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Original Research

Hot Loading Reduces Time to Intervention for ST-segment Elevation Myocardial Infarction Patients Being Transferred by Helicopter

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A B S T R A C T

Objective: The aim of this study was to quantify the effect of helicopter hot loading on the time to percutaneous intervention (time-to-PCI) in patients with ST-segment elevation myocardial infarction (STEMI) undergoing interhospital transfer.

Methods: We performed a retrospective cohort study using data from 2009 to 2014, looking at all patients who had an STEMI, were transferred from a single non-PCI hospital by helicopter emergency medical services, and who received PCI intervention at the PCI-capable hospital. Differences in loading method, flight details, and patient demographics were analyzed to measure the effectiveness of the intervention.

Results: During the 5-year study period, 134 STEMI patients were transferred. Sixty-four were hot loaded (47.7%), and 70 were cold loaded. Patients who were hot loaded had a median reduction in interhospital transfer and time-to-PCI of 22.3 minutes from 91.0 minutes (interquartile range, 65–117 minutes) by cold load to 69.5 minutes (interquartile range, 47.5–91.5 minutes) by hot load. There was no increase in reported safety-related events during the hot load process. The median length of hospital stay was equivalent for both groups at 3 days.

Conclusions: This protocol of helicopter hot loading STEMI patients presenting to a non-PCI hospital significantly reduced the median time of interhospital transfer and time-to-PCI without an increase in reported safety events.

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The leading cause of death in the United States is heart disease, which is often manifested as a myocardial infarction. One of the most damaging types of myocardial infarctions is an ST-segment elevation myocardial infarction (STEMI), which indicates a block of blood flow to the entire thickness of the myocardial wall. In the treatment of STEMI, quick reperfusion has the potential to save cardiac muscle. The 2013 American College of Cardiology/American Heart Association reperfusion guidelines recommend a door-to-balloon time (DTBT) of less than 90 minutes for all STEMI patients presenting to percutaneous coronary intervention (PCI)-capable hospitals and less than 120 minutes for those same patients presenting to non-PCI hospitals.¹

The DTBT of STEMI patients undergoing interhospital transfer regularly exceeds the recommended 120 minutes at some centers. Several studies have shown methods for decreasing this time through well-designed systems of rapid triage and transfer.²

The use of helicopter emergency medical services (HEMS) may be an important component in lowering DTBT for interhospital transfers in areas where there may be a long distance between non-PCI and PCI-capable hospitals.^{3,4}

To further decrease DTBT, another option for some STEMI patients is to “hot load” them in order to expedite transfer from non-PCI hospitals to PCI-capable hospitals. Hot loading is a method of patient loading in which the helicopter’s blades and engine are not shut off upon landing. The patient is then loaded into the helicopter while the blades are still spinning. It is thought that hot loading saves time in patient transport when compared with “cold loading” (ie, the blades are completely stopped and the engine shut down for the duration of patient loading). Flight crews estimate that the time saved by hot loading may be 12 to 20 minutes in some cases.⁵ Conversely, there is concern that this expedited process may pose a safety hazard for staff and patients; it also decreases the integrity of patient handoff from the non-PCI hospital to HEMS. A handful of studies have investigated the role of hot loading in transport time for trauma scenes, but this overall body of literature remains sparse.⁶

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In this study, we investigate the impact of the implementation of hot loading and a rapid handoff on the time to PCI (time-to-PCI) in patients undergoing interhospital transfer for STEMI.

Methods

This study was reviewed and approved by our medical center's institutional review board.

Study Design

We performed a retrospective cohort study with historic data from a single HEMS agency's flights from 2009 to 2014. Interhospital STEMI transfers from a single, non-PCI, community hospital to a larger PCI-capable academic medical center were included. The program is staffed using a flight nurse, flight paramedic, and HEMS pilot and was exclusively using twin-engine full-authority digital engine control–equipped Eurocopter AS365 Dauphin helicopters during the study period. The majority of cold loads took place before 2011, after which time the majority of transports used the new hot loading protocol with rapid handoff. The referring physician determined the mode and method of transport for these patients with input from the receiving physician.

