Outcomes of Physician-Staffed Versus Non-Physician-Staffed Helicopter Transport for ST-Elevation Myocardial Infarction

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Background—The effect of physician-staffed helicopter emergency medical service (HEMS) on ST-elevation myocardial infarction (STEMI) patient transfer is unknown. The purpose of this study was to evaluate the characteristics and outcomes of physician-staffed HEMS (Physician-HEMS) versus non-physician-staffed (Standard-HEMS) in patients with STEMI.

Methods and Results—We studied 398 STEMI patients transferred by either Physician-HEMS (n=327) or Standard-HEMS (n=71) for primary or rescue percutaneous coronary intervention at 2 hospitals between 2006 and 2014. Data were collected from electronic medical records and each institution's contribution to the National Cardiovascular Data Registry. Baseline characteristics were similar between groups. Median electrocardiogram-to-balloon time was longer for the Standard-HEMS group than for the Physician-HEMS group (118 vs 107 minutes; P=0.002). The Standard-HEMS group was more likely than the Physician-HEMS group to receive nitroglycerin (37% vs 15%; P<0.001) and opioid analgesics (42.3% vs 21.7%; P<0.001) during transport. In-hospital adverse outcomes, including cardiac arrest, cardiogenic shock, and serious arrhythmias, were more common in the Standard-HEMS group (25.4% vs 11.3%; P=0.002). After adjusting for age, sex, Killip class, and transport time, patients transferred by Standard-HEMS had increased risk of any serious in-hospital adverse event (odds ratio=2.91; 95% CI=1.39–6.06; P=0.004). In-hospital mortality was not statistically different between the 2 groups (9.9% in the Standard-HEMS group vs 4.9% in the Physician-HEMS group; P=0.104).

Conclusions—Patients with STEMI transported by Standard-HEMS had longer transport times, higher rates of nitroglycerin and opioid administration, and higher rates of adjusted in-hospital events. Efforts to better understand optimal transport strategies in STEMI patients are needed. **(*J Am Heart Assoc*. 2017;6:e004936. DOI: 10.1161/JAHA.116.004936.)**

Key Words: acute myocardial infarction • outcome • percutaneous coronary intervention • ST-segment elevation myocardial infarction • treatment

Primary percutaneous coronary intervention (PCI) improves survival in patients with ST-elevation myocardial infarction (STEMI) and is the optimal treatment when performed expeditiously.[1] Over 70% of patients experiencing STEMI in the United States initially present to hospitals without PCI capability and thus are at risk for delayed reperfusion.[2] To ensure rapid interfacility transport for PCI, regional systems of care are recommended.[3–5]

Helicopter Emergency Medical Services (HEMS) are commonly used to transport patients from non-PCI centers (ie, STEMI referral hospitals) to PCI centers (ie, STEMI receiving hospitals). HEMS have been shown to be feasible, safe, and reduce transport time to the receiving facility.[6–8] Thus, HEMS are important in rural or urban areas where ground transport times are predicted to be too long. The HEMS flight crew typically consists of paramedics and flight nurses who are skilled at performing a variety of advanced cardiac life support procedures. However, only ≈5% of HEMS in the United States will also include an emergency-medicine–trained physician as part of the flight crew.[9] Local resources, cost, and hospital affiliations are factors that currently influence HEMS availability and crew composition.

There are limited data evaluating the composition and outcome of HEMS and no data comparing different HEMS

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systems on transport times, treatments administered during patient transport, and in-hospital events in patients with STEMI. As such, practice guidelines do not address the issue of crew composition during interfacility transfer. The primary objective of this study was to evaluate the characteristics, treatment patterns, in-transport, and in-hospital outcomes of STEMI patients transferred by physician-staffed HEMS (Physician-HEMS group) versus nonphysician (Standard-HEMS group) flight crews.

Methods

The institutional review boards of both the University of Wisconsin Hospital and Clinics (UWHC) and Mayo Clinic approved this study. Patient demographic information, in-transport treatments and events, and in-hospital outcomes were abstracted from institutional contributions to the National Cardiovascular Data Registry (NCDR), electronic medical records, and the HEMS flight records. STEMI was defined based on 3 criteria: (1) electrocardiogram (ECG) evidence of ST-elevation based on the 2013 American Heart Association/American College of cardiology (AHA/ACC) STEMI Guidelines[5]; (2) a culprit artery identified by emergency invasive coronary angiography; and (3) performance of either primary PCI or PCI following fibrinolytic administration (ie, rescue PCI).

