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# In-flight automated external defibrillator use and consultation patterns

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## Abstract

**Background—**Limited information exists about the in-flight use and outcomes associated with automatic external defibrillators (AED) on commercial airlines.

**Methods—**We collected self-reported cases of AED use to an airline consultation service from three US airlines between May 2004 and March 2009. We reviewed all available data files, related consult forms, and recordings. For each case, demographics, initial rhythm, shock delivery/success, survival to admission, and ground medical consultation use were obtained. Success was defined as the return of a perfusing rhythm. Initial rhythms were classified as: sinus, heart block, SVT, atrial fibrillation/flutter, asystole, PEA and VF/VT.

**Results—**There were a total of 169 AED applications with 40 cardiac arrests. The mean ages were 58 years (SD 15) and 63 years (SD 12) respectively; both populations were 64% male. AEDs were applied for monitoring in 129 (76%) cases with initial rhythms of: sinus 114 (88%); atrial fibrillation/flutter 7 (5%); complete heart block 4 (3%); and SVT 4 (3%). Presenting rhythms among the cardiac arrest population were: asystole 16 (40%); ventricular fibrillation/ventricular tachycardia 10 (25%); and PEA 14 (35%). Fourteen patients were defibrillated including nine of the 10 patients with initial VF/VT and five for the presence of VF/VT after resuscitation for initial PEA/asystole. Defibrillation was advised but not performed in the remaining case of initial VF/VT and no medical consult was obtained. All five successful defibrillations occurred in patients with initial VF/VT. There were 6 (15%; 95% CI 3–27%) survivors with 5 occurring after successful defibrillation for initial VF/VT and one with return of a perfusing rhythm after CPR for a junctional rhythm. Survival in those with VF/VT was 5/10 (50%; 95% CI 14–86%). Medications were delivered twice. The median time to first shock was 19 (IQR 12–24) seconds from AED application. Medical consultation was obtained in 56 (33%) of the 169 AED cases and 14 (35%) of the cardiac arrests.

**Conclusion—**AEDs resulted in 50% survival among those with VT/VF in-flight and 14% overall survival for cardiac arrest. Survival is poor among patients presenting with non-shockable rhythms. AEDs are used extensively for in-flight monitoring with significant rhythms identified. Ground medical consultation is sought in only one-third of AED uses and cardiac arrests.

## Introduction

Sudden cardiac arrest remains a leading cause of death in the United States and throughout the world.[1] Early defibrillation including the early use of automatic external defibrillators (AEDs) by both emergency responders and trained lay persons produced improved survival in out-of-

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hospital cardiac arrest.[2,3,4] Hallstrom postulates that early automatic defibrillation becomes more imperative during situations in which trained emergency personnel or advanced care with defibrillation capabilities are not immediately available such as during airline flight or in rural areas.[5]

These findings led the Federal Aviation Administration (FAA) to mandate as part of its 2001 safety guidelines that by 2004 all commercial airlines carry AEDs and train personnel in their use.[6] During early airline implementation studies, AEDs were properly discharged for almost all cases of ventricular tachycardia (VT)/ventricular fibrillation (VF) resulting in approximately 33–55 percent survival to hospital discharge among the 22–51 percent of patients with an initial VT/VF.[7,8] These studies included cases of cardiac arrest occurring while at the boarding gate as well as in-flight. In addition, AEDs were often used for monitoring with limited discussion of this use. Ground medical consultation during these trial periods was highly regimented based on extensive study protocols. Since the mandate of airline AED use in 2004, there has been one previous European case series of 12 in-flight cardiac arrest patients performed following a company wide training program.[9] Besides this case series, current data in the literature comes only from implementation trials with a highly protocolized approach, possibly altering the reported effectiveness of this intervention and utilization of ground medical consultation during AED use.

This investigation serves to describe the characteristics and outcomes of AED use during in-flight emergencies including in-flight cardiac arrest. Unlike previous investigations, we describe cardiac arrest outcomes during routine AED use rather than during research protocols. Finally, we attempted to describe ground medical consultation patterns among reported medical cases in which AEDs were used as little is known about medical consultation patterns during medical emergencies.

