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Renal Protection using Remote Ischemic Peri-conditioning during Inter-Facility Helicopter Transport of Patients with ST-segment Elevation Myocardial Infarction: a Retrospective Study

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Abstract

Objective—To assess the impact of remote ischemic peri-conditioning (RIPC) during inter-facility air medical transport of ST-segment elevation myocardial infarction (STEMI) patients on the incidence of acute kidney injury (AKI) following primary percutaneous coronary intervention (pPCI).

Background—STEMI patients who receive pPCI have an increased risk of AKI for which there is no well-defined prophylactic therapy in the setting of emergent pPCI.

Methods—Using the ACTION Registry-GWTG, we evaluated the impact of RIPC applied during inter-facility helicopter transport of STEMI patients from non-PCI capable hospitals to two PCI-hospitals in the United States between March, 2013 and September, 2015 on the incidence of AKI following pPCI. AKI was defined as 0.3mg/dl increase in creatinine within 48–72 hours after pPCI.

Results—Patients who received RIPC (n=127), compared to those who did not (n=92), were less likely to have AKI (11 of 127 patients [8.7%] versus 17 of 92 patients [18.5%]; adjusted odds ratio=0.32, 95% CI 0.12–0.85, p=0.023) and all-cause in-hospital mortality (2 of 127 patients [1.6%] versus 7 of 92 patients [7.6%]; adjusted odds ratio=0.14, 95% CI 0.02–0.86, p=0.034) after adjusting for socio-demographic and clinical characteristics. There was no difference in hospital length of stay (3 days [interquartile range, 2– 4] versus 3 days [interquartile range, 2– 5], p=0.357) between the two groups.

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Conclusion—RIPC applied during inter-facility helicopter transport of STEMI patients for pPCI is associated with lower incidence of AKI and in-hospital mortality. The use of RIPC for renal protection in STEMI patients warrants further in depth investigation.

Keywords

ischemic preconditioning; acute kidney injury; contrast-induced nephropathy; acute myocardial infarction

INTRODUCTION

Acute kidney injury (AKI) occurs frequently after percutaneous coronary intervention (PCI), and is associated with increased hospital length of stay, cost and mortality.^{1–7} In particular, acute ST elevation myocardial infarction (STEMI) patients undergoing urgent primary PCI (pPCI) have a high risk of developing AKI, with studies suggesting a 20% incidence of AKI in this population.^{8,9} PCI guidelines recommend that patients be risk-assessed for AKI before cardiac catheterization and emphasize AKI prevention strategies including hydration, use of low or iso-osmolar contrast agents, and low contrast volume as much as possible.^{10,11} However, these strategies are often not practicable in the setting of STEMI where prompt revascularization via emergent pPCI is of utmost priority. Emerging evidence suggests that remote ischemic conditioning (RIC), elicited by brief episodes of ischemia and reperfusion at a distant vascular bed, may protect vital organs such as the heart and kidney from subsequent injury.^{12–14} This strategy appears to be protective when applied prior to ischemic injury (pre-conditioning), during ischemic injury (peri-conditioning) or at the onset of reperfusion (post-conditioning).¹⁴ Studies suggest that RIC may attenuate AKI associated with elective coronary angiography¹⁵ and PCI.^{16–18} However, recent studies in patients undergoing cardiac surgery have yielded mixed results.^{19–23} We assessed the associations between remote ischemic peri-condition (RIPC) and AKI in STEMI patients using data from National Cardiovascular Data Registry® (NCDR) Acute Coronary Treatment and Intervention Outcomes Network Registry®-Get With the Guidelines™ (ACTION Registry–GWTG) from two PCI-hospitals in the United States that are utilizing RIPC during inter-facility helicopter transport of STEMI patients for pPCI.