In-transport adverse events were defined as death, cardiac arrest, serious arrhythmia (ie, rapid supraventricular arrhythmias requiring direct current cardioversion, sustained ventricular tachycardia or ventricular fibrillation, or brady-arrhythmias requiring external pacing), or endotracheal intubation. Data pertaining to the use of adjunctive medications, additional procedures, and vital signs were also recorded. In-hospital outcomes were reviewed by trained abstractors using standard definitions established by the NCDR ACTION Registry and included death, stroke, cardiac arrest, bleeding, cardiogenic shock, new requirement for dialysis, recurrent myocardial infarction (MI), and vascular complications.[10]

Helicopter Emergency Medical Services

Within both institutions' STEMI systems of care, HEMS are requested directly by the STEMI referral hospital. The choice of commercial HEMS is dependent upon availability, local contractual affiliation, and regional emergency department staff preference. The majority of STEMI transfers destined for the UWHC are managed by UW Med Flight, a physician-staffed service. The physician-staffed HEMS crew is comprised of an emergency-medicine–trained flight physician, a flight nurse, and a pilot. This service utilizes EC-135 model helicopters (American Eurocopter, Grand Prairie, TX), which have a maximum speed of 140 knots (kts).

Non-physician-staffed HEMS that transport to UWHC (REACT of Rockford, IL; Flight for Life, Milwaukee and Fond du Lac, WI; and MedLink Air of La Crosse, WI) consist of a pilot and either 2 flight paramedics or a flight paramedic and a flight nurse. These HEMS utilize either EC-145 model or BK-117 helicopters (American Eurocopter). The EC-145 and BK-117 models have maximum speeds of 145 and 150 kts, respectively.

All HEMS and STEMI referring and receiving hospitals follow a standardized antithrombotic protocol, which includes aspirin 325 mg, clopidogrel 600 mg loading dose, and weight-adjusted heparin; however, deviation from the protocol can occur when clinically appropriate.[11] The STEMI protocol suggests that nitroglycerin and opioids (morphine or fentanyl) may be administered as clinically indicated.

Statistical Analysis

Continuous variables were analyzed using the Wilcoxon rank-sum test. Categorical variables were tested using the chi-square test. Fischer's exact was applied in those instances where the counts of observed outcomes were numerically small or the expected cell counts <5. Logistic regression models were constructed to evaluate independent predictors of outcomes. All tests were considered statistically significant if $P<0.05$. All analyses were performed using Statistical Package for the Social Sciences (SPSS) software (version 23.0; IBM Inc., Chicago, IL).

Results

From August 2006 through December 2014, a total of 398 STEMI patients were transferred for primary or rescue PCI. Of those, 327 patients were transported by Physician-HEMS and 71 patients by Standard-HEMS.

Patient Characteristics

There was no significant difference in baseline age or frequency of cardiovascular disease risk factor between the Physician-HEMS and Standard-HEMS groups (Table 1). There was no significant difference in the baseline Killip class between the 2 groups (P=0.790). The right coronary artery (RCA) was the most common culprit artery in both groups. However, the Physician-HEMS group was more likely to have the left anterior descending (LAD) coronary artery as the culprit for STEMI (P=0.017; Table 1).

In-Transport Events

In transport mortality was 0% in both groups. There was no significant difference in the frequency of serious adverse events, such as cardiac arrest, arrhythmia, intubation or need for transcutaneous pacing, direct current cardioversion, or

Table 1. Patient Characteristics*

	Physician-HEMS (n=327)	Standard-HEMS (n=71)	*P* Value
Age, y	60.4±13.0	61.3±12.3	0.187
Male, n (%)	248 (75.8)	50 (70.4)	0.340
Diabetes mellitus, n (%)	88 (26.9)	14 (19.7)	0.208
Active smoker, n (%)	164 (50.2)	36 (50.7)	0.952
Hypertension, n (%)	209 (63.9)	41 (57.7)	0.330
Dyslipidemia, n (%)	227 (69.4)	48 (67.6)	0.764
Previous MI, n (%)	57 (17.4)	9 (12.7)	0.329
Initial vital signs			
Median SBP, mm Hg (IQR)	128 (116–145)	137 (116–162)	0.148
Median DBP, mm Hg (IQR)	78 (68–90)	82 (72–98)	0.117
Median HR, rate per minute (IQR)	71 (62–86)	77 (63–89)	0.616
Killip class			0.790
I, n (%)	253 (77.4)	56 (78.9)	
II, n (%)	3 (0.9)	2 (2.8)	
III, n (%)	14 (4.3)	2 (2.8)	
IV, n (%)	57 (17.4)	11 (15.5)	
Culprit coronary artery			0.017
LAD, n (%)	135 (41.3)	19 (26.8)	
RCA, n (%)	155 (47.4)	35 (49.3)	
Left circumflex, n (%)	33 (10.1)	14 (19.7)	
Other, n (%)	4 (1.2)	3 (4.2)	
Rescue PCI, n (%)	26 (8.0)	4 (5.6)	0.626

