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Achieving timely percutaneous reperfusion for rural ST-elevation myocardial infarction patients by direct transport to an urban PCI-hospital

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Abstract

Backgrounds ST-elevation myocardial infarction (STEMI) guidelines recommend reperfusion by primary percutaneous coronary intervention (PCI) ≤ 90 min from time of first medical contact (FMC). This strategy is challenging in rural areas lacking a nearby PCI-capable hospital. Recommended reperfusion times can be achieved for STEMI patients presenting in rural areas without a nearby PCI-capable hospital by ground transportation to a central PCI-capable hospital by use of protocol-driven emergency medical service (EMS) STEMI field triage protocol. **Methods** Sixty STEMI patients directly transported by EMS from three rural counties (Nassau, Camden and Charlton Counties) within a 50-mile radius of University of Florida Health-Jacksonville (UFHJ) from 01/01/2009 to 12/31/2013 were identified from its PCI registry. The STEMI field triage protocol incorporated three elements: (1) a cooperative agreement between each of the rural emergency medical service (EMS) agency and UFHJ; (2) performance of a pre-hospital ECG to facilitate STEMI identification and laboratory activation; and (3) direct transfer by ground transportation to the UFHJ cardiac catheterization laboratory. FMC-to-device (FMC2D), door-to-device (D2D), and transit times, the day of week, time of day, and EMS shift times were recorded, and odds ratio (OR) of achieving FMC2D times was calculated. **Results** FMC2D times were shorter for in-state STEMIs (81 ± 17 *vs*. 87 ± 19 min), but D2D times were similar (37 ± 18 *vs*. 39 ± 21 min). FMC2D ≤ 90 min were achieved in 82.7% in-state STEMIs compared to 52.2% for out-of-state STEMIs (OR = 4.4, 95% CI: 1.24–15.57; $P = 0.018$). FMC2D times were homogenous after adjusting for weekday *vs*. weekend, EMS shift times. Nine patients did not meet FMC2D ≤ 90 min. Six were within 10 min of target; all patient achieved FMC2D ≤ 120 min. **Conclusions** Guideline-compliant FMC2D ≤ 90 min is achievable for rural STEMI patients within a 50 mile radius of a PCI-capable hospital by use of protocol-driven EMS ground transportation. As all patients achieved a FMC2D time ≤ 120 min, bypass of non-PCI capable hospitals may be reasonable in this situation.

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1 Introduction

Current American College of Cardiology (ACC)/American Heart Association (AHA) guidelines recommend that ST-elevation myocardial infarction (STEMI) patients be transported by an emergency medical service (EMS) directly to a percutaneous coronary intervention (PCI)-capable hospital for primary PCI-administered reperfusion in ≤ 90 min from time of first medical contact (FMC).[1] However, meeting this goal is challenging in rural areas that lack a nearby PCI-capable hospital. To address this challenge, the ACC through its Door-to-Balloon (D2B) Alliance and AHA (Mission: Lifeline) helped establish protocols and regional systems of STEMI care. Improved treatment times for STEMI patients in rural areas have been reported by use of pre-hospital STEMI identification and a STEMI protocol that includes direct transportation to a PCI-capable hospital or rapid inter-hospital transfer, and pre-hospital activation of the cardiac catheterization laboratory.[2–7] Gross, *et al*.,[8] reported that a door-to-patent infarct artery time of < 90 min is achievable in 58% of cases where STEMI is paramedic-diagnosed accompanied by direct triage to a PCI-capable hospital. In accordance with the ACC/AHA guidelines, a STEMI field triage and direct transportation system was developed between University of Florida Health-Jackson-

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ville (UFHJ) and the EMS agencies serving three rural counties in northeast Florida and southeast Georgia lacking PCI capabilities. We report the performance of this system to achieve guideline-recommended FMC-to-device (FMC2D) and door-to-device (D2D) times, and identify any barriers to meeting these goals for STEMI patients directly transported by ground ambulances from those rural counties to University of Florida Health-Jacksonville.

