Prognostic Factors for Outcomes of In-Flight Sudden Cardiac Arrest on Commercial Airlines

Paulo M. Alves; Charles A. DeJohn; Eduard M. Ricaurte; William D. Mills

BACKGROUND: In-flight cardiac arrest (IFCA) is a relatively rare but challenging event. Outcomes and prognostic factors are not entirely understood for victims of IFCAs in commercial aviation.

METHODS: This was a retrospective cohort study of airline passengers who experienced IFCA. Demographic and operational variables were studied to identify association in a multivariate logistic regression model with the outcome of survival-to-hospital. In-flight medical emergencies were processed by a ground-based medical center. Subsequent comparisons were made between reported shockable-rhythm (RSR) and reported non-shockable-rhythm (RNSR) groups. Logistic regression was also used to identify predictors for shock advised and flight diversions using a case control study design. Significant predictors for survival-to-hospital were RSR and remaining flight time to destination.

RESULTS: The percentage of RSR cases was 24.6%. The survival to hospital admission was 22.7% (22/97) for passengers in RSR compared with 2.4% (7/297) in the RNSR group. The adjusted odds ratio for survival-to-hospital for the RSR group compared to the RNSR group was 13.6 (5.5–33.5). The model showed odds for survival to hospital decreased with longer scheduled remaining flight duration with adjusted OR = 0.701 (0.535–0.920) per hour increase. No correlation between diversions and survival for RSR cases was found.

CONCLUSIONS: Survival-to-hospital from IFCAs is best when an RSR is present. The percentage of RSR cases was lower than in other out-of-hospital cardiac arrest (OHCA) settings, which suggests delayed discovery. Flight diversions did not significantly affect resuscitation outcome. We emphasize good quality cardio-pulmonary resuscitation (CPR) and early defibrillation as key factors for IFCA survival.

KEYWORDS: cardiopulmonary resuscitation, defibrillation, heart arrest, survival.

Alves PM, DeJohn CA, Ricaurte EM, Mills WD. *Prognostic factors for outcomes of in-flight sudden cardiac arrest on commercial airlines.* Aerosp Med Hum Perform. 2016; 87(10):862–868.

Recent data of the incidence and case-fatality rate of EMS (Emergency Medical Services) assessed out-of-hospital cardiac arrest (OHCA) suggest that each year almost 321,000 adults experience an OHCA in the U.S., most of which are cardiac in origin.[20]

In general, the chances of survival from OHCA are greater when the initial rhythm is ventricular fibrillation (VF). The incidence of VF varies depending on the location where the cardiac arrest occurs, being lower in private homes and higher in public spaces.[31]

Over 700 million people travel on commercial airlines each year in the U.S. alone. It is estimated that around 3.3 billion passengers fly every year world-wide and the International Air Transport Association (IATA) projects a 4.1% yearly growth.[16] Estimates of in-flight deaths aboard commercial airlines vary between studies. One study estimated the average annual in-flight death rate to be 0.31 per million passengers while cardiac causes were believed to be responsible for 53–60% of such deaths.[4] Using these data, an estimated 130 cardiac deaths occur on U.S. commercial flights per year. The true incidence of in-flight cardiac deaths due to VF events or the outcomes for such in-flight cardiac arrests (IFCAs) are not known. Most previous studies have been based on small numbers of subjects and are reported differently by different

From MedAire Inc., Tempe, AZ, and FAA Civil Aerospace Medical Institute, Oklahoma City, OK.

This manuscript was received for review in September 2015. It was accepted for publication in June 2016.

Address correspondence to: Paulo M. Alves, M.D., Global Medical Director, Aviation Health, MedAire Inc., 1250 Washington Street, Suite 442, Tempe, AZ 85281; paulo.alves@medaire.com

DOI: 10.3357/AMHP.4479.2016

investigators, some of which include cases that occur while the aircraft is on the ground, making comparisons and extrapolations difficult.[2,23,24]

Although the carriage of Automated External Defibrillators (AEDs) on commercial aircraft is not mandatory in all countries, since the 1990s they have been progressively implemented by many airlines globally.[22,23] In 2004, the U.S. Federal Aviation Administration (FAA) mandated that all commercial airline flights with at least one flight attendant carry AEDs onboard and train cabin crew in their use.[9] In one study on OHCAs, the availability of onsite AEDs was associated with a survival rate of 49.6% of the victims as opposed to 14.3% for dispatched AEDs.[1] The full impact of AEDs on aircraft is still incompletely understood, but is suspected to be less than the usual experience on the ground, due to inherent challenges in flight such as lack of access to structured advanced life support (ALS) systems, access to the patient, and limited physical space to perform basic life support (BLS) and ALS.