DBP indicates diastolic blood pressure; HR, heart rate; IQR, interquartile range; LAD, left anterior descending; MI, myocardial infarction; PCI, percutaneous coronary intervention; Physician-HEMS, physician-staffed helicopter emergency medical service; RCA, right coronary artery; SBP, systolic blood pressure; Standard-HEMS, non-physician-staffed helicopter emergency medical service.
*Continuous variables are expressed as means±SD (standard deviation) or median±IQR.

cardiopulmonary resuscitation (Table 2). The Standard-HEMS group was more likely than the Physician-HEMS group to receive intravenous analgesics, such as fentanyl or morphine and nitroglycerin, during transport (42.3% vs 21.7% and 36.6% vs 15.3%; $P<0.001$ for both; Table 2). Of the 76 patients who received nitroglycerin during transport, 30 (39.5%) had RCA as culprit vessel. In the Standard-HEMS group, 12 of 32 (37.5%) of the patients who had occluded RCA received nitroglycerin compared to 18 of 155 (11.6%) patients in the Physician-HEMS group ($P<0.001$). The Standard-HEMS group was more likely to receive fluid bolus and anti-thrombotic medication in-flight. The median first electrocardiogram-to-balloon (ECG2B) time was longer for the Standard-HEMS group

Table 2. In-Transport Events, Procedures and Medications

	Physician-HEMS (n=327)	Standard-HEMS (n=71)	*P* Value
Events			
Death, n (%)	0	0	NA
Cardiac arrest, n (%)	8 (2.4)	1 (1.4)	1.00
Serious arrythmia, n (%)	11 (3.4)	3 (4.2)	0.715
Procedures			
Intubation, n (%)	18 (5.5)	5 (7.0)	0.051
DCCV, n (%)	7 (2.1)	2 (2.8)	0.651
Transcutaneous pacing, n (%)	3 (0.9)	1 (1.4)	0.522
CPR, n (%)	3 (0.9)	5 (7.0)	1.00
Medications			
Analgesics, n (%)	71 (21.7)	30 (42.3)	<0.001
Paralytics, n (%)	7 (2.1)	0	0.608
Fluid bolus, n (%)	18 (5.5)	9 (12.7)	0.019
Intravenous metoprolol, n (%)	43 (13.1)	3 (4.2)	0.057
Vasopressors, n (%)	2 (0.6)	3 (4.2)	0.036
Anti-arrhythmics, n (%)	8 (2.4)	3 (4.2)	0.408
Anti-thrombotics, n (%)	14 (4.3)	22 (31)	<0.001
Nitroglycerin, n (%)	50 (15.3)	36 (36.6)	<0.001

CPR indicates cardiopulmonary resuscitation; DCCV, direct current cardioversion; Physician-HEMS, physician-staffed helicopter emergency medical service; Standard-HEMS, non-physician-staffed helicopter emergency medical service.

compared to the Physician-HEMS group (118 vs 107 minutes; $P=0.002$; Table 3). There was no statistical difference in flight distance, ground time, and flight time between the 2 groups.

Table 3. Transportation Metrics*

	Physician-HEMS (n=327)	Standard-HEMS (n=71)	*P* Value
Flight distance, nautical miles (IQR)	33 (30–37)	33 (29–37)	0.980
Ground time, minute (IQR)	18 (15–21)	17 (13–21)	0.057
Flight time, minute (IQR)	18 (15–20)	19 (16–22)	0.619
ECG2B, minute (IQR)	107 (94–121)	118 (98–138)	0.002
D2B, minute (IQR)	113 (99–134)	124 (102–148)	0.014

D2B indicates time from arrival at percutaneous coronary intervention (PCI) referring hospital to balloon inflation; ECG2B, time from first electrocardiogram acquisition to balloon inflation; Flight time, time from helicopter takeoff to landing; Ground time, time from helicopter landing at PCI referring hospital to take-off; IQR, interquartile range; PS-HEMS, physician-staffed helicopter emergency medical service; Standard-HEMS, non-physician-staffed helicopter emergency medical service.
*Continuous variables are expressed as median±IQR.

