

BRIEF COMMUNICATION

# Incidence, Mechanism, and Outcomes of On-Plane Versus Off-Plane Cardiac Arrest in Air Travelers

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**BACKGROUND:** Air travel affords an opportunity to evaluate resuscitation performance and outcome in a setting where automated external defibrillators (AEDs) are readily available.

**METHODS AND RESULTS:** The study cohort included people aged  $\geq 18$  years with out of hospital cardiac arrest (OHCA) traveling through Seattle-Tacoma International Airport between January 1, 2004 and December 31, 2019 treated by emergency medical services (EMS). The primary outcomes were pre-EMS therapies (cardiopulmonary resuscitation, application of AED), return of spontaneous circulation, and survival to hospital discharge. Over the 16-year study period, there were 143 OHCA occurring before EMS arrival, 34 (24%) on-plane and 109 (76%) off-plane. Cardiac etiology (81%) was the most common mechanism of arrest. The majority of arrests were bystander-witnessed and presented with a shockable rhythm; these characteristics were more common in off-plane OHCA compared with on-plane (witnessed: 89% versus 74% and shockable: 72% versus 50%). Pre-EMS therapies including cardiopulmonary resuscitation and AED application were common regardless of arrest location. Compared with on-plane OHCA, off-plane OHCA was associated with greater rates of return of spontaneous circulation (68% versus 44%) and 3-fold higher rate of survival to hospital discharge (44% versus 15%). All survivors of on-plane OHCA had AED application with defibrillation before EMS arrival.

**CONCLUSIONS:** When applied to air travel volumes, we estimate 350 air travel-associated OHCA occur in the United States and 2000 OHCA worldwide each year, nearly a quarter of which happen on-plane. These events are survivable when early arrest interventions including rapid arrest recognition, AED application, and CPR are deployed.

**Key Words:** automatic external defibrillator ■ cardiac arrest ■ cardiopulmonary resuscitation

Each year,  $\approx 5$  billion people travel on commercial airlines worldwide.<sup>1</sup> Air travel has been associated with high-risk cardiovascular events through a range of mechanisms including increased cardiopulmonary stress, perturbations of autonomic function, and induced alterations in blood hemostasis.<sup>2-6</sup> For individuals who sustain an out-of-hospital cardiac arrest (OHCA) successful resuscitation requires an integrated chain of actions including early arrest recognition, timely cardiopulmonary resuscitation (CPR), and defibrillation, expert advanced life support and post-resuscitation care.<sup>7</sup> Air travel is distinguished by circumstances which could impact resuscitation

outcome. Favorable characteristics of public setting, multiple bystanders, and the availability of automated external defibrillators (AEDs) are balanced against the logistic challenges of access and expedient therapy, particularly in the on-plane location. Indeed, air travel has been considered an opportunity to implement and innovate resuscitation guidelines to better achieve early CPR and defibrillation.<sup>8</sup> Resuscitation strategies have been reinforced by legislation featured in the 2004 requirement of the Federal Aviation Authority that all United States commercial airlines be equipped with AEDs.<sup>9</sup> Yet little is known about the incidence, care, or outcomes of on-plane OHCA characteristics and

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**Table. Characteristics, Mechanism, and Outcomes of On-Plane and Off-Plane Cardiac Arrests Between 2004 to 2019**

