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Commentary and concepts

Applying lessons from commercial aviation safety and operations to resuscitation☆

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ABSTRACT

Both commercial aviation and resuscitation are complex activities in which team members must respond to unexpected emergencies in a consistent, high quality manner. Lives are at stake in both activities and the two disciplines have similar leadership structures, standard setting processes, training methods, and operational tools. Commercial aviation crews operate with remarkable consistency and safety, while resuscitation team performance and outcomes are highly variable. This commentary provides the perspective of two physician–pilots showing how commercial aviation training, operations, and safety principles can be adapted to resuscitation team training and performance.

1. Introduction

An increasing number of medical specialists[1–3] consider commercial aviation operations to represent a best practice model for safer, higher quality medical care. As physician–pilots who fly a prop-jet aircraft and are experienced in resuscitation, we would like to offer a unique perspective by showing how commercial aviation training, operations, and safety principles can be adapted to resuscitation team training and performance.

2. Similarities and differences between commercial aviation and resuscitation

Both commercial aviation and resuscitation are complex activities in which team members must respond to unexpected emergencies in a consistent, high quality manner. Lives are at stake in both activities and both disciplines have similar leadership structures, standard setting processes, training methods (including simulation), and operational tools (Table 1).

The similarities end there. Scheduled air carriers are so reliable that the odds of being killed in a crash are now 1 in 4.7 million flights[4] and fatalities per million flight miles have decreased 2000-fold since 1929.[5] Commercial aviation has accomplished this by instituting standard operating procedures that provide consistent performance regardless of who is on the crew and processes that decrease, trap, or mitigate simple human errors before they lead to tragedy. In contrast, there is marked variation in both in- and out-of-hospital cardiac arrest survival[6–14] and variation in code team performance (e.g., "code team errors") has been linked to a lower return of spontaneous circulation and survival rates.[15]

Commercial aviation culture focuses on safety, standardized operations, effective communication, use of checklists and other "tools", and consistent, structured team behavior ("crew resource management", also known as "CRM").[16–18] There is a defined expectation of quality and consistency, and consequences for not providing it. In resuscitation, we often tolerate wide variations in skill and team performance.

Pilots recognize that authorization to fly is a privilege – not a right – and compliance with all rules and operational procedures is required, unlike medicine where practitioners often "individualize care" rather than defining and applying best practice when such evidence-based guidance exists. Pilots recognize that their personal survival depends on consistent execution of correct procedures.

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Table 1
Similarities between commercial aviation and resuscitation.

	Aviation	Resuscitation
Person in charge	Pilot in command	Team leader
Lives at stake	Up to hundreds	1
Multiple phases	Yes	Yes
Didactic training	Flight school	BCLS, ACLS, PALS
Scenario-based training	Flight simulator	Code simulation
Standard setting organization	FAA, ICAO	AHA, ERC, ILCOR, etc.
Tools	Checklists	Algorithms

In contrast, resuscitation team member lives are not directly on the line. Pilots are trained to provide consistent, nearly reflexive responses in emergencies, whereas medical education tends to focus on the science behind decision making, strongly rejecting a "one size fits all" standardized approach. Flight crew members have clearly defined roles and can function effectively in collaboration with other crew members because they are trained to a consistent level of individual and team competence. Finally, there are strict requirements for maintenance of pilot proficiency that include periodic simulation training and check rides. Such requirements are infrequent in healthcare (one noteworthy, laudable exception in the United States is the Maintenance of Certification in Anesthesiology in which simulation is a required, integral component of board recertification).

3. Applying commercial aviation procedures to resuscitation

Resuscitation training materials and algorithms help code team members to follow a general sequence during resuscitation. Commercial aviation also uses didactic materials and logic flow, dictated in pilot operating handbooks that detail operating procedures (both normal and emergency) and provide checklists and aircraft/equipment limitations.

4. Briefings

Pilots are required to check weather, navigational aid status, aircraft equipment, airport conditions, and other relevant items prior to every flight. The counterpart in resuscitation would be requiring the team to check all resuscitation equipment, drug expiration dates, environmental issues (e.g., staffing levels of in-hospital healthcare providers, integrity of patient monitors that might signal a cardiac arrest, or first responder/ambulance availability in an EMS system, etc.) at the beginning of every duty shift.