A diversion is an unplanned landing at a destination other than the originally intended airport. Diversions can result in significant delays and missed flight connections for passengers and additional expenses for the airline. In addition, flight safety may be compromised due to several factors, such as landings at airports with which the aircrew are not familiar.[10,14]

From an operational standpoint diversions are not always immediately possible. Depending upon the actual location of the aircraft, weather conditions, and the adequacy of surrounding airfields a diversion may take from 20 min in overland flights to 3 h in longer flights over water. Studies have shown flight diversions for medical reasons range from approximately 2–13% of in-flight medical events (IFMEs)[25,29] and cardiac events represent the greatest risk for a diversion.[6,25,29] Estimates for the cost of diversions can range from a few thousand to several hundreds of thousands of dollars. From a medical standpoint, diversions are warranted when dealing with a life-threatening situation, or when there is the possibility of limb or organ loss. The ultimate decision to divert resides with the aircraft captain, who has to weigh all factors involved including the safety of the remaining passengers and crew.

Patient survival decreases by up to 10% for each minute of delay in the implementation of CPR and defibrillation[7]; therefore, onboard AEDs and trained cabin crews, supplemented by passenger volunteers if necessary, is the only effective approach for passengers in cardiac arrest.

To define the current status of IFCAs and current efforts at treatment with AEDs now on board, we examined a large, modern aviation medical emergencies database kept by MedAire, a subsidiary company of the International SOS Group.

METHODS

Subjects

Passengers traveling flights operated by airlines utilizing ground-based medical support from MedLink were considered the subjects. This project was approved by the FAA Institutional Review Board (IRB) under expedited rules.

Material

MedLink is a ground-based medical advisory center of MedAire Inc., located in the emergency department of Banner Good Samaritan Hospital in Phoenix, AZ. The center is staffed with board certified emergency physicians. Nonmedically trained communications specialists were in charge of handling the communication with the flight reporting the IFME and managing case documentation. We reviewed a 10-yr period of a database consisting of electronic case records for every in-flight medical event handled by the provider. Records were created even for cases where the company was engaged after the fact, not having actively participated in managing the event, when helping only with activating medical personnel to meet the flight at its destination. For each case we obtained a narrative summary of the IFME as well as operational data such as airline, aircraft type, flight origin and destination, flight diversion status, estimated remaining time in flight to the scheduled destination and revised estimated remaining flight time to the new destination when the flight diverted. Medical details included the availability of onboard volunteer medical professionals (i.e., physicians, nurses, emergency medical personnel, etc.), patient age, gender and past medical history, AED use, and patient outcome. Follow-up information from the hospital or other sources was reviewed to determine survival-to-hospital and survival-to-discharge. Flight distance, estimated by the great circle distance between the city pairs was later added to the data.

Procedure

This database was carefully examined for the use of an in-flight AED from 1 January 2001 through 31 December 2010. Cases were divided into two groups: reported shockable-rhythm (RSR) and reported non-shockable-rhythm (RNSR), depending on whether a shock was indicated when the AED was applied.

Excluded from analysis were cases where: 1) AED use was for monitoring purposes only; 2) the event occurred on the ground; 3) MedAire was informed postfact; 4) the case was related to transport of a patient with a medical escort; and 5) information was insufficient.

Statistical Analysis

Logistic regression models were used to determine odds ratios for relevant predictive factors for the outcomes survival-to-hospital, survival-to-discharge, shock advised, and flight diversion. For the primary outcomes survival-to-hospital and survival-to-discharge the independent variables included shock advised, scheduled minutes remaining to destination, age, gender, diversion status, distance, and whether a physician volunteered. A variable was also created for actual time to arrival as an indicator of time to ALS using either the original scheduled time to destination or the time to the diversion airport for diverted flights. The model for the secondary outcome shock advised included age, gender, scheduled minutes remaining, distance, and whether a physician responded. Independent variables for the secondary outcome flight diversion included age, gender, scheduled minutes remaining to destination, whether a physician responded, and flight distance. Independent variables used in the logistic regression models were assessed for multicollinearity using tolerance and variance inflation factors and these measures were found to be satisfactory. Odds ratios (OR) with 95% confidence intervals in models that retained only the significant variables are reported. A statistical significance level of $\alpha = 0.05$ was used for all comparisons. Analyses were performed using SPSS version 21 (IBM, Armonk, NY).

RESULTS

Out of 144,804 IFMEs in the database 1263 cases met the inclusion criteria of in-flight AED use. After applying the exclusion criteria, 394 cases constituted the final sample of IFCAs for analysis. **Fig. 1** displays subject selection and outcomes. Cases were included from 39 different airlines representing 13 countries. Approximately half (49%) were from U.S. or Canadian airlines.

