Medical Guidelines for Airline Travel: Management of In-Flight Cardiac Arrest

Keith J. Ruskin; Eduard M. Ricaurte; Paulo M. Alves

INTRODUCTION: Although cardiac arrest during airline flights is relatively uncommon, the unusual setting, limited resources, and the variability of the skills in medical volunteers present unique challenges. Survival in patients who suffer a witnessed arrest with a shockable rhythm who are treated promptly has improved since the advent of widely available automated external defibrillators (AEDs). In general, the chances of survival from an out-of-hospital cardiac arrest (OHCA) are greater when ventricular fibrillation (VF) is seen as the initial rhythm or if there is return of spontaneous circulation (ROSC). Not all in-flight cardiac arrests are witnessed because cabin crew or fellow passengers might simply assume that the victim is sleeping. Based upon a review of the literature on resuscitation after OHCA, we recommend that automatic external defibrillators be carried on all commercial airline flights, regardless of duration. Patients presenting with shockable rhythm (e.g., VF, unstable ventricular tachycardia) have the best prognosis for survival and usually require diversion of the aircraft for advanced cardiac life support (ACLS). Because diversion may require interruption of cardiopulmonary resuscitation (CPR) and may impact flight safety, the volunteer rescuer, cabin crew, flight crew, and medical consultation services should discuss the possible outcome and operational considerations before recommending a diversion for a patient with a nonshockable rhythm. The recommendations in this article were developed by members of the Air Transport Medicine and Aerospace Human Performance Committees and approved by the Council of the Aerospace Medical Association.

KEYWORDS: cardiac arrest, resuscitation, CPR, ACLS, automated external defibrillator, in-flight medical emergency.

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Nearly 321,000 patients in the United States experience an out-of-hospital cardiac arrest (OHCA) each year, and approximately 60% are treated by emergency medical services. The median rate of survival to hospital discharge in patients with OHCA is 6.4%.[22] The increasing availability of automated external defibrillators (AEDs) has substantially improved survivability, especially in individuals who have a witnessed arrest, are found to have a shockable rhythm, and who receive bystander cardiopulmonary resuscitation (CPR) or advanced cardiac life support (ACLS). Although cardiac arrest during airline flights is relatively uncommon, it constitutes a specific subset of OHCA that presents unique challenges.[11] Even if an in-flight cardiac arrest is witnessed, resuscitation efforts are challenging because of the limited space available and variability of skills among rescuers. The amount of time required to divert to a suitable airport and perform an emergency descent even before the patient can be transported to a hospital exceeds transport times for OHCA that have been studied in other settings. Moreover, diverting a flight to an alternate airport for a medical emergency poses potential operational risks to the patient, rescuers, passengers, and crewmembers. This article will review outcomes after OHCA, the efficacy of resuscitation in the setting of shockable vs. nonshockable rhythms, and hazards associated with diversion due to a medical emergency. Specific recommendations for the use of AEDs, intravenous medications, and advanced airway management equipment will be offered.

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Initial Presentation and Survival

Survival in patients who suffer a witnessed arrest with a shockable rhythm and who are treated promptly has improved since the advent of widely available AEDs.[12] In general, the chances of survival from OHCA are greater when ventricular fibrillation (VF) is seen as the initial rhythm and if there is return of spontaneous circulation (ROSC).[26] The incidence of VF varies depending on the location of the patient at the onset of cardiac arrest; it is lower in private homes and higher in public spaces (e.g., casinos, airports). The higher rate of VF and improved survival after cardiac arrest in public places is thought to be because they are more frequently witnessed and treatment is initiated more rapidly. Conversely, a cardiac arrest in an apartment building or a private home, i.e., places in which residents do not spend extended periods in public areas, may not be recognized and treated as quickly. The chances of survival are highest when the interval from collapse to initial shock is less than 3 min.[29]

The presenting rhythm and whether it is shockable is an important determinant of survivability. Even if a patient with an OHCA who initially presents with a nonshockable rhythm converts to a shockable rhythm, the probability of survival remains low. In one study, 6556 EMS-treated adults with cardiac arrest presented with a nonshockable rhythm; 2.77% of patients who converted to a shockable rhythm survived to hospital discharge, while survival rate in patients who did not convert was 2.72%. The authors concluded that survival to hospital discharge was not associated with conversion to a shockable rhythm during EMS resuscitation efforts.[28] Another large systematic review found that conversion to a shockable rhythm from asystole, but not from pulseless electrical activity (PEA), was associated with prehospital ROSC and survival to hospital discharge, and that earlier conversion to a shockable rhythm was associated with higher odds of 1-mo favorable neurological outcome.[17]