Flight crews conduct briefings prior to every phase of flight to ensure that everyone is prepared to carry out their assigned duties during normal or emergency operations. Before an aircraft is cleared for takeoff, the flight crew briefs the procedure and runs through the precise actions that they will take if anything abnormal occurs. These practices can be adapted for use during resuscitation by, for example, having team members always brief what will be done prior to starting a procedure (e.g., insertion of an central line) and defining actions to be taken by team members should anything abnormal occur (e.g., hitting the artery instead of the vein or getting air return from the syringe signifying inadvertent lung puncture). Crew debriefings are also conducted immediately after every flight (as is increasingly the case in resuscitation).

5. Checklists

There are two types of checklists used in commercial aviation: "read-do" and "do-verify". Both are mandatory and employ a "challenge-response" format in which one team member calls out an item and the other checks/performs the function and verbally acknowledges its completion. "Read-do" checklists are used for "normal" procedures (e.g., preflight) that are not time critical. The resuscitation counterpart would be a checklist to verify contents of a code cart or equipment kit, or a checklist that an emergency department resuscitation team could use to verify all equipment is in place and ready prior to arrival of a cardiac arrest or trauma patient. The "read-do" checklist can also be used in resuscitation to direct sequencing of patient care. Table 2 is an example of a "read-do" checklist for pulseless electrical activity (PEA).

"Do-verify" commercial aviation checklists are used for emergency procedures (e.g., fire in the cockpit) in which the crew executes the first critical, stabilizing steps of a procedure from memory then uses their checklist to verify their initial actions and complete the remaining less time-critical items. An example of a "do-verify" checklist that for use in resuscitation is shown in Table 3.

6. Crosschecks

Crosschecks, processes by which one person independently verifies that an imminent decision or action by another is correct, play an important role in commercial aviation. If one assumes that humans will commit an error once every 1000 decisions or actions, having a second human crosscheck reduces the likelihood that neither will recognize the error to one in a million. This is why scheduled air carriers are required to have two person flight crews. Crosschecks should be used routinely by resuscitation team members to verify a correct drug and its dosage, confirm advanced airway placement, or for other critical actions.

7. Effective team size and the sterile cockpit rule

Many resuscitation events, particularly in large teaching hospitals, are performed with more healthcare workers and trainees than are needed, making it difficult for primary team members to communicate and function effectively. Imagine how challenging it would be for a flight crew to manage an in-flight emergency with onlookers crowded into the cockpit. Resuscitation teams must define the number of individuals with needed skills, and this should

Table 2
Example of a "read-do" PEA checklist.

Challenge	Response
Check oxygen and ventilation tubing circuit	Verify connected and delivering oxygen
Listen for breath sounds bilaterally	Verify present and equal bilaterally
Check neck veins	Verify collapsed or full
Perform limited bedside echocardiogram	Check for tamponade, poor LV function, collapsed (hypovolemia) or dilated RV (PE)
Perform 12-lead electrocardiogram	Check for acute myocardial infarction, hyperkalemia, evidence of drug toxicity (i.e., abnormal QTc interval)
Check blood sugar	Check for significant hyper/hypoglycemia
Measure core temperature	Check for profound hypothermia
Check medication history	Check for toxic drug/overdose
Send ABGs	Check for hypoxemia, acidosis

Table 3
An example of a "do-verify" checklist used by intensive care nurses when there is a sudden drop in oxygen saturation in a patient on a mechanical ventilator. Immediate "do" items are preceded by an asterisk (*).

Challenge	Response
*Pulse oximeter sensor & cable	Check attached to patient and monitor securely
*Ventilator alarms	Check for indicated cause of the problem
*Check oxygen and ventilation tubing circuit	Verify connected & delivering oxygen
*Capnography waveform on monitor	Check present or absent
*Rhythm, pulse, blood pressure on monitor	Verify if change causing decreased oxygen delivery to tissue.
*If oxygen saturation drop is not spurious and/or corrected after above actions	Disconnect ventilator tubing from ET tube, attach bag valve mask device running oxygen at FiO2 = 1.0, ventilate patient manually.
*Breath sounds	Immediate nurse check to evaluate ET tube placement, pneumothorax, bronchospasm, stacking
Ventilator	Turn off to avoid creating a dangerous oxygen-rich environment which can support combustion
Intensive care physician	Page to bedside stat
Breath sounds	Recheck by physician to evaluate ET tube placement, pneumothorax, bronchospasm, stacking
Respiratory therapist	Page to bedside stat
Respiratory therapist	Check for problem with mechanical ventilator

limit those allowed in the environment unless requested by the team leader.

