpit with much more distractions including noisy sound from outside operating room, ringing phone, non-relevant conversation about next patients among members, inquiries from medical students and nurses, and many more.[36] These are sources of distraction and might contribute to a lower levels of dexterity and concentration of surgeon at procedure.[37] For instance, a cardiovascular surgeon is going to start a complex endovascular procedure that two catheter introducers have to be placed. While attempting to bilateral femoral access, surgeon is distracted by an incoming phone call consulting about previously operated patient and the assisting medical student needing to discuss his report log. In the same time, anesthetist has left the operating room to fetch a stent graft and the anesthesiologist also left the room for a coffee break. Later on, surgeon finds out that heparin was administrated twice from new coming anesthetist and anesthesiologist. Countermeasures to mitigate the distraction risk could be simple such as reducing background noise by using sound proof material wall or prohibition of phone call might help create more peaceful environment. Lead surgeon can encourage team members to regain a focus by telling them that a critical phase of procedure is about to commence and all team members need to focus on the work at present before everything else. As the concept of sterile cockpit is to remain focus and concentrate on the current critical situation, surgeons ought to perform leadership and professional demeanor at work and they must take the current job at hand seriously.[38]

Human factors: fatigue and stress

Fatigue is one of the most common physiological problems for flight crews and will adversely affect individuals who are otherwise in good health condition. It has frequently been considered as the causal factor in aviation incidents and accidents as fatigue degrades performance and tired flight crews cannot carry out flying tasks as reliably and accurately as they should normally perform. Moreover, They are irritable and less alert, willing to accept lower standards of accuracy and performance.[39] Fatigue begins when the pilot commences a flight continuously and increases with each hour in the air. As a result, at the time of landing when reflexes and judgement should be at high, the pilot is most affected by the cumulative effects of fatigue. In addition, the major danger of fatigue is that it is cumulative and the pilot might not recognize its effect. Fatigue can be caused by many factors such as lack of sleep, poor food, long-haul flight, heavy workloads, frustration from work and uncomfortable working condition.[40] In this matter, pilots share the same occupational fatigue with surgeons. Many surgeons also face long working hours, night shift duties and several pressures at work. The effect of fatigue from various factor such as long working hour and work challenges on the quality of work of surgeons has been studied and it effect the same way as found in pilots.[41] Acute fatigue is easily treated by good nutrition and sufficient rest. A sound physical condition and a healthy psychological attitude combining with good diet and adequate sleep are pilots and surgeons best super weapons in fighting fatigue.[42] For the long working hours in surgeons' duty, hospital managements and surgeons need to work together and discuss the proper working hours. If surgeon and anesthesiologist decide to adjourn a procedure in case of fatigue and weariness, it may turn out to be better off for patient safety and hospital management should consider this as a proper decision.[43,44]

Stress indeed is generated by the task itself and it is not always negative as the sympathetic nervous system responds to stress and supplies the resources to deal with the upcoming demands. Factors contributing to stress are generally classified into three categories which are physical, physiological and psychological stressors. Physical stressors include extreme temperature, noise, vibration, lack of oxygen, etc. Physiological stressors include fatigue, hunger, disease, etc. Psychological stressors relate to emotional factors such as worries, poor personal relationship, financial problem, etc.[45] It is quintessential that both pilot and surgeon are able to recognize when stress levels are getting too high. If they are suffering from domestic stress, divorce, bereavement or even moody sensation, the cockpit or operating room might not be suitable places for them. Besides, the stress of flying or operating also consume energy. This energy is derived from oxygen and blood sugar. Pilots who fly for too long without eating or surgeons who operate procedures for too long and skip meal will face low blood sugar or hypo glycaemia; that is to say, their energy reserve will be low and cause reactions to be sluggish and effect their work performance drastically.[46] Due to high-reliability work context in aviation, every pilot needs to pass physical and mental fitness checkup annually to be qualified for flight duty

and medical fitness. This ensures adequate operational safety in every flight. Sign of chronic stress are varied such as forgetfulness, repeated mistakes, tense stomach and it may erode individuals' self-image. Challenges at work can also lead to burnout.[47] However, stress is manageable. There are several ways that pilots and surgeons can deal with stress. The physiological stressors can be controlled by maintaining sound physical fitness or getting adequate sleep. The physical stressors can be reduced by making the cockpit or operating room environment as relax as possible. A conscious effort to avoid stressful situation and support from family, friends and colleagues can minimize psychological stressors. If needed, professional mental counseling help restore psychological equanimity.[48-50]