Resuscitation of OHCA is one of the most challenging areas of prehospital emergency medical care and, as previously mentioned, the in-flight environment presents additional physiological and logistical challenges. Effective CPR is the best predictor of survival after OHCA with a nonshockable rhythm. One study of patients treated by a resuscitation team that included an anesthesiologist found that only 8.7% of patients treated for OHCA were discharged from the hospital alive.[8] A retrospective study of 394 cases of in-flight cardiac arrest in which an AED was used found that 24.6% of arrests were associated with a shockable rhythm. Of passengers with a shockable rhythm, 22.7% survived to hospital admission, as compared to 2.4% of passengers whose rhythm was not shockable.[1] The adjusted odds ratio for survival to hospital for the group with a shockable rhythm as compared to the group with a nonshockable rhythm was 13.6. The study found that odds for survival to hospital decreased with longer remaining flight time, but found no correlation between diversions and survival in patients with a shockable rhythm.[1] The authors suggested that effective CPR and early defibrillation are key factors in the survival of patients with an in-flight cardiac arrest. Moreover, effective CPR provides the best chances of survival after OHCA with a nonshockable rhythm.

There are several challenges to managing in-flight cardiac arrest that are specific to the in-flight environment. Many cardiac arrests on commercial flights are not witnessed. A passenger who loses consciousness while seated may often be thought to be asleep, delaying the diagnosis of a cardiac arrest. Cardiac arrest may also occur when the passenger is inside the lavatory. Patients who present with a shockable rhythm and receive care early in their presentation and in whom ROSC occurs may benefit from diversion as soon as feasible to a location where advanced medical care (e.g., ACLS) can be provided.[9,23]

Automated external defibrillators. The advent of AEDs was a significant advance in the management of OHCAs. AEDs are able to analyze the heart rhythm and an algorithm automatically identifies shockable vs. nonshockable rhythms by examining parameters such as the frequency, amplitude, and morphology of the electrocardiogram. Public access defibrillation (PAD) programs have been shown to increase survival from OHCA in different countries,[12] and rapid application of the AED improves survival in patients with OHCA.[18] Current goals for emergency medical technician first responders include a 1-min goal for application of an AED and a 90-s minimum standard for time to first shock in patients with OHCA.[3]

The adoption of AEDs by commercial airlines has closely followed those PAD initiatives. Flight attendants were identified by the American Heart Association as nontraditional first responders, who, like police officers, casino, and airport personnel, are more likely to respond to an OHCA. In the United States, Federal Aviation Administration (FAA) regulations require that AEDs be carried on airline flights (FAR 121.33), while the International Air Transport Association (IATA) recommendations allow each carrier to make an individual decision based upon the costs and benefits. The IATA does, however, recommend that airlines that equip their aircraft with an AED establish clear policies with respect to liability, maintenance, quality assurance, and training standards for AED use and CPR.[11] AEDs are now widely available on the majority of major commercial airlines. The effectiveness of AEDs is highlighted by one report that describes a 60-yr-old man who developed VF during a flight from Tokyo to Helsinki. A total of 21 shocks were administered for recurrent VF. The aircraft was diverted and when the local EMS crew encountered the patient (3 h after the initial event), the patient was again in VF and three additional shocks were administered. The patient eventually recovered, returning to his home country, fully alert, 3 wk later.[7] The authors therefore recommend that the AED be applied to an unresponsive passenger as quickly as possible, especially if cardiac arrest is suspected. The authors further recommend that the AED should remain attached to the patient and powered on if ROSC occurs after a successful shock, in order to minimize the time to shock for subsequent VF episodes.

Cardiopulmonary resuscitation. The most recent CPR guidelines were published by the American Heart Association in 2015. These guidelines call for the prompt initiation of CPR, although defibrillation should be attempted first if an AED is immediately available and the arrest was witnessed. Although

cabin crew are routinely trained and certified in CPR, an untrained rescuer (who may be the first to witness the arrest) can provide chest compressions without ventilation under the guidance of the ground-based in-flight medical consultation service. In an adult, chest compressions should ideally occur at the rate of 100 per minute with a depth of 5 cm (approximately 2″). If breaths are being given, the appropriate ratio is 2 breaths for every 30 compressions, with compressions being interrupted for no longer than 10 s.[13] The authors recommend that medical volunteers and cabin crew perform CPR in accordance with the most recent guidelines as published by the American Heart Association while following the instructions provided by the AED.