2 Methods

This retrospective study employed the UFHJ PCI registry, that captures all PCI procedures performed there, to identify all patients ≥18 years old with a diagnosis of STEMI (ICD-9 codes: 410.1–410.6, 410.8) transported directly by EMS from three neighboring rural counties (Nassau, Camden and Charlton) within a 50-mile radius of UFHJ for primary PCI between January 1, 2009 and December 31, 2013 (Figure 1). Camden and Charlton counties were defined as rural based on Census Bureau and the Office of Management and Budget definitions.[9] The Florida Department of Health rural classification of a density < 100 persons per square mile was used for Nassau County, Florida. These three neighboring rural counties have a population of over 140,000 (Camden: 50,513, Charlton: 12,171, and Nassau: 73,314), cover roughly over 2,292 mile^2, but do not have a PCI-capable hospital.[9–13] However, they contain community hospitals that have STEMI transfer protocols already in place.

The EMS paramedics were trained to employ a protocol for rapid identification and triage of STEMI patients that incorporated three elements: (1) a cooperative agreement between each of the rural EMS agency and UFHJ; (2) performance of a pre-hospital ECG with paramedic validation to avoid significant artifacts or obvious computer error accompanied by use of a clinical checklist to screen for common confounders or contra-indications to primary PCI;[14] and (3) direct transfer by ground transportation to the cardiac catheterization laboratory at UFHJ. We excluded patients < 18 years and those admitted with non-STEMI or unstable angina. The protocol was approved by University of Florida, College of Medicine Institutional Review Board after determining that the study met the definition of a research protocol that does not require informed consent.

Demographics (age, gender) and D2D times were identified from the patients' medical records. EMS contact, ECG and transportation times were obtained from EMS run sheets. When EMS contact times were not available, field ECG time was used. FMC2D time was the sum of times from EMS contact or field ECG, transportation, and D2D times. Transportation distances to UFHJ were estimated by Google maps (https://maps.google.com). The week was divided into weekdays (Monday-Friday) and weekends (Saturday-Sunday). Due to the differences in EMS shift times among the three counties, we divided EMS shifts into three eight-hour shifts, morning/early afternoon (shift 1), late afternoon/evening (shift 2), and night (shift 3), in order to explore possible nightly delays and human fatigue factors. The primary end-point was determined the performance of the system to achieve guideline-recommended D2D and FMC2D times. Secondary endpoints aimed to detect any effect of week day *vs*. weekend and EMS shift on D2D and FMC2D times.

Descriptive statistics and subsequent analysis was performed using Stata 13IC (Stata Corp., 2013; Stata Statistical Software: Release 13; College Station, TX: StataCorp LP). Normally distributed continuous variables, tested for normality with Shapiro-Wilk test, are expressed as mean ± SD. Categorical variables are presented as *n* (%). Baseline demographics (age and gender), county, EMS service, ECG and transportation times, EMS shifts, weekday/weekend, distance from the county to UFHJ were tabulated. Generalized linear models were used to examine the significance of association with these outcome variables. A *P*-value < 0.05 was considered significant.

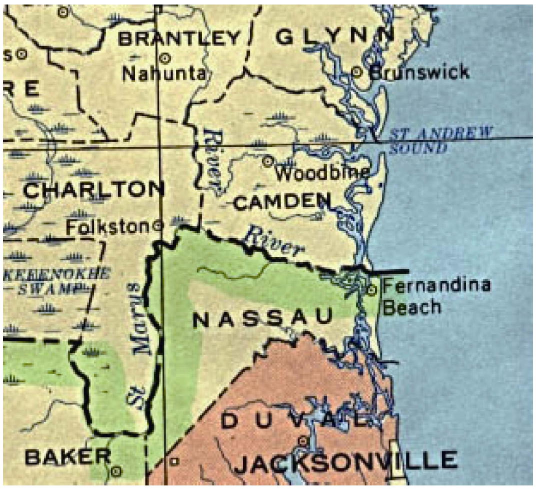

Figure 1. Map depicting the relationship of Nassau, Camden and Charlton Counties, Georgia to the University of Florida Health-Jacksonville, Jacksonville, FL, USA.