Flight crews must follow the "sterile cockpit rule" which prohibits any flight crew member from engaging in any non-flight related activity or conversation during a critical phase of flight. All resuscitation personnel should be required to follow a similar "sterile code response rule".

8. Structured communication and read back

Commercial aviation communication is highly structured, concise, and precise, allowing crew members to anticipate what a controller will direct in a given phase of flight. Pilots must read back all critical ground or air traffic controller instructions correctly. Such structured communication and verification is infrequent in resuscitation. Scenario-based code simulation training presents an ideal opportunity to teach aviation communication procedures. For example, all drug verbal orders should be read back accurately by the provider carrying out the order. In addition, it would be not difficult to script an "identify and shock VF" sequence such as "stop CPR, check rhythm, resume CPR, charge, stop CPR, everyone clear, shock, resume CPR" that is performed the same way worldwide in an effort to minimize the pre- and post-shock pause intervals.

9. Crew resource management

Crew resource management (CRM) training prepares team leaders to make optimal use of all available resources – equipment, procedures and people – to promote safe, efficient operations and problem-solving in high risk environments.[19,20] CRM focuses on interpersonal communication, leadership, and decision making in a team environment and its use is mandatory in commercial and military aviation.

CRM principles provide an excellent framework for dealing with medical emergencies because they are "time limited, have complex and multiple sources of information, included multiple players, involve rapidly changing situations, and have high-stakes outcomes".[2] CRM dictates that everyone on a crew or team has not only a right but a responsibility to speak up. Crew/team leaders are taught to create an environment that encourages and rewards such behavior at all times. Pilots review their crew responsibilities with them as part of their preflight brief. A best practice is for the pilot/resuscitation leader to remind their team members that he or she, too, can make a simple human error and is relying on them to be vigilant and speak up immediately if they have a concern or suggestion.

10. The "two challenge rule"

In commercial aviation, there is a "two challenge rule" which allows a co-pilot or other crew member to act to correct a problem if he or she has tried twice to escalate the concern but it is not being acted upon because the pilot is distracted or incapacitated. The rule states that the co-pilot will assume control of the airplane if the pilot flying the plane does not respond appropriately after two callouts.[21] An adaptation of the two challenge rule can be used in resuscitation when procedures such as intubation are performed (e.g., a second "monitoring" provider can abort the procedure in favor of bag-valve-mask ventilation if two attempts to insert an endotracheal tube are unsuccessful).[2]

11. Human factors engineering design

Modern aircraft and their systems are designed to reduce the possibility of human error. For example, the landing gear lever is shaped differently and in another location than other control levers to minimize the risk that a pilot will land with the aircraft's gear up. In addition, there are audible and visible warning annunciators that can alert the pilots if the gear is not down and locked into position. Similar engineering should be used to design the interface of monitors and defibrillators, improving a device's "intuitiveness", reliability, and safety of use.

12. Using errors and near misses to enhance safety and efficiency

The Aviation Safety Reporting System (ASRS) in the United States (and its counterpart in other countries) collects, processes, and analyzes voluntarily-submitted incident reports from pilots, air traffic controllers, dispatchers, flight attendants, maintenance technicians, and others relating to unsafe occurrences and hazardous situations.[22] The ASRS is used to track and trend data from near-misses and accidents that can be used to improve commercial aviation training, procedures, operations, facilities, and equipment. Global system change in commercial aviation is based on near-misses as well as accidents, using the philosophy that "today's miss may be tomorrow's catastrophe".

A critical feature of this voluntary program is that it conveys limited immunity from civil penalty or certificate suspension, thus providing an incentive for individuals to submit reports.

Performance improvement systems are being used increasingly to track resuscitation outcomes for both in- and out-of-hospital cardiac arrest. A number of hospitals and healthcare systems in the United States are beginning to use anonymous web-based incident reporting tools similar to the ASRS. The Richmond Ambulance Authority has implemented a comprehensive safety program that makes extensive use of commercial aviation operations and safety principles, including an ASRS-derived model for self-reporting that allows tracking and analysis of "near miss" events.[23] Incident and trend data drive change in this EMS system's training and operational procedures, which have reduced incidents, vehicle collisions, and insurance premiums (the latter by 37%).

13. Conclusion

The above concepts are critical to keeping commercial air travel safe. A good way to appreciate how far we have to go in resuscitation to achieve similar consistency is to contrast how rarely airline passengers express concern whether their flight crew is qualified to get them to their destination safely compared to the variation we tolerate in the performance of our resuscitation teams. It is time for us to demand that our resuscitation systems take flight.

Conflict of interest statement

None.

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