Transfer Protocol

When a patient presented with an STEMI to the non-PCI hospital's emergency department (ED), identified either by emergency medical services with a prehospital electrocardiogram (EKG) or with the initial EKG in the ED, a “heart alert” would be activated at the PCI-capable facility. The affiliated HEMS program would receive a standby notification and would then be dispatched at the direction of the attending emergency physician or cardiologist at the non-PCI facility. Helicopters were dispatched to the non-PCI hospital from 1 of 2 hangars based first on proximity and then availability. Hangar 1 was located 35.5 miles (57.1 km) away, and hangar 2 was 28.3 miles (45.5 km) from the non-PCI hospital. All helicopters were dispatched with an HEMS team consisting of a pilot, flight nurse, and flight paramedic. All helicopters had identical dimensions and medical equipment.

Cold Loading Protocol

Under the cold loading protocol, the sole method of loading before 2011, the helicopter landed at the sending facility's helipad, and the medical personnel proceeded to the patient's bedside in the ED while the engines were shut down by the pilot. The HEMS team received handoff from the sending facility's providers at bedside in the ED and then proceeded with the patient to the helipad for a cold load. The patient was flown to the PCI-capable facility where they were hot off-loaded and moved directly to the waiting cardiac catheterization laboratory.

Hot Loading Protocol

In July 2011, a hot loading protocol was instituted jointly by the HEMS program and the non-PCI hospital. ED staff at the non-PCI hospital completed loading and helipad safety training. Specific criteria were established for hot-loaded patients. Patients had to be hemodynamically stable, be neurologically intact, not be on more than 3 intravenous drips, not be intubated, not be on a balloon pump, and not be on a ventricular assist device. If any 1 of these criteria was not met, a cold load would be performed. If the patient met hot load criteria, the patient was moved to a partially enclosed elevator anteroom adjacent to the helipad before landing. Upon arrival, the HEMS team proceeded a short distance from the helicopter to this anteroom for a rapid handoff. The patient was then moved to the waiting helicopter for a hot load. Upon arrival at the PCI-capable hospital, the patient was hot off-loaded and moved directly to the cardiac catheterization laboratory in a similar manner as the prior protocol.

Data Collection

We collected retrospective data from patient charts (Powerchart; Cerner Corporation Inc, North Kansas City, MO), prehospital care reports (EMSCcharts.com; EMSCharts Inc, Pittsburgh, PA), and flight logs (Aeromed; Aeromed Software LLC, Phoenix, AZ) for each interhospital transfer for STEMI from the non-PCI hospital. This information was stored in a secure database. A single investigator performed primary data collection with a second investigator performing random checks as confirmation to assess for the accuracy of data extraction.

Data Analysis

Comparisons of transport times to the time of the first PCI balloon inflation were made based on the loading method (ie, hot vs. cold loading). Because the times of patient symptom onset or arrival at the non-PCI hospital were not universally available in the electronic medical record, a decision was made to measure the time from helicopter dispatch from the hangar to first balloon inflation in the heart catheterization laboratory as “wheels-up-to-balloon time” (WTBT) as a consistent surrogate for DTBT or time-to-PCI. WTBT and the length of hospital stay were compared across loading methods using Wilcoxon rank sum testing and reported as the median interquartile range (IQR) because of skewed data. Demographic and procedural data were reported as percentages or mean standard deviations and compared across groups using 2-sample *t* tests. Calculations were performed in SAS (Version 9.4; SAS Institute, Cary, NC) with the aid of a biostatistician. Safety-related events were captured using the HEMS program's standard incident report process.

Results

During the 5-year study period, 134 STEMI patients were identified; 64 were hot loaded, and 70 were cold loaded. Of the total 134 flights meeting the inclusion criteria, 34 (25.4%) were transports by a helicopter dispatched from hangar 1 and 100 were from hangar 2.

Our demographic data showed that the hot-loaded cohort was slightly younger, with a mean age of 64 years (vs. 70 years for cold-loaded patients), and heavier, with a mean mass of 91 kg (vs. 84.9 kg for cold-loaded patients) although these were not statistically significant differences. The distribution of sex in both groups was nearly identical (78% male for hot loading and 77% for cold loading, $P = .892$).