METHODS

Protocol Implementation and Data Sources

The design and conduct of this RIPC protocol during air medical transport has been previously published.²⁴ Two tertiary care STEMI receiving centers (University of Pittsburgh Medical Center Presbyterian Hospital and Passavant Hospital) implemented a protocol for delivering RIPC to STEMI patients transported from non-PCI capable hospitals from within a 16-county region of Southwestern Pennsylvania and Eastern Ohio. Protocol implementation was performed through a quality improvement process and was approved by the Total Quality Council of the University of Pittsburgh Medical Center. The protocol was reviewed and approved by the regional Emergency Medical Services (EMS) council, the state EMS advisory council, the Pennsylvania Department of Health, and the University of Pittsburgh Institutional Review Board.

Prehospital transport and RIPC procedural data were obtained from the air medical service's (STAT MedEvac) electronic patient record (emsCharts, Inc., Warrendale, PA). Procedural data, including number of RIPC cycles completed, were entered by the treating medical crew members prospectively using a custom survey as part of the implementation of RIPC in this air medical transport agency.²⁴ Data from the RIPC quality improvement program were linked to ACTION Registry®-GWTG™ data using deterministic matching. The ACTION Registry-GWTG is a nationwide, voluntary, quality improvement registry sponsored by the American College of Cardiology and the American Heart Association. The registry was established in January 2007 as a risk-adjusted, outcomes-based quality improvement program that focuses exclusively on high-risk STEMI and non-STEMI patients. Details of the design and conduct of the registry have been previously described.^{25,26}

Patient Population

We identified 536 patients with STEMI that presented to the two PCI centers for pPCI from March 2013 through September 2015. Analyses were limited to STEMI patients with inter-facility air transport within the period that the RIPC protocol was implemented. The protocol was first implemented at two air medical base sites as a pilot, then extended to 12 additional base sites, resulting in a cohort of patients that did or did not receive RIPC during transport. STEMI was defined as chest pain or epigastric pain for more than 30 minutes and either (a) new ST elevation at the J point in two contiguous leads with the cut-off points of 0.2 mV in men or 0.15 mV in women in leads V2-V3 or 0.1 mV in all other leads or (b) new or presumed new left bundle branch block on electrocardiogram. Patients were excluded if they arrived directly to the Emergency Department of the two PCI centers (n=88), or were transferred from the field directly to the two PCI centers (n=177). Of the remaining 271 inter-facility transferred STEMI patients, those transported by ground ambulance (n=49), and those with persistent hypotension at the time of air transport (n=3) were excluded. Patients transported by ground ambulance were excluded from the analyses since RIPC was not being done by ground ambulances in this EMS system. We defined hypotension as systolic blood pressure less than 100 mmHg. The final population included in this analysis were 219 inter-facility STEMI patients that were transported by air ambulance and received pPCI with coronary stenting or plain old balloon angioplasty.

Protocol

Remote ischemic peri-conditioning (RIPC) was performed during inter-facility air medical transport by repeated 5-minute cycles of inflation to 200 mmHg and deflation of a blood pressure cuff in the upper arm as previously reported.²⁴ The RIPC protocol utilized a standard manual blood pressure cuff and a commercially available digital timer. STAT MedEvac flight crews comprised primarily of a flight nurse and flight paramedic were instructed to initiate RIPC in eligible patients as soon as possible and continue cycles of inflation and deflation until a maximum of four cycles were achieved or at arrival at the receiving unit. In all patients, RIPC was stopped upon patient arrival in the catheterization lab or the Emergency Department. The RIPC procedure was performed en route, and standard medical care for these patients and timeliness of transport were prioritized over RIPC. RIPC was initiated in 127 patients and 102 (80.3%) received 3 or 4 cycles of RIPC while 25 (19.7%) received 1 or 2 cycles of RIPC en route. All patients received standard

medical care according to established clinical practice guidelines and institutional protocol for STEMI.