Advanced Management of OHCAs

Intravenous medication administration. There is a paucity of data to support the use of intravenous administration of medications in an OHCA. One systematic review found that high-dose epinephrine and standard-dose epinephrine improved the rates of ROSC and survival to hospital admission, but not survival to discharge or neurological outcomes.[16] In one study, patients with nontraumatic OHCAs were randomized by ambulance personnel to receive either ACLS including intravenous drug administration or ACLS without intravenous drugs. Patients who were randomized to resuscitation without an intravenous drug administration received intravenous access 5 min after ROSC, with drugs then given as indicated. A total of 851 of 1183 patients were included in the study. Of patients in the intravenous drug administration group, 10.5% survived to hospital discharge, while 9.2% of patients who did not receive intravenous drugs survived. Of patients who received drugs, 9.8% survived with a favorable neurological outcome, while 8.1% of patients who did not receive drugs experienced a similar outcome. Of patients who received drugs, 10% vs. 8% of patients who did not were alive at 1 yr.[25]

The role of antiarrhythmic agents in OHCA has also been questioned. In a large systematic review and network meta-analysis, amiodarone and lidocaine were associated with improved survival to hospital admission, but neither antiarrhythmic was superior to placebo for survival to hospital discharge or neurologically intact survival.[19] Endotracheal administration of drugs appears to have little effect on the survival of patients with an OHCA. In a study of patients with an OHCA, medications were given either intravenously or through an endotracheal tube at twice the intravenous dose. Drugs administered through the endotracheal tube during cardiac arrest and CPR were found to have no benefit. No patient who received endotracheal drugs survived to hospital discharge.[24] However, ACLS guidelines call for the use of intravenous medications and their use might also enable a select group of patients to survive to hospital admission. It therefore seems reasonable to include them in the in-flight emergency medical kit. Rescuers should ensure that efforts to obtain intravenous access and administer drugs do not compromise the quality of chest compressions.

Advanced airway management. ACLS training includes airway management with bag-valve-mask ventilation and advanced techniques such as endotracheal intubation. Although many healthcare providers are trained in airway management, there is little data to support including equipment such as laryngoscopes, endotracheal tubes, and laryngeal mask airways in onboard emergency medical kits. The majority of currently published studies do not support the use of advanced airway management equipment in out-of-hospital cardiac arrest. In fact, some studies show a negative correlation between advanced airway management and survival,[6,20] although there is a possibility that advanced airway management might be associated with either difficult ventilation or more serious disease, which could in turn lead to a poorer outcome. If so, these results might not necessarily reflect a cause and effect relationship.

Advanced airway management in the setting of in-flight cardiac arrest probably does not improve outcome and may be associated with worse outcome. One study analyzed a multicenter database of prehospital resuscitation to determine the effects of endotracheal intubation, a supraglottic airway, or no advanced prehospital airway management.[20] In a total of 10,691 patients with OHCA, the rate of neurologically intact survival was 5.4% in patients who received endotracheal intubation, 5.2% in patients who received a supraglottic airway, and 18.6% in patients who received no advanced airway management. The authors concluded that their results support the value of emphasizing CPR continuity, but caution against the generalization of their findings to all patients. Potential reasons for the superiority of endotracheal intubation in this study included the possibility that the use of a supraglottic airway may act as a marker for a failed endotracheal intubation. Moreover, the survival differences were limited to patients with an initially shockable ECG rhythm.

Another prospective, observational study of 37,873 cardiac arrests found that both epinephrine administration and advanced airway management were associated with reduced long-term survival. The adverse effect of advanced airway management on survival was not changed by its timing (i.e., early or late in the resuscitation process). The resuscitation personnel in this study were experienced paramedics who received both classroom and practical training, and who were required to complete 30 successful endotracheal intubations in the operating room under the supervision of anesthesiologists.[6] Although the study did not address airway management by rescuers without specific training, it seems reasonable to assume that less-experienced personnel who attempt advanced airway management will have even worse outcomes.

Laryngeal mask airways have been proposed as an alternative airway management technique in OHCA, but there is a paucity of data to support their use in the setting of in-flight cardiac arrest. One such study found that while 100% of anesthesiologists could correctly insert a laryngeal mask airway into a manikin on the first attempt, only 35% of personnel without medical training could do so.[15] One small study found that 79% of untrained first responders were able to ventilate a manikin when given an instruction card and a specially labeled supraglottic airway (SGA).[27] In one of the largest such studies in a clinical setting, a total of 615 patients were recruited and

randomized to two types of SGAs or endotracheal intubation (the standard practice). Paramedics received structured training in the use of two different SGAs before patient recruitment. The primary outcome of this study was to determine the feasibility of a larger study, while secondary outcomes included survival to hospital discharge and 90 d. The SGA arm was terminated early for safety reasons after three adverse events occurred (ejection of gastric contents onto the rescuers). There was no difference in survival, neurocognitive function, or quality of life between patients who received a SGA device or endotracheal intubation during resuscitation after OHCA.[2] At the present time, there is little data to determine the likelihood that a first responder would be able to successfully ventilate a patient with a SGA after an in-flight cardiac arrest.