3 Results

As shown in Figure 2, 60 of 732 STEMI patients who presented to UFHJ for PCI between January 1, 2009 and

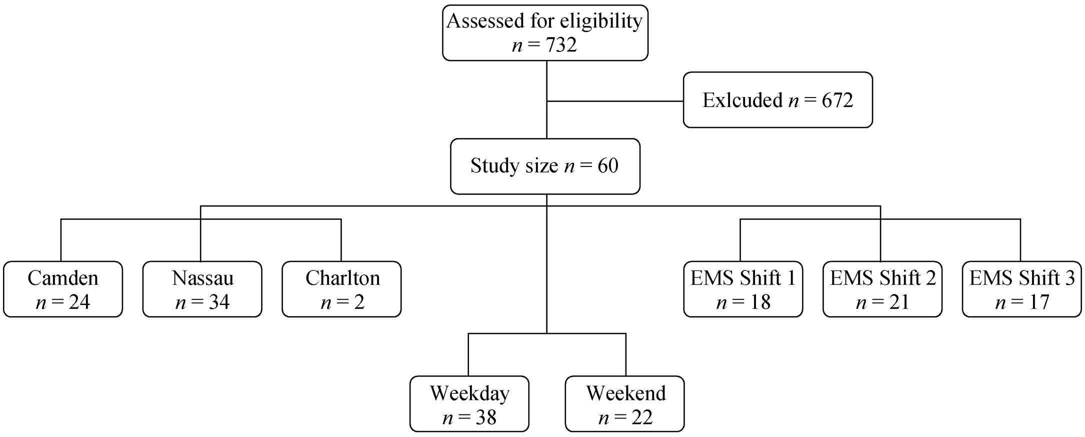

Figure 2. Patient enrollment flowchart. EMS: emergency medical service.

December 31, 2013 met inclusion criteria. Their mean age was 56.6 ± 14.3 years, and 28.3% were females. As only two STEMI cases (3.3%) were from Charlton County, they were combined with those from Camden County for analysis, and the Georgia total was compared to those from Nassau County, Florida. The mean distances that EMS traveled from Charlton, Camden, and Nassau Counties were 48.9, 44.2, and 22.6 miles, respectively.

As delineated in Tables 1 & 2, 36.7% of STEMI cases arrived on weekends, and the number transported by each EMS shift was fairly evenly distributed. The mean FMC2D time was 83.4 ± 17.8 min for the 52 patients for which it could be determined, while the mean D2D time was 38.1 ± 19.3 min. FMC2D times tended to be longer for those transported from Georgia than Florida (86.9 ± 18.6 *vs*. 80.6 ± 16.9 min, P = 0.21), but D2D times were not different (37.4 ± 17.8 *vs*. 38.7 ± 20.7 min, P = 0.77). Although there was a trend for longer FMC2D and D2D times on weekends, it did not reach statistical significance. Similarly, the EMS shift did not significantly impact those times.

Table 1. Patient and system characteristics.

*Age, yrs	56.6 ± 14.3
Gender	
Females	17 (28.3%)
Males	43 (71.7%)
Weekend	
No	38 (63.3%)
Yes	22 (36.7%)
EMS shift	
1	18 (32.1%)
2	21 (37.5%)
3	17 (30.4%)
EMS service	
Camden	24 (40%)
Nassau	34 (56.7%)
Charlton	2 (3.3%)
*D2D, min	38.1 ± 19.3
#FMC2D, min	83.4 ± 17.8

Data are presented as n (%) or mean ± SD. *n = 60, #n = 52. D2D: door-to-device; FMC2D: first medical contact-to-device.

Table 2. Results of system performance.