Study Outcomes

The primary study outcome was incidence of AKI defined as a relative increase in serum creatinine of ≥ 0.3 mg/dl compared with initial creatinine within 48–72 hours after pPCI (the peak measured concentration of serum creatinine within 48–72 hours of hospitalization post pPCI was used to ensure complete data capture). This definition was based on the 2012 Kidney Disease Improving Global Outcomes (KDIGO) Clinical Practice Guideline on Acute Kidney Injury.²⁷ Severity of AKI was categorized as: Stage 1, ≥ 0.3 mg/dl increase and less than 2.0 times baseline creatinine; stage 2, 2.0 to 2.9 times baseline creatinine; and stage 3, ≥ 3.0 times baseline creatinine. Secondary outcomes included all-cause in-hospital mortality and hospital length of stay after pPCI.

Data Analysis

Descriptive characteristics of the study population are presented as median (interquartile range) or mean (SD) for continuous variables and n (%) for categorical variables. Baseline differences between patients that received RIPC vs. those that did not were tested using Wilcoxon rank-sum tests for continuous variables and chi-squared tests for categorical variables (Fisher's Exact test for very small cells). For outcomes analyses, we report i) the percentage of patients who experienced AKI, ii) the percentage of patients who experienced in-hospital mortality, and iii) the hospital length of stay.

This was not a randomized study and there were some differences in baseline characteristics between the patients that received RIPC and those that did not receive RIPC. To assess the robustness of our results when accounting for potential confounders, we present the effect of RIPC on AKI with a multivariable logistic regression model adjusted for variables with significant baseline differences and selected variables of clinical significance: age, sex, race, smoking, presence of cardiac arrest, heparin use, total contrast used, and initial creatinine.

We also performed secondary analyses exploring the consistency of the effect of RIPC on AKI in a variety of subgroup populations. All statistical analyses were performed using SAS version 9.4 (SAS Institute, Cary, NC).

RESULTS

The study population is described in Table 1. The median age was 62 years (interquartile range: 54–71 years); patients were mostly male (70%) and white (96.8%). Out of the 219 STEMI patients who were transported by air ambulance for pPCI and included in this analysis, 127 patients received RIPC and 92 did not. The RIPC and non-RIPC patients were generally similar in demographic and baseline clinical characteristics as summarized in Table 1. Other than higher prevalence of cardiac arrest in the non-RIPC group, there were no differences in angiographic and procedural characteristics summarized in Table 2. Although baseline creatinine was lower in patients who received RIPC, other renal function parameters as determined by estimated glomerular filtration rate (eGFR) and stage of kidney disease at baseline were similar between the two groups (Table 2). Of note, inter-facility

transit time, door-to-balloon time, left ventricular ejection fraction and peak troponin were not different between the two groups (Table 2).

The overall incidence of AKI in this STEMI population was 12.8% (28/219). As shown in figure 1, STEMI patients who received RIPC were less likely to have AKI compared to patients who did not receive RIPC (8.7% versus 18.5%; unadjusted OR=0.42, 95% CI 0.18–0.94, $p=0.036$). Adjusting for age, sex, race, cardiac arrest, smoking, unfractionated heparin use, cardiac arrest, total contrast used, and initial creatinine did not change the odds of AKI (adjusted OR=0.32, 95% CI 0.12–0.85, $p=0.023$) (Table 3). Further subgroup analyses showed that the magnitude and direction of the RIPC effect on incidence of AKI was generally consistent among different subgroups with the exception of those with morbid obesity ($BMI>35$) as shown in Figure 2.

Similarly, RIPC, compared to non-RIPC, was associated with lower incidence of all-cause, in-hospital mortality (1.5% [2/127] versus 7.6% [7/92], $p=0.026$). Although patients that did not receive RIPC were more likely to have cardiac arrest on first medical contact, adjusting for this factor and other baseline differences did not change the odds of in-hospital mortality (adjusted OR=0.14, 95% CI 0.02–0.86, $p=0.034$). There was no difference in hospital length of stay (3 days [interquartile range, 2–4] versus 3 days [interquartile range, 2–5], $p=0.357$) between the two groups (Table 3).