Of these cases, 25% presented with an RSR, while 75% had an RNSR cardiac arrest. Victims of IFCA survived to hospital admission in 7.4% of cases. The presence of an RSR and scheduled minutes remaining to destination were the only significant predictors of survival-to-hospital in a logistic regression model. This model initially included age, gender, diversion status, distance, and whether a physician volunteered; however, none of these variables made a significant contribution to the model, were not significantly associated with survival and were eliminated from the final model. The results of the full model are included in **Fig. 2**. In this full model the only significant variable was shock advised. Scheduled minutes remaining was also significant when the model was reduced to retain only significant variables.

Actual time to arrival was also not significantly associated with survival when it was included in place of scheduled time remaining and diversion. The survival rate for passengers in an RSR was 22.7% compared with 2.4% in the RNSR group ($P < 0.001$). The model retaining only variables with a significant contribution resulted in an adjusted OR for survival-to-hospital for the RSR group compared with the RNSR group of 13.6 (95% CI 5.5–33.5, $P < 0.001$). These results are summarized in Fig. 1.

From the case descriptions of the seven instances of RNSR survivors to hospital, we were unable to rule out whether a shock was given in three cases. Another case was possibly not a true cardiac arrest. We are confident the remaining three cases were correctly classified. However, any misclassification of cases as RNSR or noncardiac arrest would have resulted in a finding that RSR was even more advantageous than reported here.

The predicted odds for survival to hospital increased as scheduled flight time remaining decreased with adjusted OR = 1.43 (95% CI 1.09–1.87, $P = 0.010$) per hour decrease. The data reveals that survival rates are better during each of the last 3 h of originally scheduled flight time remaining with an average of 9.6% survival compared to a survival rate of 3.0% when the scheduled flight time remaining is longer than 3 h ($P = 0.018$). This association held only when flights longer than 2500 miles were examined to eliminate the possibility that the event occurred near the beginning of those flights.

In 95 of 394 cases (24%) the total number of shocks given was reported by the flight crew. The survival-to-hospital ratios were 13/49 (26.5%) for 1 shock, 3/17 (17.6%) for 2 shocks, 2/14 (14.3%) for 3 shocks, 1/6 (16.7%) for 4 shocks, and 2/6 (33.3%) for 5 shocks. One survivor received a total of 12 shocks. There was no statistically significant difference in survival-to-hospital vs. number of shocks administered.

In a logistic regression model for presence of shockable rhythm only gender was a significant predictor. The OR for men (63.5%) compared to women (36.5%) was 1.69 (95% CI 1.02–2.79, $P = 0.041$) with 28.0% of men and 18.8% of women found with an RSR. This model also initially included age, scheduled minutes remaining, distance, and whether

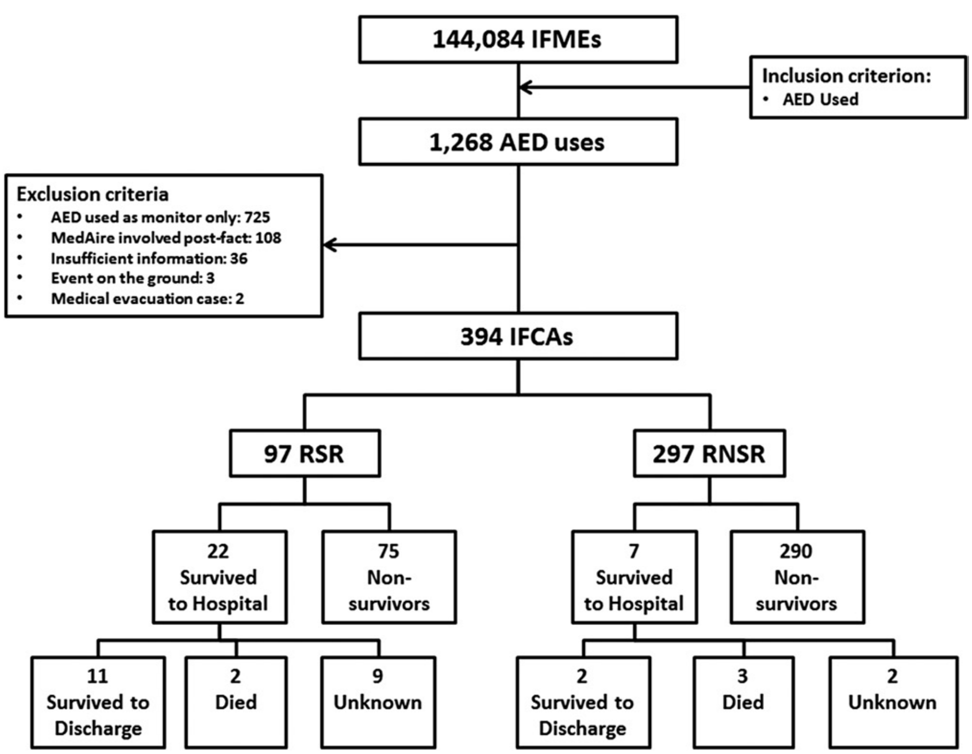

Fig. 1. Study overview. IFME: in-flight medical event; AED: Automated External Defibrillator; IFCA: in-flight cardiac arrest; RSR: reported shockable-rhythm; RNSR: reported non-shockable-rhythm.