Baseline characteristic	On-plane			Off-plane		
	Overall	Shockable	Non-shockable	Overall	Shockable	Non-shockable
Group size, n (%)	34	17 (50)	17 (50)	109	78 (72)	31 (28)
Age, y	65±21	70±19	64±22	65±16	65±14	65±18
Male sex, n (%)	27 (79)	15 (88)	12 (71)	90 (83)	68 (87)	22 (71)
Etiology of arrest, cardiac,* n (%)	26 (76)	16 (94)	10 (59)	90 (83)	74 (95)	16 (52)
Traveler status, n (%)						
Inbound	22 (65)	7 (41)	15 (88)	37 (34)	23 (29)	14 (45)
Outbound	9 (26)	7 (41)	2 (12)	19 (17)	13 (17)	6 (19)
Unknown	3 (9)	3 (18)	0 (0)	53 (49)	42 (54)	11 (35)
Arrest witnessed, n (%)	25 (74)	14 (82)	11 (65)	97 (89)	73 (94)	24 (77)
Therapies before EMS, n (%)						
Bystander CPR	30 (88)	16 (94)	14 (82)	85 (78)	63 (81)	22 (71)
AED applied	24 (71) <sup>†</sup>	15 (88)	9 (53)	60 (55)	48 (62)	12 (39)
AED shock, if applied	13 (54)	13 (87)	0 (0)	42 (70)	41 (85)	1 (8)
Intravenous access	2 (6)	1 (6)	1 (6)	0 (0)	0 (0)	0 (0)
Oxygen	4 (12)	1 (6)	3 (18)	0 (0)	0 (0)	0 (0)
Epinephrine	4 (12) <sup>‡</sup>	2 (12)	2 (12)	0 (0)	0 (0)	0 (0)
Other medications <sup>§</sup>	2 (6)	1 (6)	1 (6)	1 (1)	1 (1)	0 (0)
Return of spontaneous circulation at end of EMS care, n (%)	15 (44)	9 (53)	6 (35)	74 (68)	57 (73)	17 (55)
Admitted to hospital	15 (44)	9 (53)	6 (35)	73 (67)	56 (72)	17 (55)
Hospital care, n (% of admitted)						
TTM	8 (53)	3 (33)	5 (83)	29 (40)	23 (41)	6 (35)
Coronary angiogram	7 (47)	6 (67)	1 (17)	45 (62)	43 (77)	2 (12)
PCI	2 (13)	2 (22)	0 (0)	17 (23)	17 (30)	0 (0)
Survival to discharge, n (%)	5 (15)	5 (29)	0 (0)	48 (44)	42 (54)	6 (19)
Favorable neurological status at discharge (CPC 1 or 2) <sup>  </sup> , n (% of those discharged)	5 (100)	5 (100)	...	45 (94)	40 (95)	5 (83)

AED indicates automatic external defibrillator; CPC, Cerebral Performance Category; CPR, cardiopulmonary resuscitation; EMS, emergency medical services; PCI, percutaneous coronary intervention; and TTM, targeted temperature management.

\*Arrest etiology was adjudicated following review of dispatch transcripts, EMS records, and hospital records.

<sup>†</sup>AED application for all on-plane arrests used an on-aircraft AED.

<sup>‡</sup>Of 4 individuals who received epinephrine, 2 received epinephrine via intravenous access the other 2 via intramuscular delivery.

<sup>§</sup>Other medications included atropine, sodium bicarbonate, dextrose, and nitroglycerin.

<sup>||</sup>In the Cerebral Performance Category classification, category 1 represents good cerebral performance; 2, moderate cerebral disability; 3, severe cerebral disability; 4, coma or vegetative state; and 5, death.

outcomes since this federal requirement. In this study, we evaluated on-plane and off-plane OHCA over a 16-year period following the 2004 federal requirement with focus on arrest etiology, onboard care, and clinical outcomes.

The study cohort was comprised of people aged ≥18 years with non-traumatic OHCA on and off airplanes traveling through Seattle-Tacoma International Airport between January 1, 2004 and December 31, 2019 who were treated by emergency medical services (EMS). The data that support the findings of this study are available from the corresponding author upon reasonable request. Although the focus was on those who arrested on-plane, we report

the presentation, care, and outcome among those who arrested off-plane in the airport for clinical context since these patients are drawn from the same traveler population. The EMS system maintains a registry of all EMS-treated OHCA in the study community including all OHCA treated at Seattle-Tacoma International Airport. EMS care includes basic life support provided by emergency medical technician-trained firefighters equipped with AEDs and advanced life support provided by paramedics who are trained in rhythm recognition, manual defibrillation, intubation, and administration of intravenous medications. Patients who achieve return of circulation are transported to hospitals equipped with coronary

catheterization and intensive care services, including availability of targeted temperature management.