In-Hospital Outcomes

There was no statistical difference in the rate of in-hospital death between the Standard-HEMS and Physician-HEMS groups (9.9% vs 4.9%; *P*=0.104; Table 4). The rate of any serious in-hospital adverse event was higher in the Standard-HEMS group compared to the Physician-HEMS group (25.4% vs 11.3%; *P*=0.002), including cardiac arrest (8.5% vs 1.2%; *P*=0.003), cardiogenic shock (14.1% vs 5.5%; *P*=0.01), and need for intra-aortic balloon counter-pulsation (21.1% vs 11.9%; *P*=0.04). Of the patients who sustained any in-hospital adverse outcome (n=52), 3 of 15 (20%) in the Standard-HEMS group were given nitroglycerin versus 6 of 37 (16.2%) of those in the Physician-HEMS group (*P*=0.044). Similarly, 6 of 15 (40%) of the patients who were given analgesics in the Standard-HEMS group sustained an in-hospital adverse event compared to 10 of 37 (27%) of those in the Physician-HEMS group (*P*=0.025).

Median length of hospital stay was not statistically different between the 2 groups (3 days for both groups; *P*=0.234). After adjusting for age, sex, Killip class, and transport time, patients transferred by Standard-HEMS had an increased risk of any serious in-hospital adverse event (odds ratio [OR]=2.91; 95% CI=1.39–6.06; *P*=0.004; Table 5).

Table 4. In-Hospital Outcomes*

	Physician-HEMS (n=327)	Standard-HEMS (n=71)	*P* Value
Death, n (%)	16 (4.9)	7 (9.9)	0.104
IABP, n (%)	39 (11.9)	15 (21.1)	0.04
Cardiogenic shock, n (%)	18 (5.5)	10 (14.1)	0.01
Bleeding, n (%)	4 (1.2)	2 (2.8)	0.291
Tamponade, n (%)	2 (0.6)	0	1.00
Ventricular free wall rupture, n (%)	1 (0.3)	0	1.00
Need for dialysis, n (%)	1 (0.3)	0	1.00
Ventilator-associated pneumonia, n (%)	1 (0.3)	2 (2.8)	0.083
Cardiac arrest, n (%)	4 (1.2)	6 (8.5)	0.003
Serious arrhythmia, n (%)	8 (2.4)	12 (16.9)	<0.001
Recurrent MI, n (%)	3 (0.9)	1 (1.4)	0.546
Stroke, n (%)	2 (0.6)	0	1.00
Any adverse event, n (%)	37 (11.3)	18 (25.4)	0.002
Median LOS, days (IQR)	3 (2–3)	3 (2–4)	0.234
Median LVEF, % (IQR)	50 (40–55)	50 (41–56)	0.514

IABP indicates intra-aortic balloon counterpulsation; IQR, interquartile range; LOS, length of stay; LVEF, left ventricular ejection fraction; MI, myocardial infarction; Physician-HEMS, physician-staffed helicopter emergency medical service; Standard-HEMS, non-physician-staffed helicopter emergency medical service.
*Continuous variables are expressed as median±IQR.

Discussion

To our knowledge, this is the first study to compare physician-staffed to non-physician-staffed HEMS for patients with STEMI. The main findings from our study are that patients transferred by Standard-HEMS: (1) were more likely to receive opioid analgesics during transport; (2) were more likely to receive nitroglycerin and intravenous fluids; and (3) had a nearly 3-fold higher adjusted risk of in-hospital adverse outcomes. These differences were not associated with a statistically significant difference in mortality between the groups.

A previous study showed that nonphysician HEMS transport of patients with acute coronary syndrome was safe.[12] However, that study was not designed to compare different methods of transportation. A survey of flight nurses showed that physicians made unique and important contributions to the care of 18% of patients with MI.[13]

Outcomes comparison before and after implementation of physician-staffed HEMS has been done for trauma transport. One study found that physician-staffed HEMS was associated with lower mortality of >250 blunt trauma patients.[14] Contemporary series have shown several benefits of having physician-staffed crews for regional trauma systems, including faster transport time.[15,16]

We think that the observed association between Standard-HEMS and higher rates of adverse in-hospital outcomes, such as cardiac arrest and cardiogenic shock, might be explained by several factors. First, the Standard-HEMS group had slightly longer ECG2B time, but the effects of early revascularization on survival are well known.[17] Given that the ground time and flight time were not significantly different between the 2 groups, this could be because of shorter transfer time after landing at the receiving PCI hospital. Or, this could be

Table 5. Predictors of Any Adverse In-Hospital Outcomes of ST-Elevation Patients Transferred by Helicopter Emergency Medicine Services*

	OR	95% CI	*P* Value
Age	1.01	0.99 to 1.04	0.417
Sex	0.77	0.37 to 1.56	0.462
Killip class	2.17	1.71 to 2.75	<0.001
Ground time	0.94	0.89 to 0.99	0.025
Flight time	1.03	0.96 to 1.10	0.479
Non-physician-staffed HEMS	2.91	1.39 to 6.06	0.004