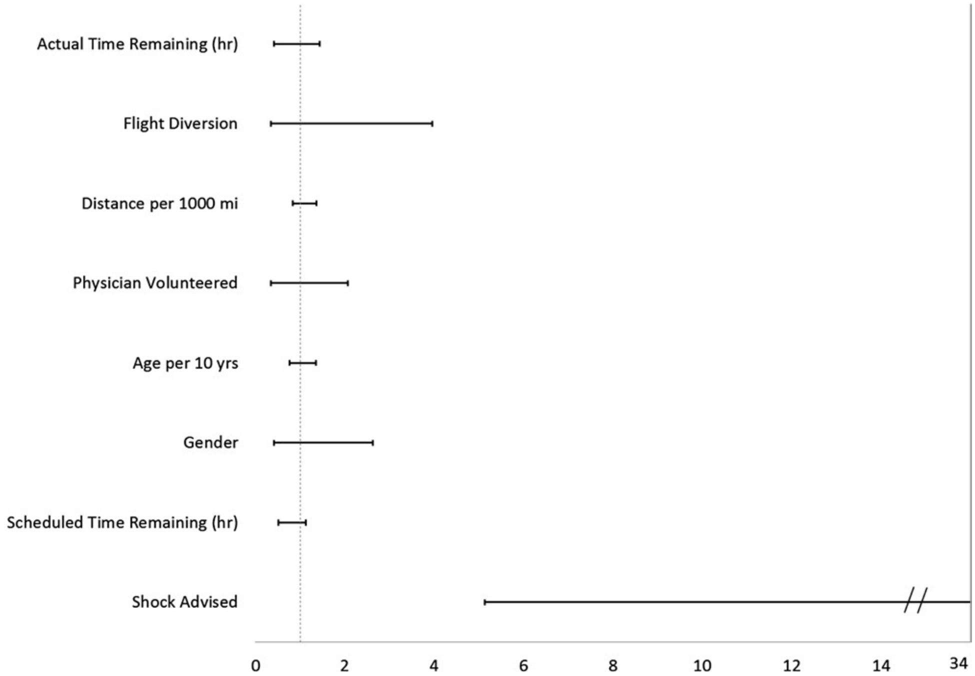

Fig. 2. Results of complete logistic regression model for survival-to-hospital.

In over 90% of all flights and 89% of diverted flights there was a volunteer medical professional helping the crewmember. Physicians volunteered to assist in 67% of all flights and 59% of diverted flights. In addition, nurses volunteered in 17% of all cases, paramedics in 2%, EMTs in 1%, and other healthcare professionals in 2% with 11% not reported. For RSR there was no significant difference in the odds of a flight diverting whether or not a physician volunteered; however, for RNSR, the odds of a flight diverting was two times greater if a nonphysician assisted compared to when a physician responded (95% CI 1.2–3.4, $P = 0.005$).

Although diversions are recommended following successful resuscitation, there was no significant correlation between flight diversions and survival to hospital for passengers in a RSR.

The point estimates and 95% CIs for survival to hospital by flight diversion and shockable rhythm are displayed in **Fig. 3**. Note that comparison for the RNSR cases included cells with only 2 and 5 data points.

Final survival status was available for 385 cases. Of the 29 cases who survived to the hospital, survival to discharge status was available for 20 cases. Of these 20 cases, 13 (65%) are known to have survived to discharge. In a logistic regression model, the only variable that was significantly associated with survival to discharge was the presence of RSR with OR = 20.8 (95% CI 4.5–96.0, $P < 0.001$). This model initially also included age, gender, flight distance, whether a physician responded, and scheduled minutes remaining but none of these made a significant contribution and were removed from the final model.

a physician responded, but these did not make a significant contribution and were not retained in the final model.

In more than half of all cases (50.8%) no history of prior medical condition was reported. Where medical history was reported, a past cardiac history was the most frequent finding (48.5%); however, there was no difference in the incidence of RSR between patients with a history of a previous cardiovascular condition compared to those without a cardiac history. **Table I** summarizes the characteristics of the RSR and RNSR groups.