DISCUSSION

Our results indicate that RIPC applied during inter-facility air medical transport of STEMI patients is associated with a decreased incidence of AKI and in-hospital mortality after pPCI. To the best of our knowledge, this is the first study to report the reno-protective impact of RIPC applied during inter-facility helicopter transport of STEMI patients. Our finding of decreased AKI rate associated with RIPC is consistent with existing evidence.^{15–18}

STEMI patients undergoing pPCI are in particular at high risk of developing AKI.^{8,9} The AKI incidence (18.7%) in patients who did not receive RIPC in the present study is consistent with prior studies.^{8,9,17,19} Factors that may contribute to this risk include use of high volumes of contrast, micro embolization to the kidneys, hemodynamic alterations, and inability to provide appropriate prophylaxis for AKI in the emergent setting of pPCI.^{8,9,28,29} The association of increased serum creatinine and/or AKI with long-term morbidity and mortality^{3–7,30,31} provides further rationale for the development of reno-protective strategies for this patient population.

Emerging evidence suggests that remote ischemic conditioning may protect the kidney from AKI in various clinical settings.^{15–21} Among patients with impaired renal function undergoing elective coronary angiography, Er et al. showed that remote ischemic pre-conditioning of the limb was associated with a reduced rate of AKI.¹⁵ In another clinical trial involving patients with non-STEMI, Deftereos et al. found a reduced rate of AKI with remote ischemic post-conditioning elicited by intermittent angioplasty balloon inflations and deflations in the coronary artery.¹⁶ However, there are potential safety concerns with

intermittent balloon inflations in coronary arteries, including additional myocardial injury and thrombus micro-embolization.³² In a recent small clinical trial of STEMI patients (n=94) in Japan, Yamanaka et al. showed that RIPC applied in the hospital and before PCI significantly reduced AKI (10.6% versus 36.2%) compared with PCI alone.¹⁸ Our study extends upon these findings and provides new insight by demonstrating that RIPC applied to the arm during inter-facility air transport of STEMI patients for emergency pPCI is associated with reduced incidence of AKI. With the exception of those with morbid obesity, the association of RIPC with reduced incidence of AKI appears to be consistent for all subgroups, regardless of the presence of cardiovascular risk factors.

Although the mechanism of kidney protection by RIPC are not entirely clear, it has been suggested that the potential pathophysiological mechanisms involve complex anti-inflammatory, neuronal, and humoral signaling pathways. These include release of nitric oxide and adenosine, induction of hypoxia inducible factor, release of damage-associated molecular pattern molecules, mitigation of free radicals and modulation of mitochondrial activity. These processes ultimately enhance the ability of the kidney to withstand prolonged ischemia and reperfusion injury.^{14, 19,33,34}

Another finding of the present study is an association of RIPC with reduced incidence of in-hospital mortality. Although prior studies have shown no effect of RIPC on in-hospital and 30-day mortality in patients undergoing cardiac surgery.^{19,22,23} In Japanese STEMI patients (n=94), Yamanaka et al. showed a clear trend towards significance for lower major adverse cardiac events in RIPC group (4 versus 14 patients, p=0.07), compared to the control at 30 days following pPCI. In that study, 3 patients had cardiac death in the control group while there was no death in the RIPC group. Furthermore, long-term (3.8 years) follow-up data from a randomized controlled study of RIPC in STEMI patients in Denmark showed reduced major adverse cardiac events (13.5% versus 25.6%) and all-cause mortality (4% versus 12%) in patients that received RIPC, compared to those that did not.³⁵ The results of the present study, which is based on real-world STEMI patients in the US, provide further evidence of the possible beneficial impact of RIPC on mortality. Our observed in-hospital mortality rate of 7.6% in the non-RIPC group is higher than the recently published in-hospital mortality rate of 4.6% in the ACTION registry.³⁶ This may be related to differences in patient population. While the mortality rate reported by McNamara et al included all STEMI patients regardless of mode of presentation, the present analysis is limited to inter-facility transfers who are known to have longer ischemic time and higher mortality rate compared to STEMI patients that present directly to PCI-facility.³⁷ Consistent with other studies, we did not find any significant association of RIPC with in hospital length of stay.^{22,23}