	N	D2D	**P* value	*N*	FMC2D	**P* value
EMS Service	60			52		
Camden/Charlton	26	37.4 ± 17.8	Reference	23	86.9 ± 18.6	Reference
Nassau	34	38.7 ± 20.7	0.77	29	80.6 ± 16.9	0.21
Weekend	60			52		
No	38	35.7 ± 19.3	Reference	32	81.1 ± 16.2	Reference
Yes	22	42.3 ± 19.1	0.21	20	87.1 ± 19.9	0.24
EMS shift	56			51		
1	18	39.2 ± 21.5	Reference	15	87.9 ± 17.8	Reference
2	21	36.6 ± 17.0	0.67	20	79.9 ± 15.5	0.19
3	17	43.3 ± 17.4	0.51	16	84.1 ± 20.7	0.56

Data are presented as mean ± SD or n. *P value refers to the reference values for each time interval. D2D: door-to-device time; FMC2D: first medical contact-to-device time.

Overall, a FMC2D ≤ 90 min was achieved in 36 (69.2%) patients (Table 3). However, patients transported from Nassau County were more likely to achieve a FMC2D ≤ 90 min compared to those from Georgia (82.8% *vs*. 52.2%; OR 4.4; 95% CI: 1.24–15.57; P = 0.018). A FMC2D ≤ 90 min tended to be more likely achieved in weekdays (63.9%) than weekends (56.3%) (P = 0.60). The best performance was achieved on shift 2 where 16/20 (80%) of patients transported achieved a benchmark FMC2D time (P = 0.10 *vs*. shift 1).

Sixteen (31%) patients did not meet guideline FMC2D times. The causes responsible for the delay could be determined in 8 patients and are listed in Table 4. The most common cause was simultaneous arrival STEMI patients requiring PCI (three patients), while communication issues accounted for a delay in two patients. Despite those system problems, all but one patient achieved FMC2D time ≤ 120 min.

4 Discussion

There is no debate in the benefit of early reperfusion in patients presenting with STEMI. Initiatives such D2B Alliance and Mission: lifeline have spurred establishment of protocols and regional systems of STEMI care that have helped achieve early reperfusion in patients who do not have immediate access to PCI-capable hospital. Utilization of systems of STEMI care improves D2D times.[6,14–17] Guideline recommended reperfusion times are achievable for patients transported to a PCI capable hospital from up to 200 miles away by incorporation of both standardized protocols combining air and ground transport in an integrated transfer system.[8,19] Nallamothu, *et al*.,[20] determined that 47.8% of all rural residents lived within 60 min driving time to a PCI hospital, and 53% would experience < 30 min delay in care by bypassing a closer non-PCI Hospital; percentages for the South Atlantic region were 76.2% and 72.7%, respectively. As many patients are admitted to a non-PCI center, Pathak, *et al*.,[21] modeled inter-hospital ground transfer times of STEMI patients in Florida. They reported that only 2.9% of STEMI patients in rural/nonmetro counties could be transferred to a medium/high volume PCI hospital in 30 min. This led McMullan, *et al*.,[22] to report that pre-hospital transport times could be significantly reduced by EMS initiating on-scene helicopter transport directly to a PCI center. By 2009, almost 90% of STEMI in Florida were directly admitted to a high volume PCI hospital (≥ 400 PCI/year), and residents of nonmetro/rural counties were more likely to be admitted to those hospitals than residents of major metropolitan areas.[23] Supporting this observation was our finding that FMC2D ≤ 90 min was achievable in over 80% of STEMIs directly transported from rural Nassau County. In contrast, only 52% of patients transferred from out-of-state achieved a FMC2D ≤ 90 min despite living within 50 miles of UFHJ. Longer ground transportation times could be an explanation, as the mean distance traveled by the Georgia residents was approximately double that of the Florida residents while the D2D times were not significantly different.[20,21] Importantly, the majority of STEMI patients from neighboring rural counties lacking a PCI capable hospital were able to achieve guideline recommended FMC2D times regardless of day of the week or EMS shift times by direct transportation by EMS to UFHJ using a protocol for rapid STEMI identification. These findings are consistent with other published studies evaluating transfer of STEMI patients from rural areas.[2,4,18]

Eight patients had documented causes for a prolonged FMC2D time. Transit times at certain times of the day, certain days of the week, travel conditions not limited to accidents, ongoing road construction and weather (which is not captured in our database) could delay to treatment.[21] Inclement weather can obviate the use of air transport for those STEMI patients who might benefit from air transport, but they may have no option other than ground EMS trans-

Table 3. Comparison those who achieved a guideline recommended FMC2D compared to those who did not.