A logistic regression model developed for flight diversions identified the following significant predictors: RSR (OR = 2.2, 95% CI 1.4–3.7, $P = 0.002$), nonphysician volunteer (OR = 2.0, 95% CI 1.3–3.2, $P = 0.03$), longer scheduled time remaining per hour (OR = 1.3, 95% CI 1.1–1.4, $P < 0.001$), and shorter flights per 1000 miles (OR = 0.74, 95% CI 0.64–0.85, $P < 0.001$). Age and gender were initially in the model but were not significant and were eliminated from the model.

Table I. Baseline Characteristics of the RSR and RNSR Groups.

VARIABLE	RSR	RNSR	OR (95% CI)	*P*-VALUE
Age (years; Mean/SD)	63.14/15.62	60.82/15.16	-	0.21
Gender (M/F)	70/27	180/117	1.69 (1.02-2.78)	0.04
Scheduled Time Remaining, (minutes; Median (Min-Max))	124 (19-771)	119 (0/672)	-	1
Distance of flight (miles; Median (Min-Max))	2594(333-7286)	3114(324-7258)	-	0.1087
Flight Diversion (Yes/No)	52/45	101/196	2.24 (1.41-3.57)	0.001
Previous Cardiovascular History (Yes/No)	25/72	69/228	1.14 (0.68-1.95)	0.35
Volunteer Medical Professional (Yes/No)	90/7	266/30	1.45 (0.61-3.41)	0.26
Actual Time Remaining (minutes; Median (Min-Max))	36 (3-771)	59 (0-656)	-	0.006

* RSR = Reported Shockable-Rhythm; † RNSR = Reported Non-Shockable-Rhythm.

DISCUSSION

We found 25% of IFCA cases in an RSR, which were assumed to be VF since only VF and certain wide QRS complex forms of ventricular tachycardia (VT) are deemed shockable by the AED internal ECG recognition algorithm. Although lower than the 43–47% found for some ground-based studies,[12,13] it is very close to the 22–25% reported in other in-flight studies.[2,23] This lower

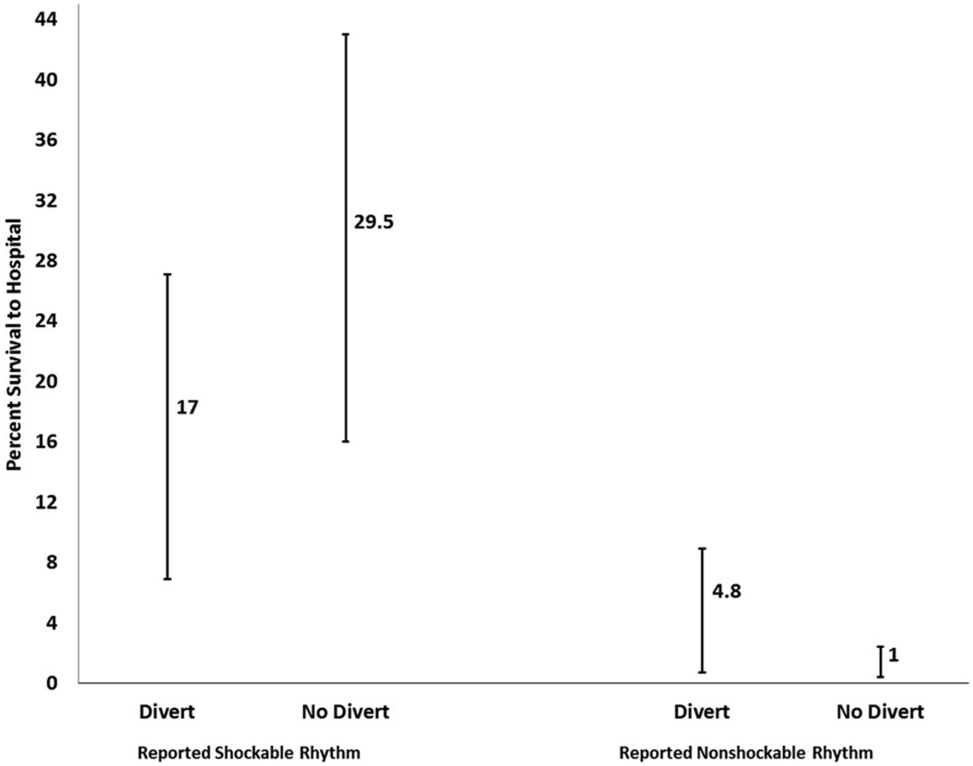

Fig. 3. Point estimates and 95% confidence intervals for survival to hospital by flight diversion and shockable rhythm.