Many physicians who respond to an in-flight cardiac event and request the emergency medical kit may not know how to intubate the trachea or how to insert a SGA. An inexperienced rescuer may, however, feel pressured to attempt advanced airway management, interrupting chest compressions or possibly causing harm to the patient. The employment of advanced airways might pose additional problems: after the airway is secured, a system to reliably ventilate a patient is required, as would be sufficient oxygen to keep the fraction of inspired oxygen (F_IO_2) in an appropriate range for the duration of the transport. All of this equipment would have to be moved to the patient's location or would require the movement of an unstable patient to the equipment's location, potentially requiring that CPR be suspended. However, current ACLS guidelines call for advanced airway management if trained personnel are present. Endotracheal intubation might also enable a select group of patients to survive to hospital admission. It therefore seems reasonable to attempt airway management only if an experienced rescuer is present, the equipment is readily available, and doing so would not interrupt chest compressions.

Termination of Resuscitation

Multiple studies have demonstrated that resuscitation may be terminated after specific criteria have been met. The Universal Termination of Resuscitation Guidelines suggest that attempts at resuscitation should be terminated if, after at least four 2-min intervals of cardiopulmonary resuscitation, three criteria are met:

1. The arrest was not witnessed by emergency medical services;
2. ROSC has not occurred; and
3. No shocks were delivered.

Morrison et al. evaluated a clinical prediction rule that allows rescuers to consider the termination of resuscitation if there is no ROSC, if the patient has not received any shocks before transportation was initiated, and if the cardiac arrest was not witnessed by EMS personnel. They found that the prediction rule had a positive predictive value of 99.5% and a specificity of 90.2%.[21] In addition to the futility of using limited resources to treat a patient who has little chance of surviving the event, the authors concluded that a "lights and sirens" rescue carries risks not only for the rescuers but for motorists and pedestrians. They also cite the risks to the EMS personnel, who may be subject to biohazards such as needle stick injuries. Drennan et al. studied the Universal Termination of Resuscitation guideline and found that 9467 out of 36,543 patients were transported to the hospital without ROSC after an OHCA. Among the survivors with good neurological outcome in this study, 90% had ROSC by 20 min and 99% by 37 min. Of patients who met the guideline for transport, 3% survived, as compared to 0.7% who met the Universal Termination of Resuscitation Guideline for termination.[4] These recommendations form the basis of the IATA guidelines, which state that if resuscitation efforts have been continued for at least 30 min after the last shock was delivered without ROSC the passenger may be presumed dead and continuing resuscitation efforts may be futile.[10]

Levine et al. studied the role of end-tidal carbon dioxide ($P_{ET}CO_2$) in predicting outcome after cardiac arrest.[14] They found that an $P_{ET}CO_2$ of less than 10 mmHg measured after 20 min of ACLS predicted death with 100% sensitivity, specificity, positive predictive value, and negative predictive value. Although capnographs are not currently included in emergency medical kits, small, battery-powered devices are commercially available. The authors suggest that the utility of capnography to guide in-flight resuscitation and the feasibility of including capnographs as part of the emergency medical kit be considered as future topics of research.

Large, well-designed studies have shown that there is little possibility of a good neurological outcome in patients without ROSC who meet the guidelines for termination of resuscitation. Given that the Universal Termination of Resuscitation Guidelines are widely applied in other OHCAs, the authors recommend that attempts at resuscitation be discontinued if ROSC has not occurred after 30 min of CPR.

Flight Diversion

Diversion of a commercial flight to an unscheduled destination for a medical emergency is a potential hazard that requires balanced consideration of operational risk as well as the medical problem. The decision to divert the aircraft is ultimately made by the pilot in command, who will almost always consult with ground-based medical consultation services and onboard medical volunteers. Factors in this decision include the potential medical benefit to the patient, including the patient's medical condition and acuity, the ability to stabilize the patient's condition with onboard medical equipment and expertise, the amount of flight time that will be saved by diverting, and the proximity and nature of medical resources at the diversion airport. This decision must be balanced with attention to operational factors, including airline practices, weather, fuel load, and the potential need to dump fuel (or perform an overweight landing). Additional considerations include the availability of specific aircraft services at airports and logistical issues such as air traffic control and diplomatic landing rights. The decision to divert, therefore, requires that the condition of the individual patient be balanced against his or her odds of survival and the safety of the other passengers and crew.