Theoretical concepts

Swiss cheese model

Swiss cheese model, portrayed in Fig 2, was hypothesized that most accidents or incidents could be traced to one or more of four level of failure that had been placed in order consecutively.[51] These four levels of failure include organizational influences (organization-level), unsafe supervision (supervision controls), preconditions for unsafe acts (work-related processes) and the unsafe acts themselves (people). The cheese layers can be portrayed as layers of defenses and the holes are considered as lapses in defensive layers. Whether or not latent or manifested failures, it can be seen that over time, the holes in the cheese will line up straights and threats will find a way to get through all cheese layers and cause an incidents or accidents. This event is considered as a trajectory of accident opportunities. The underpinned concepts proposed by Swiss cheese model is a proper view on human factors in term of error, that is to say, human error is a general symptom of system failures that demands explanation.[52]

In aviation context, for instance, even when many things can go wrong such as an aircraft traffic separation infringement in case that the traffic conflict is not regarded or resolved by air traffic controller, pilots or traffic collision avoidance system (TCAS) in the aircraft will still get the job done and cause a very small chance that aircraft may collide each other midair. Air traffic controller inability to resolve conflict traffic is considers and a threat that pass through a hole of one cheese but pilot and TCAS ability to detect conflict traffic is another cheese that block this threat to pass through. However, if threat can pass through all the layers of cheese, accident or incident can be anticipated. In aviation scenarios, flight crew working for an airline that has poor safety procedure (organization influence) with poor pilot training record and supervision (unsafe supervision) are operating a commercial flight, when there is an air traffic conflict during critical final approach (precondition of unsafe acts), pilots ignore cautions from both TCAS and air traffic controller (unsafe acts). In this case all holes in the cheese will line up straights and threats will get through all cheese layers and cause a serious accident. In operating room context, a vascular surgeon working for a hospital that has marginal standard operating procedure (organization influence) with poorly-trained operating room crew (unsafe supervision) is operating an axillofemoral by pass, the procedure is uneventful until the anesthesiologist notices a sharp drop in blood pressure causing a demand in blood transfusion (precondition of unsafe acts). Anesthesiologist suggests that excessive blood loss is the cause but it is disregarded by surgeon (unsafe acts). Later on, it is found that the cause is stemmed from a disagreement between the

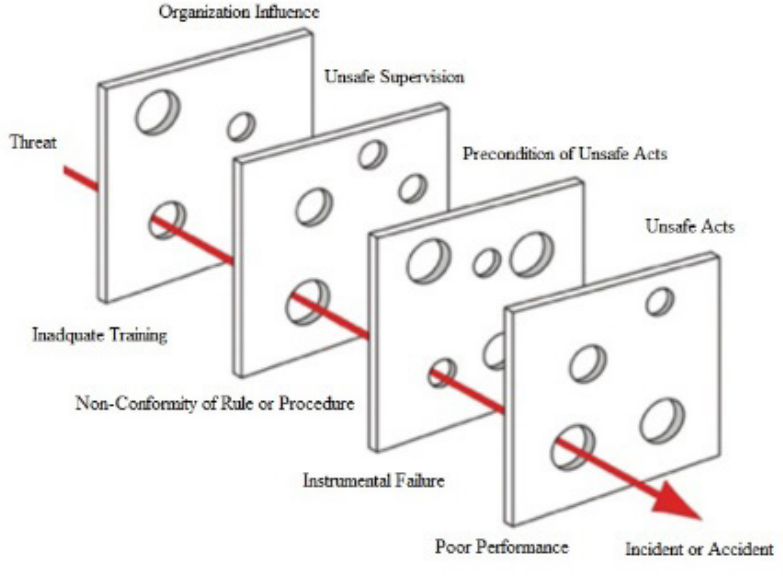

Fig 2. Swiss Cheese Model Adapted from James Reason

forceful femoral pulses and the perceived hypotension. It is also recognized that cross-clamping of the axillary artery has also intervened blood flow towards the radial artery where invasive pressure measurement occurs. In this case, the threat can pass through all defensive line and causing incident.[53,54]