## Methods

We collected all self-reported in-flight cases of AED use to an airline industry ground consultation service between May 2004 and May 2009 for two airlines (airline 1 and 2). Data was collected from a third major carrier (airline 3) between August 2008 and May 2009, coinciding with ground medical consultation contracts. The ground medical consultation service provided information on patient care as well as advice in regard to the need for diversion. The reporting of cases to the medical consultation service was not mandatory and asked for as part of a quality improvement measure. Flights included both domestic and international flights. All submitted AED data files, patient/clinical information sheets, and related medical consult forms. Cases were deemed a cardiac arrests if the AED demonstrated a rhythm compatible with cardiac arrest and the patient was unconscious. In cases where the medical consultation service was contacted, routine follow up included determination of hospital admission and discharge. Recordings were collected and reviewed by members of the research team. For each case of self-reported AED use the age, sex, presenting rhythm/end rhythm, purpose of use (monitoring/cardiac arrest), shock delivery and timing, shock success, and survival to hospital admission were extracted. There were no data available for survival to hospital discharge. All data were entered into a spreadsheet for tabulation and calculation of descriptive statistics (Microsoft Excel, 2004, Redman, WA). A second pre-existing database of all in-flight airline ground medical consultations was cross-referenced with the self-reported AED cases to determine the use of the consultation service among the reported cases of AED use. The database of all ground medical consultations also denoted the use of AEDs for each call and this information was used to determine if all AED cases in which a consult was obtained were self-reported.

All airline personnel had required current American Heart Association Basic Life Support training including application and use of AEDs. There were no specific protocols for ground medical consultation or assistance from medically trained passengers. Once the airlines contacted the ground medical consultation service they were put in contact with a board certified emergency medicine physician for consultation. Airlines 1, 2 and 3 all used models of Philips Heartstream AEDs. All airlines had resuscitation medications including epinephrine, atropine, oxygen, and intubation equipment available should a medically trained passenger deem their use necessary.

Ages were repoted as means with standard deviations, while time to defibrillation was reported as median with interquartile range (IQR). Nominal variables were described using prevalence numbers with percentages.

This study was exempt from review by the University of Pittsburgh Institutional Review Board because it was deemed a quality assurance review of de-identified pre-existing data.

## Results

### Patient Characteristics

During the consultation and collection period there were a total of 169 in-flight AED applications with 40 occurring in patients found to be in cardiac arrest. The mean age for all AED uses was 58 years (SD 15) and 63 years (SD 12) for those in cardiac arrest. Both populations were 64% male.

### Cardiac arrest presentation and outcome

Presenting rhythms among the 40 patients with in cardiac arrest were: asystole 16 (40%); ventricular fibrillation 7 (17%), pulseless ventricular tachycardia 3 (8%); and PEA 14 (35%). A total of fourteen patients were defibrillated. One patient was defibrillated 3 times during the resuscitation and all others once. Nine of the 10 patients with initial VF/VT received defibrillation. Five patients received defibrillation after conversion to VF following resuscitation from initial PEA/asystole. There were no inappropriate shocks delivered. Defibrillation was advised but not performed in the remaining case of initial VF (10%) and defibrillation was advised 3 times and delivered only once in an additional case with initial PEA that later converted to a shockable rhythm. No medical consult was sought in either case and a passenger physician was present for the second case. All five successful defibrillations with return of spontaneous circulation (ROSC) occurred in patients with initial VF/VT. There were 6 (15%; 95% CI 3–27%) survivors to hospital admission among the cardiac arrest population with 5 occurring after successful defibrillation for initial VF/VT and one with return of a perfusing sinus tachycardia rhythm after 7 minutes of CPR for an initial junctional rhythm. Therefore, survival to hospital admission in those with VF/VT was 5/10 (50%; 95% CI 14–86%) and there were no survivors in the 21 patients with initial idioventricular rhythm or asystole (0%). Medications were delivered in two cases. The median time to first shock was 19 seconds (IQR 12–24) from AED application for patients with an initial shockable rhythm.