The present study used registry data and thus could not account for confounders that were not captured in the database including amount of intravenous fluid received during and after pPCI. Therefore, we can only determine associations and not causality. Patients in the registry are mostly whites and more likely to be men, which may limit the generalizability to other populations, especially Hispanic and African-American women. Our study, however, has some important virtues. First, it characterizes for the first time, the association of RIPC delivered during inter-facility helicopter transport of real-world STEMI patients with

reduced AKI and in-hospital mortality. Second, the observed reduced incidence of AKI and in-hospital mortality in the RIPC group is an important hypothesis generating finding, for which a larger, multi-center, randomized controlled trial would be necessary.

Conclusions

RIPC applied during inter-facility air medical transport of STEMI patients for pPCI was associated with lower rate of AKI and in-hospital mortality. The use of RIPC as a potential reno-protective strategy for STEMI patients warrants further investigation.

Acknowledgments

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Figure 1.

Incidence of acute kidney injury (AKI) in patients with ST elevation myocardial infarction (STEMI) that received remote ischemic peri-conditioning (RIPC) and those that did not. The overall rate of AKI was 8.7% in the RIPC group versus 18.5% in the non-RIPC group. With regards to stages of AKI, the incidence of AKI was nominally lower in RIPC group, compared to non-RIPC group in stage 1 (6.3% versus 13.0%), stage 2 (1.6% versus 3.3%), and stage 3 (0.8% versus 2.2%) AKI.

Figure 2.
Effect of remote ischemic peri-conditioning (RIPC) on incidence of acute kidney injury (AKI) across subgroups of patients.

Table 1

Baseline Clinical Characteristics and Risk Factors

	Overall	Non RIPC	RIPC	P-Value
# Patients	219	92	127	
Demographics				
Age (Years)	62.0 (54.0–71.0)	62.5 (54.0–70.0)	62.0 (53.0–72.0)	0.715
Gender (% Male)	154 (70.3%)	69 (75.0%)	85 (66.9%)	0.197
Height (cm)	173 (163–180)	173 (166–180)	173 (163–180)	0.438
Weight (kg)	86.0 (77.0–100)	86.0 (78.5–96.5)	86.0 (74.0–100)	0.947
Body Mass Index	29.1 (25.6–33.7)	29.0 (25.1–33.7)	29.4 (25.7–33.8)	0.287
Race				0.472
White	212 (96.8%)	91 (98.9%)	121 (95.3%)	
Black	5 (2.3%)	1 (1.1%)	4 (3.1%)	
Asian	1 (0.5%)	0 (0.0%)	1 (0.8%)	
Other	1 (0.5%)	0 (0.0%)	1 (0.8%)	
Insurance				0.731
Private	111 (50.7%)	47 (51.1%)	64 (50.4%)	
Public	90 (41.1%)	36 (39.1%)	54 (42.5%)	
None	18 (8.2%)	9 (9.8%)	9 (7.1%)	
Medical History				
Smoker	88 (40.2%)	44 (47.8%)	44 (34.6%)	0.050
Hypertension	131 (59.8%)	59 (64.1%)	72 (56.7%)	0.268
Dyslipidemia	114 (52.1%)	48 (52.2%)	66 (52.0%)	0.976
Current Dialysis	0 (0.0%)	0 (0.0%)	0 (0.0%)	
Chronic Lung Disease	12 (5.5%)	5 (5.4%)	7 (5.5%)	0.638
Diabetes	41 (18.7%)	12 (13.0%)	29 (22.8%)	0.067
Prior Myocardial Infarction	31 (14.2%)	13 (14.1%)	18 (14.2%)	0.993
Prior Heart Failure	5 (2.3%)	2 (2.2%)	3 (2.4%)	0.927
Prior Percutaneous Coronary Intervention	32 (14.6%)	16 (17.4%)	16 (12.6%)	0.322
Prior Coronary Artery Bypass Graft	11 (5.0%)	3 (3.3%)	8 (6.3%)	0.310
Prior Atrial fibrillation	7 (3.2%)	3 (3.3%)	4 (3.1%)	0.963
Prior Stroke	9 (4.1%)	2 (2.2%)	7 (5.5%)	0.913
Prior Peripheral Artery Disease	5 (2.3%)	2 (2.2%)	3 (2.4%)	0.927
Home Medications				
Aspirin	68 (31.1%)	31 (33.7%)	37 (29.1%)	0.471
Clopidogrel	8 (3.7%)	3 (3.3%)	5 (3.9%)	0.792
Prasugrel	0 (0.0%)	0 (0.0%)	0 (0.0%)	
Ticagrelor	0 (0.0%)	0 (0.0%)	0 (0.0%)	
Warfarin	3 (1.4%)	1 (1.1%)	2 (1.6%)	0.759
Beta blocker	50 (22.8%)	23 (25.0%)	27 (21.3%)	0.515