Threat and error management

Originally, threat and error management model may be developed for flight deck operation; nevertheless, this can be used at healthcare or other industries as well. Threat and Error Management (TEM) is a conceptualized framework that helps in understanding, from an operational perspective, the intra-relationship between operational safety and human performance in dynamic and challenging operational context.[55] This model is descriptive and diagnostic of both human and system performance and the main objective of this model is to understand error management namely error detection and error response rather than only focusing on error causality. There are three main components in TEM, from aviation perspective: threats, errors and undesired aircraft states (UAS).

Threats are defined as events or errors that occur beyond the influence of the flight crew, increase operational complexity and which must be managed to maintain the margins of safety.[56] During operation, flight crews need to manage various external complexities. such as adverse meteorological condition, air traffic congestion and aircraft technical malfunction. Some threats can be anticipated as they are expected to flight crews such as adverse meteorological condition and air traffic. These can be found in notice to airman (NOTAM) and weather forecast information. However, some threats cannot be anticipated such as in-flight technical malfunction occurring without any warning. In this case aircrews need to apply skills and knowledge to cope with this threat. To simplify, threats are something bad that arise from outside the cockpit. However, there are some internal threats relating to human factor and limitations such as inappropriate crew scheduling event. When current flight crew are unexpectedly assigned to fly an extra flight due to an absence of other crew calling in sick, this can possibly deteriorate their flight performance and affect human factor limitation, which is fatigue.[57] Another example for internal threat ascribed to human factors is an instant diarrhea attack in flight crew during flight due to unclean food intake or norovirus transmission on an airplane. In this case, good situation awareness needs to be exercised to correct and properly manage the situation. Pilot needs to detect the symptom early and instantly pass aircraft flight control to co-pilot to avoid unusual aircraft flight attitudes.

Error are defined as actions or inactions by the flight crews that lead to deviations from flight crews intentions or expectations.[58] Unmanaged or mismanaged errors mostly lead to undesired aircraft stated and error in the operational context hence leads to reduce the margins of safety and increase the possibility of adverse events to occur. Despite the modern aircraft computer technology, erroneous pilot can input incorrect flight parameter into flight computer and this will lead to future adverse event. Regardless of the error types, errors effect on safety depends upon whether the flight crews detect and responds to the error before it may lead to an adverse event or potential unsafe outcome. From the safety aspects, operational errors that are timely detected and promptly responded to will not reduce margins of safety; besides, proper error management represents an example of successful human performance.[59,60] To simplify, errors are something bad that arise from the pilots.

Undesired Aircraft States (UAS) are defined as flight crew-induced aircraft position or speed deviations, misapplication of flight controls, or incorrect automation system configuration, associated with a reduction in margins of safety.[61] UAS resulting from ineffective threat and error management may lead to adverse situation and reduce margins of safety in flight mission as UAS is the last chance for pilots to act accordingly so as to prevent upcoming incident or accident. Examples of UAS include exceeding speed restriction during an approach, landing short of runway or lining up for the incorrect runway for takeoff. To simplify, Undesired Aircraft States (UAS) are the result from threats and errors.

In healthcare context, disturbing sound made by an overly excited orthopedic surgeon in the operating room nearby or inexperience crewmates performing incorrect procedure may contribute to reduced levels of concentration of a surgeon and these can be considered as threats. Moreover, overwork that causing fatigue and stress and surgeon's poor health condition can be considered as internal threats that affect human factor and limitations. Mismanaged operating treatment or failure to following standard operating procedure due to various factors that are stemmed from surgeon can be regarded as error. A sign of sudden drop in blood pressure and patient arrest are, in this case, considered as undesired aircraft states.