Patients who were hot loaded had a median time-to-PCI (measured by WTBT) of 69.5 minutes (IQR, 47.5–91.5); patients who were cold loaded had a median time-to-PCI of 91.0 minutes (IQR, 65.0–117.0, $P < .001$). The median length of hospital stay was equivalent for both groups at 3 days. The median transport time from the closer hangar was 5.5 minutes quicker; however, this was not statistically significant across the loading cohorts ($P = .54$). A summary of the findings is shown in [Table 1](#). There was no increase in the reporting of safety-related events during hot loads.

Discussion

A majority of hospitals in the United States lack the capabilities to perform PCI and require either interhospital transfer to PCI-capable facilities or the use of fibrinolytic therapy. Although fibrinolysis therapy can be used in advance of PCI, the use of PCI alone is associated with greater infarct artery patency, lower mortality, fewer adverse events, less recurrence, and shorter hospital stay.⁷ Thus, PCI is preferable even if in the case of interhospital transfer from a hospital lacking PCI capability to a PCI-capable hospital. Interhospital transfer of STEMI patients presents an additional time delay to reperfusion by PCI. Multiple previous studies have shown data linking decreasing time-to-PCI with improved clinical outcomes.⁸ Time-to-PCI can be measured in several ways, with the clock starting either with the onset of symptoms to PCI (symptom-to-PCI) or the first medical contact to PCI (FMI-to-PCI). The time of symptom onset can be highly

Table 1
Comparison of Demographic and Transport Data for Hot- and Cold-loaded Cohorts

Variable	Total	Hot Loaded	Cold Loaded	P value
Age (years) ^a	59.4 ± 14.1	58.3 ± 13.5	60.5 ± 14.7	.368
Weight (kg) ^a	87.9 ± 18.7	91.0 ± 19.5	84.9 ± 17.7	.064
Sex, n (%) ^b				.892
Female	30 (22.4)	14 (21.9)	16 (22.9)	
Male	104 (77.6)	50 (78.1)	54 (77.1)	
Hangar, n (%) ^b				.762
Hangar 1	34 (25.4)	17 (26.6)	17 (24.3)	
Hangar 2	100 (74.6)	47 (73.4)	53 (75.7)	
Hospital length of stay (days) ^c	3.00 (1.00)	3.00 (1.00)	3.00 (1.00)	.696
WTBT (min) ^c	81.0 (24.5)	69.5 (22.0)	91.0 (26.0)	<.001
Transport time by hangar (min) ^c		Hangar 1: 86.5 (29) Hangar 2: 81.0 (24)		.541

IQR = interquartile range; SD = standard deviation; WTBT = wheels-up-to-balloon time.

^a Two-sample *t* test, mean ± SD.

^b Chi-square test, n (%).

^c Wilcoxon rank sum test, median (interquartile range).

subjective and may differ between patients based on many factors. Previous literature has shown that the decreasing time delay in symptom-to-PCI is inconsistent, with studies showing no significant improvement in mortality. Multiple studies have shown that decreasing the time of FMC-to-PCI (often reported as DTBT) to less than 90 minutes is a more consistent measure of mortality improvement.⁹ The hospital to which STEMI patients are transferred may also have an impact on outcome. The treatment of patients at higher-volume centralized STEMI centers by physicians who perform a high volume of procedures has shown lower mortality versus low-volume centers.¹⁰

Previous literature has supported the use of HEMS to reduce DTBT in STEMI patients. In a Canadian study, patients identified as having an STEMI by an advanced care paramedic would be met by a helicopter and transferred to a PCI center by air. When compared against patients transported by ground from the same system, there was a shorter median first medical contact to balloon time (127 vs. 158 minutes,) and in-hospital mortality rates were halved (2.5% vs. 5%).¹¹ Other international systems have noted similar findings; in a Danish study, the placement of a HEMS program significantly reduced the time from the EKG diagnosis on scene to arrival at a PCI-capable facility.¹² Similarly, a study performed in the United States showed that ground EMS activation of HEMS for direct transport to a PCI-capable hospital decreased the time to reperfusion when compared with interfacility transfer.¹³

Some literature suggests that STEMI patients presenting to non-PCI-capable facilities who are transferred to a PCI-capable hospital by HEMS rarely achieve timely PCI. In 1 multicenter study of 179 STEMI patients flown to a PCI-capable hospital, only 3% had a DTBT within 90 minutes of transferring hospital arrival; the median DTBT was 131 minutes.¹⁴ Various approaches have been used to identify ways to reduce door-in door-out intervals in this population of patients.¹⁵

Previous literature has shown that hot loading offers a time savings at trauma scenes. A 1994 study showed that hot loading was associated with a decrease in mean helicopter loading time and a mean scene time of 2.0 and 3.1 minutes, respectively.⁶ This study reported that no safety events occurred during the study period and that hot loading had no impact on patient outcome.