	Overall	Non RPC	RPC	P-Value
Angiotensin Converting Enzyme Inhibitor	40 (18.3%)	13 (14.1%)	27 (21.3%)	0.178
Angiotensin Receptor Blocker	16 (7.3%)	6 (6.5%)	10 (7.9%)	0.692
Aldosterone Blocking Agent	3 (1.4%)	2 (2.2%)	1 (0.8%)	0.384
Statin	48 (21.9%)	19 (20.7%)	29 (22.8%)	0.700

Continuous variables presented as median (IQR) and categorical variables presented as n (%).

Table 2

Clinical Presentation, Reperfusion Time, Biomarkers and Angiographic Characteristics

	Overall	Non RIPC	RIPC	P-Value
# Patients	219	92	127	
Signs at Presentation				
Heart Rate (beats per minute)	76.0 (66.0–90.5)	82.0 (66.0–95.0)	76.0 (66.0–88.0)	0.091
Systolic Blood Pressure (mmHg)	145 (124– 165)	140 (117– 171)	146 (129– 163)	0.274
Shock on First Medical Contact	6 (2.7%)	4 (4.3%)	2 (1.6%)	0.215
Cardiac Arrest on First Medical Contact	22 (10.0%)	17 (18.5%)	5 (3.9%)	<0.001
Anticoagulant				
Unfractionated Heparin	204 (93.2%)	80 (87.0%)	124 (97.6%)	0.008
Enoxaparin	4 (1.8%)	2 (2.2%)	2 (1.6%)	0.727
Bivalirudin	77 (35.2%)	37 (40.2%)	40 (31.5%)	0.145
Glycoprotein 2B3A	82 (37.4%)	39 (42.4%)	43 (33.9%)	0.214
Diseased Vessels				
Vessels with Significant Disease				
Left Main	6 (2.7%)	3 (3.3%)	3 (2.4%)	0.688
Proximal Left Anterior Descending	43 (19.6%)	19 (20.7%)	24 (18.9%)	0.747
Mid/Distal Left Anterior Descending	68 (31.1%)	34 (37.0%)	34 (26.8%)	0.108
Left Circumflex	61 (27.9%)	26 (28.3%)	35 (27.6%)	0.909
Right coronary	111 (50.7%)	54 (58.7%)	57 (44.9%)	0.044
Ramus Intermedius	6 (2.7%)	3 (3.3%)	3 (2.4%)	0.688
Number of Diseased Vessels				0.491
1	151 (68.9%)	60 (65.2%)	91 (71.7%)	
2	42 (19.2%)	21 (22.8%)	21 (16.5%)	
3	26 (11.9%)	11 (12.0%)	15 (11.8%)	
Left ventricular Ejection Fraction	52.0 (40.0–58.0)	53.0 (43.0–58.0)	50.0 (40.0–57.0)	0.104
Culprit Vessels				0.999
Left Anterior Descending	77 (35.2%)	32 (34.8%)	45 (35.4%)	
Non Left Anterior Descending	142 (64.8%)	60 (65.2%)	82 (64.6%)	
Coronary Intervention/Stent Type				
Plain Old Balloon Angioplasty	23 (10.5%)	7 (7.6%)	16 (12.6%)	0.096
Bare Metal Stent	54 (24.7%)	29 (31.5%)	25 (19.7%)	
Drug Eluting Stent	142 (64.8%)	56 (60.9%)	86 (67.7%)	
Cardiac and Renal Biomarkers				
Initial Troponin (ng/mL)	0.5 (0.0– 4.5)	0.4 (0.0– 5.0)	0.5 (0.0– 4.5)	0.804
Peak Troponin (ng/mL)	40.9 (13.9– 101)	31.4 (9.4–88.8)	46.9 (16.4– 101)	0.258
Initial Creatinine (mg/dL)	1.0 (0.8– 1.2)	1.0 (0.8– 1.2)	1.0 (0.8– 1.1)	0.041
Initial BUN (mg/dL)	17.0 (13.0–21.0)	16.0 (13.0–21.0)	17.0 (13.0–21.0)	0.419
Initial eGFR by MDRD (ml/min/1.73m ²)	77.7 (62.1–93.8)	72.6 (58.0–90.7)	80.0 (65.6–93.9)	0.078