According to Fig 3, at the top of the inverted triangle is considered as safe operations. That is where the operation always strives to be; nonetheless, pilots and

surgeons experience several threats during their mission. Therefore, they should constantly be prepared for those threats to maintain a safe operation. In addition, apart from threat, several errors stemmed from pilots and surgeons can be anticipated. They need to instantly act accordingly to prevent further adverse event that will lead to undesired aircraft states and eventually accident.[62] Proper communication also plays an important role in TEM. It was regarded as Concerned, Uncomfortable and Safety (CUS) words. If surgeons hear another teammate says "I am concerned.", "I feel uncomfortable about this.", or "Patient safety is currently being compromised.", they should stop what they are doing and listen to address those concerns accordingly.

Fig 3. Threat and Error Management Model Adapted from United Airlines

All in all, both practical and theoretical concepts regarding safety can be summarized as shown in Table 1.

DISCUSSION

According to the four operational concepts and two theoretical concepts of aviation safety mentioned previously, it can be seen that there is one element that the concepts have in common, which is "communication". This finding shares the same insight corresponding with past research concerning the impact of communication in healthcare.[63-66] Therefore, even these aviation-related safety concepts might not be entirely applied to healthcare industry. Rest assured; effective communication is still be the key to promote better patient safety in healthcare environment. In regard to effective communication within team members, lead surgeons should lower their ego at work and listen to their team members even more. Even seasoned or highly-experienced surgeons can still be questioned regarding the operating problem at present and their resolution or problem-solving procedure should be explained to their teammates to ensure that the team is on the same page. Surgeons should not take team communication as the challenge to their authority but they should consider the effective communication as a better way to promote teamwork to ensure better patient safety. Another aspect relating to effective communication is briefings, pre-operative briefing is also important to promote patient safety. In aviation, pre-flight briefing is mandatory and this process is written in every company standard operating procedures (SOPs) as pre-flight briefing allows a clear understanding and awareness among flight crew about weather condition, planned flight route, passenger and cargo status and aircraft condition. Healthcare alike, pre-operative briefing regarding patient's status and planned operation procedures could allow a better understanding and awareness among team members at their mission. After finishing flight mission or operating procedure, post-flight debrief or post-operative debrief can be done to summarize overall mission scenarios. By debriefing, team members can be readily prepared for the next mission and apply experience from the past job to the next assignments.

As mentioned earlier, both aviation and health care are high-reliability fields; passenger safety must never be compromised, just as patient safety must never be compromised. That is to say, the margin of safety must never be diminished. Both pilots and surgeons must adopt these safety concepts together with effective communication skills and bring these important assets with them to the cockpit or operating room to ensure more reliability in their day-to-day operations to promote the utmost goal, which is safety at work.

CONCLUSION

This review article aims to portray aviation-related concepts that apply to surgical safety strategies. However, these concepts remain only partially applicable to healthcare. Even though a few of these operationalized concepts have been applied to surgical practice, none have been properly verified or validated. Past studies have claimed that these concepts could improve patient safety and operating outcomes, but there have also been various arguments that these concepts may not be totally compatible with healthcare.[67,68] At the very least, effective communication plays an important role to promote safety at work for both professions. Indeed, despite

TABLE 1. Summary of Practical Concepts and Theoretical Concepts in Safety.