### AED use for monitoring

AEDs were applied for monitoring in 129 (76%) cases with initial rhythms of: sinus mechanism 115 (89%); atrial fibrillation/flutter 7 (5%); complete heart block 4 (3%); and SVT 3 (2%). AEDs were applied for the following known passenger complaints: shortness of breath, chest pain, dizziness, convulsions, diaphoresis, palpitations, and confusion. None of the patients with the AED applied for monitoring received an inappropriate shock and there were no reported in-flight deaths. There were two reported deaths prior to hospital discharge for patients presenting with sinus tachycardia and complete heart block.

### Ground Medical Consultation

In-flight medical consultation was obtained in 42 (33%) of the 129 reported cases when the AED was used as a monitor and 14 (35%) of the 40 reported cardiac arrests. Following successful resuscitation for cardiac arrest, the ground medical consult service was contacted in two of the six cases (33%). The consult service was contacted on 7 of the 15 patients (47%) with non-sinus rhythms on monitoring. The ground medical consult service was not contacted for 2 cases of complete heart block, 4 cases of atrial fibrillation/flutter, and 2 cases of SVT. Medical consultation recommended diversion for one case of complete heart block and one case of atrial fibrillation due to symptoms and distance to final destination. During the same period of the 169 reported AED uses, the airlines contacted the ground consultation service for 131 cases in which an AED was used. Only 56 of the cases overlapped between the two databases suggesting a significant under-reporting of cases in which an AED was used as well as a lack of consultations on many AED cases.

## Discussion

This descriptive study of self-reported AED cases confirmed previous reports that AEDs are used effectively during in-flight emergencies by delivering appropriate shocks to patients in VF/VT. In addition, the median time from application to defibrillation in patients with initial VF/VT was 19 seconds. This resulted in an approximate 50% survival to hospital admission for the reported in-flight cardiac arrest with the initial rhythm of VF/VT. The exact point estimate of survival should not be the focus of this investigation as it is the result of only self-reported cases. However, it can be concluded the AEDs were used effectively and resulted in the establishment of a perfusing rhythm in the patients presenting with VF/VT. Despite the possibility of selection bias in this self-reported sample of cardiac arrests, the reported routine effectiveness of AEDs is consistent with prior trials in multiple settings and produced what would be expected results based on the circumstances. The survival rate is consistent with previous reports of survival from in-flight cardiac arrest; however, we report survival to admission rather than discharge. Therefore, the true survival rate may be lower than previous research based in-flight reports. The overall survival to admission is lower, as expected, than for cardiac arrests with the presence of an AED in other locations such as casinos or airports.[3,4,10] The percent of patients presenting in VF/VT (25%) is notably lower in this in-flight study compared to those in the casino (71%) and airport terminal (86%) settings, likely contributing to our lower overall survival from cardiac arrest. Previous airline studies have found the rate of VF/VT to be 22% and 38% percent; however, the latter includes cases of witnessed arrest in the terminal near the boarding gates, which likely increased the rate of VF due the increased awareness and likelihood of quick response in this setting.[7,8] On board aircraft persons are often sleeping or resting making an acute collapse much less obvious compared to the terminal or casino, therefore leading to a longer time to recognition and higher degradation of potentially shockable rhythms to asystole/idoventricular rhythms.

In this study as well as in previous studies presenting rhythm during in-flight cardiac arrest appears to be of paramount importance for survival. Among those with PEA or asystole as a presenting rhythm survival remains poor with only one survivor among the 30 patients (3%) who had a non-perfusing junctional rhythm. There were no survivors among patients with asystole/idoventricular rhythms. These numbers are similar to the other large airline AED reports with no reported survivors without initial shockable rhythms. In this report there were several patients with initial PEA/asystole that converted to VF; however, resuscitations in these patients were ultimately all unsuccessful emphasizing the importance the discovery of patients with initial VF/VT. This is contrast to EMS based studies that show similar overall survival to admission, but improved survival for initial PEA/asystole due to more advanced care but lower survival from VF/VT due to less witnessed arrests and immediate availability of defibrillation.

[11] The performance and quality of CPR in these cases is unknown and may have impacted survival.[12,13] The importance of early defibrillation in austere medical environments (during flight) is likely related to limited advanced care, prolonged time to hospital transfer, and sub-optimal resuscitation conditions. Strategies to enhance survival should include the use of monitoring in patients presenting with concerning symptoms, use of quality CPR prior to defibrillation in cases of unwitnessed arrest and early application of the AED in all patients with loss of consciousness.