With all of this in mind, we offer a hot loading protocol that both decreases the time of FMC-to-PCI, quantified here in a component WTBT, and allows greater centralization of STEMI treatment at a high-volume hospital. Although our study cannot directly link a decrease in time-to-PCI with improved outcomes or mortality, FCM-to-PCI is a regional and national focus of quality improvement initiatives.⁸ To our knowledge, this is the first study to quantify time

savings in regard to interhospital STEMI transfer. Aside from the obvious benefits to time savings and the inferred benefit to patient outcomes, there are benefits to equipment as well. The increased frequency of helicopter engine starts and stops, as seen in a cold load, are associated with higher engine wear and tear.¹⁶ However, when considering maintenance cost savings versus safety, one must always choose the latter.

A potential disadvantage of hot loading is perceived safety issues to bystanders, providers, and patients in the prehospital environment.^{6,16} During our study period, no events occurred in which the loading process needed to be stopped. Although the protocol dictated that all personnel helping with patient loading be trained in loading zone safety, there were occasional hospital personnel who had not participated in training who were with the patient on the helipad. This is likely because of the availability of trained staff at the time of helicopter arrival.

Another difficulty noted by the flight and non-PCI hospital teams was the handoff. Team members noted difficulties relaying information quickly because of the partially enclosed design of the anteroom and noise from the nearby helicopter. Flight crews reported difficult and limited patient assessments at the time of handoff. Studies on intensive care unit transfers show that incomplete handoffs are commonly associated with increased rates of adverse events, increased in-hospital mortality, and less cost-efficient care.¹⁷ A 2013 study showed that the location of handoff for trauma patients at the receiving facility had a significant impact on patient outcome; patients with a formal handoff in the trauma bay were sicker but had an 11 times greater survival rate than those with rapid handoff on the helipad.¹⁸ Although these studies may not entirely apply to the interhospital transfer of patients with STEMI, they do underscore the critical importance of the handoff. The time savings of hot loading should not come at the expense of an adequate handoff. Further research is needed to evaluate the effect of hot loading and rapid handoff on patient outcome.

A final issue raised by flight teams was that the non-PCI hospital would occasionally call for a hot load on a patient who did not meet the criteria. This is likely because of a lack of familiarity with the protocol and its exclusions by non-PCI ED staff. This poses a potential safety issue for loading patients with advanced airways or multiple intravenous medications; however, all of these instances were noted immediately by flight crews who then proceeded with a cold load.

Study Limitations

The hot loading protocol had specific requirements that made it possible to exclude hot loading certain patients who might be the sickest. Because of their complexity, these patients required cold

loading and may have incurred intrinsically longer transport times and created a selection bias in the mortality data. However, this bias is minimized because of the lack of hot loading before 2011. All patients were cold loaded at this point, which provided us with a large cohort of baseline cold loading data. Our study reflects the hot loading protocol in place at a single interhospital route by a single flight program, which may limit extrapolation to all flight programs. Because of the nature of the historic data, the time of patient arrival at the non-PCI hospital was not reliably available through flight records or patient charts, necessitating the use of WTBT as a measure of FMC-to-PCI. This is a consistent but incomplete measure of time of FMC-to-PCI that does not evaluate the timeliness of the non-PCI hospital's triage and heart alert activation. Lastly, our historic flight data did not specify the landing position of the helicopter on arrival at the non-PCI hospital. This may have additional implications not only with loading and transport time but also with staff and patient safety.

Conclusion

A protocol of helicopter hot loading and rapid handoff of STEMI patients presenting to a single non-PCI hospital resulted in a reduction of median transportation time and time-to-PCI by 22.3 minutes.

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