Safety Concepts	Aviation Context	Healthcare Context	Similarities	Differences
Crew Resource Management (CRM)	- Two pilots, which are Captain and First Officer, work with Cabin Crew, Engineer and Air Traffic Controller within the flight mission.	- Surgeon works with Anesthesiologist, Anesthetist, Medical Technician within the operating room.	- Team working operates in high-risk environments. - Team members are skillful and professional and always change in difference tasks.	- Pilot-in-Command or Captain is responsible for absolute decision. - Disagreement needs to be solved by consensus from both surgeon and anesthesiologist.
Checklists	- Checklists are mandatory and any deviation from checklists is considered as a violation. - Checklists have been developed for each phase of the flight.	- Checklists are optional. - Surgical Checklists proposed by WHO can be edited to suite different interests of interventions.	- Checklists have been designed to suite different phrase or different progress of work.	- In aviation, checklists are mandatory. - In healthcare checklists are optional.
Readbacks	- A procedure whereby the receiving station repeats a received transmitted message or an appropriate part thereof back to the transmitting station to attain confirmation of correct reception.	- The person receiving information repeats it back verbally to the sender and the sender will know whether the message has been received correctly.	- The concept of “reading-it-back” to confirm the correctness and completeness of communication.	- In flight, readbacks are required as a transmission over radio frequency might not be clear due to radio noise and frequency interruption. - In healthcare, readbacks are encouraged in the critical phase of clinical communication to promote more patient safety.
Sterile Cockpit	- Flight crews keep the environment of a cockpit free from all non-relevant conversation during critical phases of flight.	- Operating crews encourage each other to regain a focus in a critical phase of procedure.	- The notion of “staying focus” on the critical phase of work.	- Flight deck is isolated and well-structured. - Operating room is less-structured than a cockpit with more distractions from both inside and outside
Human Factor: Fatigue	- Fatigue begins after a long flight hour.	- Fatigue begins after a long hour of clinical work.	- Fatigue degrades work performance.	- Flight duty time is regulated by law. - Management and surgeons need to set a middle ground on working hour.
Human Factor: Stress	- Stress is generated by continuous challenges at flight mission.	- Stress is generated by the operating task itself.	- Mild stress is acceptable but intensive stress will deteriorate work performance.	- Annually, every pilot needs to pass both physical and mental fitness examination before flight. - Physical and mental fitness examination is not required to perform duty in healthcare.
Swiss Cheese Model	- Four levels of failure can be poor SOPs, inadequate training, instrument failure and poor piloting technique	- Four levels of failure can be poor SOPs, insufficient training, poor operating tools technique, and improper operating skill	- Four levels of failure include organizational influence, unsafe supervision, preconditions for unsafe acts and unsafe acts.	- Aviation accident result in enormous loss of lives and assets and pilots pay it with their own life. - Failure in operating room cause a single loss of life.
Threat and Error Management (TEM)	- Threat: Bad weather, congested air traffic, technical failure. - Error: Poor piloting technique, cockpit mismanagement. - UAS: Improper airspeed, Failure to maintain glide path during approach.	- Threat: Improper procedure performed by inexperience teammate. - Error: Mismanaged operating treatment by surgeon. - UAS: A sign of sudden drop in blood pressure, patient arrest.	- Threat is considered as an external factor. - Error is regarded as an internal factor. - Undesired Aircraft States (UAS) is a result from threat and error and this considered as a last chance to correct to prevent future adverse event.	- In aviation, in spite of advance technology of aircraft computer, aircraft automation can be overridden by erroneous pilot. - In operating theater, error can be prevented by suitable communication between crews.

obvious similarities between these two professions, there are a number of differences as well. Besides, the implementation of aviation safety practices and concepts in the surgical context may be less than optimal. For example, pilots are required to conform to flight duty time strictly as this is regulated by law. Nonconformity to this rule and overworking as a pilot can be considered a serious safety violation; both the pilots and their airlines will be penalized accordingly. However, long working hours contributing to fatigue among healthcare professionals are not formally regulated by law. In this matter, hospital management and surgeons need to have a mutual agreement regarding the limits of working hours. Notwithstanding, the sound and solid safety record of aviation has been indisputable and proven itself for decades. These aviation safety concepts will continue to be a useful source of inspiration for any healthcare professional striving to achieve superior patient safety standards.

Limitations

Even though this review article shed light on novel aspects of aviation safety concepts into patient safety in healthcare context, there were some limitations. Because this article is a review article, future study should probably extend the concepts of this review into an experimental research to analyze the effect of those concepts on actual healthcare settings. Additionally, qualitative research may prove useful to investigate the real application of these concepts in actual healthcare context as qualitative study can delve deep down into richer results that quantitative research cannot find.

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