It would also be useful to further investigate the medical training of responders using AEDs to determine the value of flight crew training and if AED training should instead be aimed at other populations. For instance, there were several patients with complete heart block in this study and a pacing feature may have been useful in this select population; however, it is likely that this is beyond the training of most in-flight responders. Importantly, the goal need not be to produce a flying hospital, and as evidenced by the low use of medications in this study, it is unlikely the responders would use more advanced tools if available.

The role of ground medical consultation during in-flight cardiac arrest is likely limited as care should focus on early defibrillation and quality CPR. Medical consultation should likely be obtained once a perfusing rhythm has been established or in cases of prolonged resuscitation. Previous reports have suggested that physicians are available in approximately 70% of commercial airline cardiac arrests;[8] however, their subspecialty training can be variable. In this study, ground medical consultation was sought in only one-third of the post-cardiac arrest patients. The flight crew may have sought out the closest medical facility; however, it is unclear who were involved in making decisions during the post-arrest care. In addition, there were multiple patients with abnormal rhythms during monitoring in which no medical consultation was obtained. The decision of diversion involves multiple factors that should be made by medical professionals familiar with both air transport and its unique medical environment. For example, some abnormal rhythms may not be new and not require diversion while others require emergent intervention. Moreover, many physicians are unfamiliar with the current complement of medications carried on airlines and some may be unfamiliar with their clinical use if not used in their practice. In general, the training of those making ground medical consult decisions should include understanding of the capabilities and resources available to the crew, the benefit of expedited transfer to a medical facility for the involved condition, and the risk/cost involved in the decision to divert the specific aircraft.

One strategy for the management of cardiac arrest patients in flight is the immediate diversion to the closest airport. However, evidence suggests that at the current time diversion for patients presenting with non-shockable rhythms may be futile., aircraft diversion includes additional risks including: emergent landings, potential need to dump fuel, landing with overweight aircraft, altered flight patterns, landing in poor weather, and landing in unfamiliar conditions. With cost estimates of $15,000 to as high as $893,000 per diversion, this is not only a clinical question but also an important safety and financial decision.[14] The effect of ground medical consultation on diversions is currently unknown, but does have the potential to limit diversions in cases where no significant change in clinical condition or outcome would result. Should it be found that diversions could be avoided with consultation, then our observed under utilization of ground medical consultation would become an important issue with respect to diversion as well.

It is also unclear if the use of ground medical consultation currently improves outcomes for in-flight cardiac emergencies. The usefulness of ground medical command is somewhat limited by the lack of information available to the consultant. The use of the AED as a monitor can provide the medical consultation service with valuable information and should certainly be relayed to aid in educated medical decisions. Future models of AEDs should provide uplinks

that can provide consultants with ECG printouts for symptomatic passengers facilitating better treatments decisions and remote activation of services such as cardiac catheterization.

### Limitations

This is a retrospective descriptive study. No causal relationships can be drawn between consultation patterns, AED use, resuscitation efforts, or responder decisions and outcomes. The investigated cases are likely the result of selection bias as they represent only the self reported uses of AEDs. However, our survival rate of 50 percent among patients with VF/VT and low percentage of VF/VT is consistent with previous reports that consisted of all in-flight AED uses during implementation periods. This suggests limited effect on the results of the self-reporting and there was likely not an over reporting of successful cases. Notably, there was no specific protocol for medical consultation or AED use in conscious patients. Thus, we believe these data represent current practice patterns for most US commercial airline carriers. For those requiring inpatient care, hospital discharge data is limited for many cases as ground medical consults were not obtained in 2/3 of cases, thus preventing the consultation service from obtaining follow-up. In addition, the data reporting was limited for patient presenting symptoms, use of CPR, medication administration, and responding parties during flight.

## Conclusion

AEDs resulted in 50% survival among those with VT/VF in-flight. Survival is poor among patients presenting with non-shockable rhythms. AEDs are used extensively for in-flight monitoring with significant rhythms identified. Ground medical consultation is sought in only one-third of AED uses and cardiac arrests.

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