	Overall	Non RIPC	RIPC	P-Value
eGFR Categories				0.199
<60	49 (22.4%)	26 (28.3%)	23 (18.1%)	
60–90	101 (46.1%)	40 (43.5%)	61 (48.0%)	
>90	69 (31.5%)	26 (28.3%)	43 (33.9%)	
Contrast Media				
Total Contrast Used (mL)	175 (150– 220)	175 (150– 217)	178 (140– 220)	0.566
Contrast Type				0.538
Non-ionic Monomers (Isovue/Omnipaque)	198 (94.7%)	85 (93.4%)	113 (95.8%)	
Non-ionic Dimer (Visipaque)	11 (5.3%)	6 (6.6%)	5 (4.2%)	
Reperfusion Time Intervals				
Door-In-Door-Out (minutes)	54.0 (41.0–72.0)	55.0 (41.0–90.0)	52.0 (40.0–70.0)	0.237
Transport Time (minutes)	29.0 (19.0–35.0)	25.5 (16.0–35.0)	30.0 (22.0–35.0)	0.186
Procedure Time (minutes)	29.0 (23.0–41.0)	31.0 (23.0–50.0)	29.0 (23.0–38.0)	0.255
Door-To-Balloon Time (minutes)	114 (91.0– 138)	114 (92.0– 142)	114 (90.0– 131)	0.294
Door-To-Balloon Time Goal Category				0.623
<120 minutes	128 (58.4%)	52 (56.5%)	76 (59.8%)	
>120 minutes	91 (41.6%)	40 (43.5%)	51 (40.2%)	

Continuous variables presented as median (IQR) and categorical variables presented as n (%).

eGFR = estimated glomerular filtration rate; MDRD = modification of diet in renal disease.

Univariate and multivariate associations of remote ischemic peri-conditioning with acute kidney injury, in-hospital mortality and length of stay

Table 3

	Unadjusted			Adjusted*		
	OR	95% CI	P-Value	OR	95% CI	P-Value
Acute Kidney Injury	0.42	(0.18, 0.94)	0.036	0.32	(0.12, 0.85)	0.023
In Hospital Mortality	0.19	(0.03, 0.96)	0.044	0.14	(0.02, 0.86)	0.034
	Beta	95% CI	P-Value	Beta	95% CI	P-Value
Length of stay	-0.71	(-1.6, 0.27)	0.157	-0.59	(-1.6, 0.44)	0.259

Logistic regression for dichotomous acute kidney injury (AKI) and in-hospital mortality outcomes; linear regression for length of stay outcome

* Adjusted for age, sex, race, cardiac arrest at presentation, smoker, unfractionated heparin use, total contrast used, and initial creatinine