Our finding that men (28.0%) were significantly more likely than women (18.8%) to be found with an RSR agrees with a previously published general population based study.[17]

In our study, 7.4% victims of IFCA survived to hospital including 22.7% RSR cases compared with 2.4% of RNSR cases ($P < 0.001$). A recent meta-review of 79 OHCA studies found the pooled survival rate to hospital admission was 23.8%.[26] In another study of VF victims in Las Vegas casinos, where cardiac arrest victims are recognized early due to the presence of security cameras, survival ranged from 74%, for collapse-to-shock time less than 3 min, to 49% for longer response times.[30]

It is well known that as time elapses VF amplitude decreases[5] and can fall beyond the AED VF recognition threshold. In our study we were not able to measure the collapse-to-shock time. This could be a factor in explaining the low incidence of shockable rhythms in the in-flight environment, as the detected incidence of VF could be artificially low if the AED is not attached early enough.

incidence of an RSR, implying underlying VF or VT, compared with other OHCA scenarios, is unexpected, particularly when compared to the 85% reported at airports,[3] which should represent samples of the same demographics of the traveling public, or the 71% reported in casinos.[30] There are several factors that might explain those differences. In reality, OHCA scenarios are truly heterogeneous in many aspects, in regards to the probability of witnessing a collapse. Weisfeldt et al. showed that the incidence of VF is significantly higher in truly public spaces than in residential settings where prompt discovery is less likely.[31] The in-flight environment may be compared to the home setting, particularly in long-haul overnight flights. Airline passengers who become unconscious while seated may often be mistaken for being asleep.[8] Other cases could occur when the passenger is inside the lavatory. In both situations a collapse may frequently not be witnessed and it would be expected that the survival rate for onboard cardiac arrest would be lower than in settings where unconsciousness is more likely to be recognized promptly.

In addition, other factors associated with air travel could be playing a role. Deep vein thrombosis and pulmonary embolism (PE) are greater risks on long haul flights where cardiac arrest secondary to PE is more often associated with an RNSR (e.g., pulseless electrical activity). However, the reported incidence of PE is likely not enough to explain the observed difference.[18,19] The most likely explanation for the lower incidence of RSR in flight may be the lack of early recognition of the cardiac event as survival rates are known to drop sharply as time to defibrillation is delayed.[30]

Properly performed CPR is the best predictor of survival for nonshockable OHCAs.[28] It is paramount that the diversion process, if so decided by the pilot, must not interfere with the delivery of good quality chest compressions for an adequate period of time. This should be decided on a case by case basis. Since nine cases survived to hospital receiving multiple shocks, resuscitation efforts should continue for as long as shocks are advised by the AED. A case of survival to hospital discharge after more than 20 shocks is reported in the literature.[11]

Our logistic regression model showed statistically significant improved odds of survival-to-hospital as originally scheduled flight time remaining becomes shorter; however, we could not adequately explain this finding. We speculated that scheduled flight time remaining would have been an indicator of cabin activity level that could have accounted for early recognition of passengers in cardiac arrest; however, this did not appear to be the case, possibly because of unknown confounding variables.

We anticipated that shorter actual flight time remaining would have been an advantage to survival but our results did not support this. In most instances the eventual actual time remaining in flight, even when a flight diversion was undertaken, was above 30 min, making it highly unlikely that, given this elapsed time, access to advanced care played a significant role.[27]

Dalzell and Adgey[5] showed that the VF amplitude, age, and number of shocks had the greatest significant contribution in predicting discharge from hospital. A recent meta-review of 79 studies of OHCA found the pooled survival rate to hospital discharge was 7.6%.[26] We were not able to obtain information about survival to discharge in 11 cases, mainly due to medical confidentiality aspects preventing the acquisition of follow-up data. Nonetheless, out of the 29 cases who survived to hospital, 13 were confirmed to survive to discharge. Assuming the worst case scenario that these 11 unknown cases lost to follow-up all died, then 13/29 or at least 45% of those who survived to hospital also survived to discharge. Considering the opposite, namely that all the 11 unknown cases survived to discharge, this would total 24/29 or at best 83% survived to go home. Of those not lost to follow-up, 13/18 or 72% survived to discharge. Although the numbers were small, the presence of a shockable rhythm was strongly associated with this outcome: OR = 20.8 (95% CI 4.5–96.0, $P < 0.001$). The overall rate for survival to discharge was 3.3% with a rate of 11.3% in the RSR group and 0.7% in the RNSR group.