The goal of diverting a flight in the scenario of an in-flight cardiac arrest is to expedite access to advanced medical care. However, reduced transport time to ACLS in OHCA was not shown to improve survival to discharge as shown by a recent meta-analysis and systematic review.[5] The most detailed study of in-flight cardiac arrest did not find evidence that diversion was associated with an improved outcome after cardiac arrest, but did find that longer flight duration was associated with a worse outcome.[1] If ROSC occurs, it seems reasonable to divert the flight as soon as practicable, in order to facilitate escalating the level of care available to the patient. If, however, ROSC has not occurred despite 30 min of CPR after the last shock was delivered, the passenger may be presumed dead and both diversion and continuing resuscitation efforts may be futile. Under those circumstances it is reasonable to speculate that the risks associated with a diversion may outweigh the benefits to all involved. A decision to divert for a nonshockable rhythm entails the need to continue performing effective CPR during an emergency descent and landing at an airport that may be unfamiliar to the flight crew. Interruption of CPR ensures a fatal outcome, but continuing CPR requires that crewmembers or volunteers remain in an aisle, unsecured by a seat belt during landing. The presence of the patient will also obstruct the exit path in the event that an emergency evacuation is required due to a landing accident. In any event, the decision to divert should be made in conjunction with ground-based medical consultation services in order to assure the best outcome for the patient while minimizing the potential impact on flight safety.

Documentation

The volunteer rescuer is encouraged to take notes on the sequence of events, including how and when the cardiac arrest occurred (i.e., time and date), airline and flight number, seat location, personnel who were involved in the resuscitation, history (if available), physical findings, shocks delivered by the AED, duration of CPR, and any other interventions (e.g., airway management, intravenous access, and drugs administered). The rescuer should also document whether a decision was made to divert and when the patient was handed off to EMS.

Conclusions

Although cardiac arrests on commercial flights may be witnessed by passengers or cabin crewmembers who are trained in the administration of CPR, early recognition is not always possible, resulting in a delay before resuscitation attempts are initiated. The AED should be used to determine whether a shockable rhythm (e.g., ventricular fibrillation, ventricular tachycardia) is present. As long as the cardiac rhythm is shockable as determined by the AED, attempts at cardiac resuscitation should continue.

If the AED indicates that the presenting rhythm is not shockable (i.e., PEA), this suggests that resuscitation attempts will be futile. Current recommendations call for 30 min of CPR for cardiac arrest with a nonshockable rhythm or absence of ROSC. Given that 30 min or longer would likely be required to find a suitable airport and land an aircraft that is flying at cruising altitude, there are no good data to suggest whether the aircraft should immediately initiate a diversion or wait until CPR has been performed for 30 min. This decision should factor in both the remote possibility of a good outcome and the potential impact on flight safety. Given the fact that emergency diversions pose operational risks, we recommend that previously established criteria that have already been established for not transferring a patient to the hospital and for termination of resuscitation for out-of-hospital cardiac arrests be adopted for passengers on board commercial aircraft.

Given the lack of data to support these techniques, we recommend that emergency medical kits continue to include a self-inflating bag, masks, and oral airways to facilitate ventilation. Although the results of several studies suggest that advanced airway management does not improve outcome after OHCA, the decision to include equipment such as laryngoscopes, endotracheal tubes, and SGAs should be left to individual airlines. We further suggest that more studies should be undertaken in order to determine the utility of advanced airway management in the setting of in-flight cardiac arrest. The authors strongly recommend a systematized way to better capture data points that may guide research in this important area and ultimately improve the outcome of passengers with in-flight cardiac arrest.

Recommendations. AEDs should be available in all commercial flights regardless of duration. The AED should be applied as soon as possible after a passenger is found to be unresponsive. The AED should remain attached to the patient and powered on if ROSC occurs after a shock.

Because patients presenting with shockable rhythm are associated with a better prognosis for survival, a diversion of the aircraft is usually recommended.

Patients presenting with nonshockable rhythms carry a poor prognosis. Careful consideration is therefore warranted before recommending a diversion, which could impose an unacceptable level of risk to the safety of flight. Diversion may also interfere with the quality of CPR, which is the primary factor determining favorable outcome for this subgroup.

Attempts at resuscitation should be discontinued if the patient presents with a nonshockable rhythm and ROSC has not occurred after 30 min of CPR.

The authors strongly recommend a systematized registry that can better capture data on in-flight events. This may improve the care of passengers who succumb to this potentially fatal event.

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