HEMS indicates non-physician-comprised helicopter emergency medicine flight crews; OR, odds ratio.
*Any adverse in-hospital outcome was defined as having any of the following: death, stroke, cardiac arrest, need for intra-aortic balloon pump, bleeding, cardiogenic shock, new requirement for dialysis, recurrent myocardial infarction, serious arrhythmia, or vascular complication.

explained by a delay from first ECG to HEMS arrival. Second, the Standard-HEMS group was more likely to receive intravenous nitroglycerin and opioid analgesics, such as morphine and fentanyl. This finding could suggest that flight paramedics and nurses are more likely to give these medications routinely compared with flight physicians. Interestingly, in this study, almost 40% of the patients who received nitroglycerin had RCA as the culprit vessel. Previous studies have shown that nitroglycerin can cause hypotension and worse outcomes, particularly in the setting of right ventricular infarction.[18,19] In a recent study, STEMI patients who were given morphine demonstrated decreased response to antiplatelet agents, possibly attributed to delayed gastric transit and impaired absorption. This effect could increase risk of thrombosis and recurrent MI.[20] The 2013 AHA/ACC STEMI guidelines recommend morphine for chest pain and pulmonary edema, but this medication has been linked to increased mortality.[21] Third, the Standard-HEMS group was more likely receive intravenous fluid bolus, which could lead to pulmonary edema in patients who already have a propensity for high left ventricular filling pressure.

Baseline demographics and cardiovascular disease risk factors were similar in the 2 groups and thus are unlikely to explain the difference in outcomes. Also, baseline Killip class—a strong predictor of adverse outcomes[22]—was not significantly different between the 2 groups. The same was also true when we compared the demographics and patient management transferred to University of Wisconsin without a physician (n=23) and the Mayo La Crosse group (n=48). The Physician-HEMS group had a higher rate of LAD occlusion than the Standard-HEMS group. We think that this difference is also unlikely to have affected our results because LAD occlusion has been shown to be associated with worse prognosis,[23] which is contrary to our findings given that the Physician-HEMS group had lower rates of in-hospital adverse outcomes.

Our study has several limitations that are worth mentioning. First, this is a retrospective analysis and is potentially subject to documentation and recall bias. Second, the Physician-HEMS group was larger than the Standard-HEMS group. This is because the majority (>90%) of STEMI patients transferred by helicopter to the University of Wisconsin is by physician-staffed HEMS. Third, the overall number of patients in our study is modest, but still larger than similar studies on helicopter transport of STEMI patients.[6] However, we had enough clinical events to construct robust models for multivariable adjustment. The patient cohorts received treatment by 2 different care teams at two hospitals, which is a potential confounder despite similar baseline characteristics. Also, the indications for medications (such as nitroglycerin and analgesics) given during transfer were unavailable, and thus we could not assess appropriateness of medication administration.

Furthermore, we were unable to compare troponin concentrations (to estimate infarct size) in the 2 groups because University of Wisconsin uses Troponin-T, but Mayo Clinic uses Troponin-I. However, we had information on postprocedure left ventricular ejection fraction (LVEF), and this was not different between the 2 groups. Because of study design, we could not report compliance with medications such as antithrombotics or beta-blockers before transfer. However, the vast majority of the patients received recommended medical therapy during their acute hospitalization for STEMI. Last, a more-detailed analysis of the HEMS crews (eg, physician/registered nurse [RN] vs RN/paramedic or paramedic/paramedic) may have given additional insight into crew composition and its association with outcomes.

In conclusion, our findings suggest a higher rate of in-hospital adverse outcomes in STEMI patients transferred by non-physician-staffed HEMS. However, there was no difference in the rate of adverse events during transport. The higher risk of in-hospital adverse outcomes could be related to medications such as nitroglycerin or intravenous analgesics in-flight or because of other patient- or transport-related unmeasured confounders. The data are retrospective and thus only hypothesis generating. However, the results could have important clinical implications if confirmed in prospective or randomized trials. One potential implication is a novel recommendation for physician-staffed HEMS in STEMI transfer systems. A cost-benefit analysis would be helpful before such implementation because of increased cost related to the addition of a physician to the flight crew.[12] Finally, our results underscore the importance of judicious use of nitroglycerin and intravenous analgesics for STEMI patients. Further investigation of administration of these medications during transport is needed.

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Disclosures

None.

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Outcomes of Physician–Staffed Versus Non–Physician–Staffed Helicopter Transport for ST–Elevation Myocardial Infarction

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