We found that flights are more likely to divert when a shockable rhythm is present, when the scheduled time remaining is longer, and when total flight distance is smaller. As scheduled time remaining becomes longer the need to divert will be greater. Shockable rhythm is thought to be associated with diversion since they are associated with successful resuscitation. Return of spontaneous circulation after a shock is delivered in flight is a good indication for diversion, since further care in a hospital setting would be required.[14,21] If resuscitation efforts have been continued for at least 30 min after the last shock was delivered, with no return of spontaneous circulation, the victim may be presumed dead and continuing resuscitation efforts may be futile.[15] Our findings suggest a physician is more comfortable with the decision to cease CPR than other health professionals, as judged by the increased diversion rate for the latter in RNSR cases.

Our findings cannot be utilized to infer the true incidence of IFCAs, which should be higher than reported here, because some cases were excluded from the study and others were not reported to MedAire. We could not be certain of the true incidence of VF because we were unable to confirm the actual underlying rhythms since the AED data were not available to us. In addition, our outcome data included only survival status so we were unable to ascertain the functional status of survivors. Future prospective research should address the issue of medical confidentiality by developing specific communication to be sent to the treating facility explaining the scientific nature of the request.

CONCLUSIONS

This study indicates that discovery of an RSR was the most important prognostic factor for the survival of passengers with IFCA, which is consistent with current knowledge. Even more critically than other OHCA situations, the in-flight environment demands the provision of excellent timely basic life support which includes early recognition and AED utilization.

Further studies are necessary to address a few remaining practical questions emerging from this report. Should AED utilization take precedence over chest compressions in cases where extricating the victim from his/her seat is expected to delay time to shock? Does the location of the victim before and after resuscitation affect survival outcome? How long should rescuers continue rescue attempts while performing adequate chest compressions in cases when a shock is not recommended? Should providing good quality CPR take precedence over immediate diversion in cases of RNSR?

Until these and other important questions are answered, high situational awareness to identify IFCA victims and prompt AED utilization should be strongly recommended to enhance survival.

ACKNOWLEDGMENTS

The authors thank Dr. Neil Nerwich, Dr. Erdinç Ercan, and Dr. Viviana Ortiz, for their contribution with the initial data preparation and analysis; Dr. Douglas Chamberlain and Dr. Karl Kern for review and editing assistance; and Katheryn Bleckley for statistical advice.

Disclosures: Dr. Paulo M. Alves receives salary support from MedAire Inc., a company providing medical solutions in the aviation sector, including remote medical support, medical training and medical equipment, including AEDs. Dr. Charles A. DeJohn, Dr. Eduard M. Ricaurte, and Dr. William D. Mills receive salary support from the Federal Aviation Administration. No specific funding was allocated to this research.

Authors and affiliations: Paulo M. Alves, FAsMA, MedAire Inc. Global Medical Director Aviation Health, Phoenix, AZ; Charles A. DeJohn, DO, FAsMA, Eduard M. Ricaurte, MD, FAsMA, and William D. Mills, MD, Ph.D., Federal Aviation Administration, Civil Aerospace Medical Institute, Oklahoma City, OK.

REFERENCES

1. Berdowski J, Blom MT, Bardai A, Tan HL, Tijssen JG, Koster RW. Impact of onsite or dispatched automated external defibrillator use on survival after out-of-hospital cardiac arrest. Circulation. 2011; 124(20):2225–2232.
2. Brown AM, Rittenberger JC, Ammon CM, Harrington S, Guyette FX. In-flight automated external defibrillator use and consultation patterns. Prehosp Emerg Care. 2010;14(2):235–239.
3. Caffrey SL, Willoughby PJ, Pepe PE, Becker LB. Public use of automated external defibrillators. N Engl J Med. 2002; 347(16):1242–1247.
4. Cummins RO, Chapman PJ, Chamberlain DA, Schubach JA, Litwin PE. In-flight deaths during commercial air travel. How big is the problem? JAMA. 1988; 259(13):1983–1988.
5. Dalzell GWN. A.A.J A. Determinants of successful transthoracic defibrillation and outcome in ventricular fibrillation. Br Heart J. 1991; 65:311–316.
6. DeJohn CA, Wolbrink AM, Veronneau SJ, Larcher JG, Smith DW, Garrett JS. An evaluation of in-flight medical care in the U.S. Aviat Space Environ Med. 2002; 73(6):580–586.
7. Department of Health and Human Services, General Services Administration. Guidelines for Public Access Defibrillation Programs in Federal Facilities. Washington (DC): GSA; 2001.
8. Donaldson E, Pearn J. First aid in the air. Aust N Z J Surg. 1996; 66(7): 431–434.
9. Federal Aviation Administration. Emergency medical equipment. Final rule. Fed Regist. 2001; 66(71):19028–19046.
10. Gendreau MA, DeJohn C. Responding to medical events during commercial airline flights. N Engl J Med. 2002; 346(14):1067–1073.