Data on patient demographics, circumstances, presenting arrest rhythm (as reflected by earliest rhythm adjudication by public access defibrillator application or EMS), arrest etiology, clinical care, and outcome were collected using dispatch reports, EMS patient care reports, hospital records, and death certificates. Clinical outcomes included survival to hospital admission, survival to hospital discharge, and Cerebral Performance Category at hospital discharge. We estimated the incidence of OHCA overall and according to on-plane versus off-plane location using official traveler counts for Seattle-Tacoma International Airport and extrapolated the airport-specific rate to national and global traveler volumes. The study was approved by the University of Washington and Public Health—Seattle and King County review boards. The requirement for informed consent was waived.

Over the 16-year study period, there were 34 individuals with on-plane OHCA and 109 people with off-plane OHCA occurring before EMS arrival at an airport with 25 million travelers annually.<sup>1</sup> Table presents on-plane and off-plane arrests with each location group stratified by initial rhythm. Overall, average age was 65 years; 82% were men. A cardiac etiology was the most common underlying mechanism for both on-plane (76%) and off-plane (83%) arrests. Compared with off-plane OHCA, on-plane OHCA was less likely to be witnessed (74% versus 89%) and less likely to present with a shockable rhythm (50% versus 72%).

Bystander CPR and AED application were common in both on- and off-plane OHCA (Table). For on-plane OHCA, an onboard AED was applied in 24 of 34 individuals (71%) before EMS arrival, including 15 of 17 (88%) of those found to have a shockable rhythm. For off-plane OHCA, a public access defibrillator was applied in 60 of 109 arrests (55%), with the majority of public access defibrillator application by a lay person (35 of 60) and the remainder by on-site law enforcement (25 of 60). Following EMS care, return of spontaneous circulation was more common in off-plane OHCA compared with on-plane OHCA (68% versus 44%).

Among 88 patients admitted to the hospital, there were no differences in post-arrest care including targeted temperature management, coronary angiography, and percutaneous coronary intervention between off-plane and on-plane OHCA (Table). Overall, survival to hospital discharge was 3-fold higher in those who sustained off-plane OHCA compared with on-plane OHCA (44% versus 15%). Among on-plane OHCA, survival to hospital discharge was only observed in those with a shockable rhythm who received bystander-initiated CPR and AED application with defibrillation before EMS arrival.

This 16-year evaluation of a major US airport provides an opportunity to estimate the public health toll of OHCA related to air travel. Extrapolating the study results to national and global air travel volumes,<sup>1</sup> we estimate that each year there are ~350 OHCA in the United States and 2000 OHCA globally, a quarter of which occur on-plane. Most air travelers manifested an initial shockable OHCA rhythm of ventricular fibrillation, underscoring the primary cardiac mechanism in this population.<sup>10</sup>

This study highlights the potential for the early links in the chain to achieve survival.<sup>7</sup> The majority of air travelers with OHCA received CPR and AED application before EMS arrival. Importantly, bystander CPR and AED shock were uniform actions among on-plane OHCA survivors, suggesting that survival in this special circumstance may be especially reliant on these fundamental treatments. Conversely, prompt recognition of cardiac arrest was less common on-plane than off-plane, as was a shockable rhythm presentation. These factors, along with the more confined quarters for performing adequate CPR on-plane (potentially further compromised by interruption of CPR during extrication) may account for some of the differences in survival between the 2 groups. A minority of individuals did not receive AED application, highlighting a potential opportunity to improve care in light of the availability of AEDs in the air travel setting. Given the measurable on-plane incidence, the primary mechanism of arrest, and observed survival, the study results support the legislative and programmatic efforts to equip aircraft with AEDs and train flight crew in resuscitation skills.<sup>9</sup> Put simply, on-plane-OHCA does occur and is survivable.

Study limitations include assessment of OHCA at a single international airport in a region with high-quality resuscitation infrastructure, which may limit generalizability. Details about the resuscitation training of airline and airport employees were lacking, as were specific explanations for lack of AED application. Finally, for on-plane arrests, details on flight characteristics including whether a flight was redirected were not prespecified in EMS records.

The current investigation suggests that OHCA is responsible for thousands of air traveler deaths annually worldwide, nearly a quarter of these occurring on-plane. For on-plane OHCA, early CPR and AED defibrillation were uniform components of successful resuscitation and should be emphasized in this unique and challenging circumstance.

## ARTICLE INFORMATION

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