	FMC2D ≤ 90 min, *n*	FMC2D > 90 min, *n*	OR	*P*-value
EMS			4.4 (1.24–15.57)	0.018
Nassau	24	5		
Camden/Charlton	12	11		
Weekend			1.38 (0.415–4.565)	0.601
No	23	13		
Yes	9	7		
EMS Shift				0.244
1	8	7	Reference	
2	16	4	0.28 (0.06–1.27)	0.100
3	11	5	0.52 (0.12–2.25)	0.381

FMC2D: first medical contact-to-device time.

Table 4. Causes for prolonged FMC2D.

Cause	*N*
Simultaneous multiple PCI on arrival.	3
Pre-Hospital cardiac arrest	1
Intubation on arrival to PCI capable Hospital	1
Cardiac arrest prior to PCI	1
Communication delay (paging system)	2

FMC2D: first medical contact-to-device time; PCI: percutaneous coronary intervention.

port.[22] Although one cannot predict transit conditions, further improvements in EMS system performance may reduce FMC2D and D2D times and increase the percentage of those meeting those guidelines. A majority of the patients who had above average FMC2D time presented either late in the evening (after 7P.M.) or early morning (before 7A.M.) when the STEMI team was not in the hospital. Although D2D times were met regardless of EMS shift times, D2D times were shorter during the day when the STEMI team was in the hospital. The longer mean FMC2D time for STEMI patients presenting on weekends may have been driven by longer D2D times on weekends. Although on-call 24 h a day, 7 days a week, the STEMI team has to commute from home to the hospital on weekends and nights once the STEMI activation has been confirmed. Other factors that affected D2D times in our study included providing ACLS and or intubating patients prior to PCI, multiple elective or non-elective PCI cases occurring simultaneously with arrival of STEMI patient. In two cases, the D2D time was delayed due to the pager system malfunction and the inability of the STEMI team to receive STEMI pages. However, these delays did not affect overall D2D times. Despite these issues, only one patient in this series experienced an FMC2D > 120 min.

4.1 Limitations

It is a retrospective chart review and as such has inherent limitations. Our data relies heavily on the completeness and accuracy of our database, but confirmation of accuracy could not be ascertained. As with all retrospective studies, we do cannot account for confounders. An important limitation is the small sample size which could be the result of the interaction of the small number of STEMIs in those rural counties, selection bias by EMS providers as to where to transport the STEMI patients, and geographical considerations, e.g., the greater distances of the Georgia counties to UFHJ compared to Nassau County, and the location of PCI-hospitals to the north of the Georgia Counties. Also, the small sample size, results in an underpowered the study, limiting the robustness of the statistical analysis and conclusions. Thus, we could not clearly define specific barriers that could limit achieving a guideline-recommended FMC2D time, and as a result our conclusions are at best hypothesis generating.

Prospective monitoring and recording of data on a larger population can provide more details about the intervention's effectiveness. Multi-center studies will help delineating possible logistic and/or policy challenges and barriers to the program's application in different hospital settings.

4.2 Conclusions

In conclusion, despite the limitations outlined above, we conclude that PCI-based reperfusion within published guidelines can be achieved in STEMI patients residing in rural areas within 50 miles of a PCI hospital by protocol-driven pre-hospital STEMI identification followed by direct ground transportation to that hospital. However, the data also suggest that STEMI patients transported from rural counties within the state are four times more likely to achieve recommended FMC2D times compared to those transported from out-of-state rural counties. However, as all patients achieved a FMC2D time ≤ 120 min, bypass of a closer hospital not equipped to perform PCI may be reasonable in this situation. Prospective studies incorporating larger cohorts will be need to validate these findings and also to identify approaches to improve STEMI system performance.

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