11. Harve H, Hamalainen O, Kurola J, Silfvast T. AED use in a passenger during a long-haul flight: repeated defibrillation with a successful outcome. Aviat Space Environ Med. 2009; 80(4):405–408.
12. Holmberg M, Holmberg S, Herlitz J. Incidence, duration and survival of ventricular fibrillation in out-of-hospital cardiac arrest patients in Sweden. Resuscitation. 2000; 44(1):7–17.
13. Hulleman M, Berdowski J, de Groot JR, van Dessel PF, Borleffs CJ, et al. Implantable cardioverter-defibrillators have reduced the incidence of resuscitation for out-of-hospital cardiac arrest caused by lethal arrhythmias. Circulation. 2012; 126(7):815–821.
14. Hung KKC, Cocks RA, Poon WK, Chan EYY, Rainer TH, Graham CA. Medical volunteers in commercial flight medical diversions. Aviat Space Environ Med. 2013; 84(5):491–497.
15. International Air Transport Association I. Guidelines on Health & Safety Issues. International Air Transport Association, IATA; 2012 [Accessed September 2015]. Available from: http://www.iata.org/whatwedo/safety/health/pages/index.aspx.
16. International Air Transport Association I. New IATA Passenger Forecast Reveals Fast-Growing Markets of the Future. Press Release. Geneva: International Air Transport Association, IATA; 16 October 2014. Report No.: 57.
17. Kim C, Fahrenbruch C, Cobb L, Eisenberg M. Out-of-hospital cardiac arrest in men and women. Circulation. 2001; 104(22):2699–2703.
18. Kürkciyan I, Giora M, Fritz S, Karin J, Hans D, et al. Pulmonary embolism as cause of cardiac arrest. Arch Intern Med. 2000; 160(10): 1529–1535.
19. Lapostolle F, Surget V, Borron SW, Desmaizieres M, Sordelet D, et al. Severe pulmonary embolism associated with air travel. N Engl J Med. 2001; 345(11):779–783.
20. Mozaffarian D, Benjamin EJ, Go AS, Arnett DK, Blaha MJ, et al. Heart disease and stroke statistics–2015 update: a report from the American Heart Association. Circulation. 2015; 131(4):e29–322.
21. Nable JV, Tupe CL, Gehle BD, Brady WJ. In-flight medical emergencies during commercial travel. N Engl J Med. 2015; 373(10):939–945.
22. O'Rourke M, Donaldson E. Management of ventricular fibrillation in commercial airliners. Lancet. 1995; 345(8948):515–516.
23. O'Rourke MF, Donaldson E, Geddes JS. An airline cardiac arrest program. Circulation. 1997; 96(9):2849–2853.
24. Page RL, Joglar JA, Kowal RC, Zagrodzky JD, Nelson LL, et al. Use of automated external defibrillators by a U.S. airline. N Engl J Med. 2000; 343(17):1210–1216.
25. Peterson DC, Martin-Gill C, Guyette FX, Tobias AZ, McCarthy CE, et al. Outcomes of Medical Emergencies on Commercial Airline Flights. N Engl J Med. 2013; 368(22):2075–2083.
26. Sasson C, Rogers MA, Dahl J, Kellermann AL. Predictors of survival from out-of-hospital cardiac arrest: a systematic review and meta-analysis. Circ Cardiovasc Qual Outcomes. 2010; 3(1):63–81.
27. Stiell IG, Wells GA, Field B, Spaite DW, Nesbitt LP, et al. Advanced cardiac life support in out-of-hospital cardiac arrest. N Engl J Med. 2004; 351(7):647–656.
28. Vaillancourt C, Everson-Stewart S, Christenson J, Andrusiek D, Powell J, Nichol G, et al. The impact of increased chest compression fraction on return of spontaneous circulation for out-of-hospital cardiac arrest patients not in ventricular fibrillation. Resuscitation. 2011;82(12):1501–1507.
29. Valani R, Cornacchia M, Kube D. Flight diversions due to onboard medical emergencies on an international commercial airline. Aviat Space Environ Med. 2010; 81(11):1037–1040.
30. Valenzuela TD, Roe DJ, Nichol G, Clark LL, Spaite DW, Hardman RG. Outcomes of rapid defibrillation by security officers after cardiac arrest in casinos. N Engl J Med. 2000; 343(17):1206–1209.
31. Weisfeldt ML, Everson-Stewart SSC, Rea T, Aufderheide TP, Atkins D, et al. Ventricular tachyarrhythmias after cardiac arrest in public versus at home. N Engl J Med. 2011; 364(4):313–321.