ORIGINAL RESEARCH

# Early Access to the Cardiac Catheterization Laboratory for Patients Resuscitated From Cardiac Arrest Due to a Shockable Rhythm: The Minnesota Resuscitation Consortium Twin Cities Unified Protocol

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***Background***—In 2013 the Minnesota Resuscitation Consortium developed an organized approach for the management of patients resuscitated from shockable rhythms to gain early access to the cardiac catheterization laboratory (CCL) in the metro area of Minneapolis-St. Paul.

***Methods and Results***—Eleven hospitals with 24/7 percutaneous coronary intervention capabilities agreed to provide early (within 6 hours of arrival at the Emergency Department) access to the CCL with the intention to perform coronary revascularization for outpatients who were successfully resuscitated from ventricular fibrillation/ventricular tachycardia arrest. Other inclusion criteria were age >18 and <76 and presumed cardiac etiology. Patients with other rhythms, known do not resuscitate/do not intubate, noncardiac etiology, significant bleeding, and terminal disease were excluded. The primary outcome was survival to hospital discharge with favorable neurological outcome. Patients (315 out of 331) who were resuscitated from VT/VF and transferred alive to the Emergency Department had complete medical records. Of those, 231 (73.3%) were taken to the CCL per the Minnesota Resuscitation Consortium protocol while 84 (26.6%) were not taken to the CCL (protocol deviations). Overall, 197 (63%) patients survived to hospital discharge with good neurological outcome (cerebral performance category of 1 or 2). Of the patients who followed the Minnesota Resuscitation Consortium protocol, 121 (52%) underwent percutaneous coronary intervention, and 15 (7%) underwent coronary artery bypass graft. In this group, 151 (65%) survived with good neurological outcome, whereas in the group that did not follow the Minnesota Resuscitation Consortium protocol, 46 (55%) survived with good neurological outcome (adjusted odds ratio: 1.99; [1.07–3.72], $P$=0.03).

***Conclusions***—Early access to the CCL after cardiac arrest due to a shockable rhythm in a selected group of patients is feasible in a large metropolitan area in the United States and is associated with a 65% survival rate to hospital discharge with a good neurological outcome. **(*J Am Heart Assoc.* 2016;5:e002670 doi: 10.1161/JAHA.115.002670)**

**Key Words:** cardiac arrest • cardiac catheterization • prognosis • revascularization

Each year over 300 000 out-of-hospital cardiac arrests (OHCA) occur in the United States.[1] Despite efforts to increase awareness and training of the general population, outcomes remain poor with reported survival to hospital admission and hospital discharge of 26% and 9.6%, respectively.[2]

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An accompanying Appendix S1 is available at http://jaha.ahajournals.org/content/5/1/e002670/suppl/DC1.

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There has been increased recognition of the importance of post–cardiac arrest care after return of spontaneous circulation (ROSC).[3] One of the objectives of post–cardiac arrest care is to identify and treat the reversible causes of the arrest and prevent recurrent arrest.[3] Early coronary angiography in survivors of OHCA reveals clinically significant coronary artery disease in 71% of patients and acute coronary artery occlusion in 48% of patients.[4] Coronary revascularization has been proven beneficial for patients with ST-segment elevation myocardial infarction on their postarrest ECG.[5–8] However, it is clinically difficult to decide if and when to perform coronary angiography in patients resuscitated from OHCA who remain comatose and do not have a current consistent with injury on their postarrest ECG.[4,5,9,10]

In October 2012, the Minnesota Resuscitation Consortium (MRC) developed an organized approach for the management of all patients resuscitated from shockable (ventricular fibrillation/ventricular tachycardia) rhythms in the metro area of Minneapolis-St. Paul to gain early access to the cardiac catheterization laboratory (CCL) irrespective of ECG findings. We hypothesized that a large proportion of patients presenting with VT/VF have ischemic heart disease as the underlying cause for their cardiac arrest regardless of the presence or absence of ST elevation on the postresuscitation ECG. Our aim was to determine feasibility of a strategy of rapid access to CCL and prompt revascularization of VT/VF patients. We also wanted to obtain preliminary estimates of clinical efficacy. In this article, we report our 2-year experience with the MRC protocol.

## Methods

The MRC was established in 2012 as a statewide effort to improve survival from cardiac arrest in the state of Minnesota (http://www.mrc.umn.edu). Under MRC guidelines, emergency medical services providers, emergency medical services directors, paramedics-receiving emergency departments, CCL directors, and cardiology groups work together to provide optimal resuscitation and postresuscitation care, including therapeutic hypothermia and early access to the CCL.[11] The Minneapolis-St. Paul (Twin Cities area is the 14th largest metropolitan area in the United States according to figures from the 2013 census, with a population estimated to be 3 797 883.[12] The 11 hospitals included in MRC cover 70% of the population in the state of Minnesota.

### Inclusion and Exclusion Criteria

MRC hospitals in the Minneapolis-St. Paul metropolitan area with 24/7 percutaneous coronary intervention (PCI) capabilities agreed to provide early access to the CCL (ie, within 6 hours of arrival to the emergency department, preferably within 2 hours) to all patients who were successfully resuscitated from ventricular fibrillation and/or ventricular tachycardia arrest regardless of the presence of ST-segment elevation myocardial infarction on the surface ECG (Figure 1).

Additional inclusion criteria for this prospective interventional registry were age >18 and <76, and arrest of presumed cardiac etiology. We included witnessed or unwitnessed arrests as well as comatose or conscious patients. All comatose patients received therapeutic hypothermia.[13] Patients whose initial presenting rhythm was pulseless electrical activity or asystole, had a known do not resuscitate/do not intubate status, an obvious noncardiac etiology for their cardiac arrest such as trauma, significant bleeding of any cause, and known terminal disease were excluded. We also excluded patients who did not gain return of ROSC or died prior to arrival to the emergency department. Patients who met inclusion criteria and did not meet any of the exclusion criteria were included in this analysis of the MRC protocol. A detailed review of the medical records was undertaken to understand the rationale for not going to the CCL within the stipulated time frame (Appendix S1).

### Data Collection

Patient outcomes were recorded in the state electronic database Cardiac Arrest Registry to Enhance Survival (CARES). CARES was initiated in October 2004 as a cooperative agreement between the Center for Disease Control and Prevention and the Department of Emergency Medicine at Emory University School of Medicine to identify incidents of prehospital cardiac arrest. The CARES Program is designed to consolidate all essential data elements of a prehospital cardiac arrest event in an efficient manner. The investigators identified the population from the CARES database based on the recorded information that included demographic variables, prearrest medical conditions, resuscitation efforts, postresuscitation care, and outcomes. ECGs were interpreted and coded by the on-call interventional cardiologist performing the procedure. ST-elevation myocardial infarction was defined as 1-mm elevation in the limb leads and 2-mm in the precordial leads. The ST segments were measured 0.24 s after the J point. MRC participating investigators extracted clinically related outcomes and data from the respective participating hospital records. All relevant information was entered in the Redcap database and exported to an Excel format for biostatistical analysis. The institutional review board of each institution approved the protocol and waived the need for informed consent.

The primary outcome of this study was survival to hospital discharge with a favorable neurological outcome defined as cerebral performance category (CPC) score of 1 (normal) or 2 (mild or moderate impairment but still independent).[14]

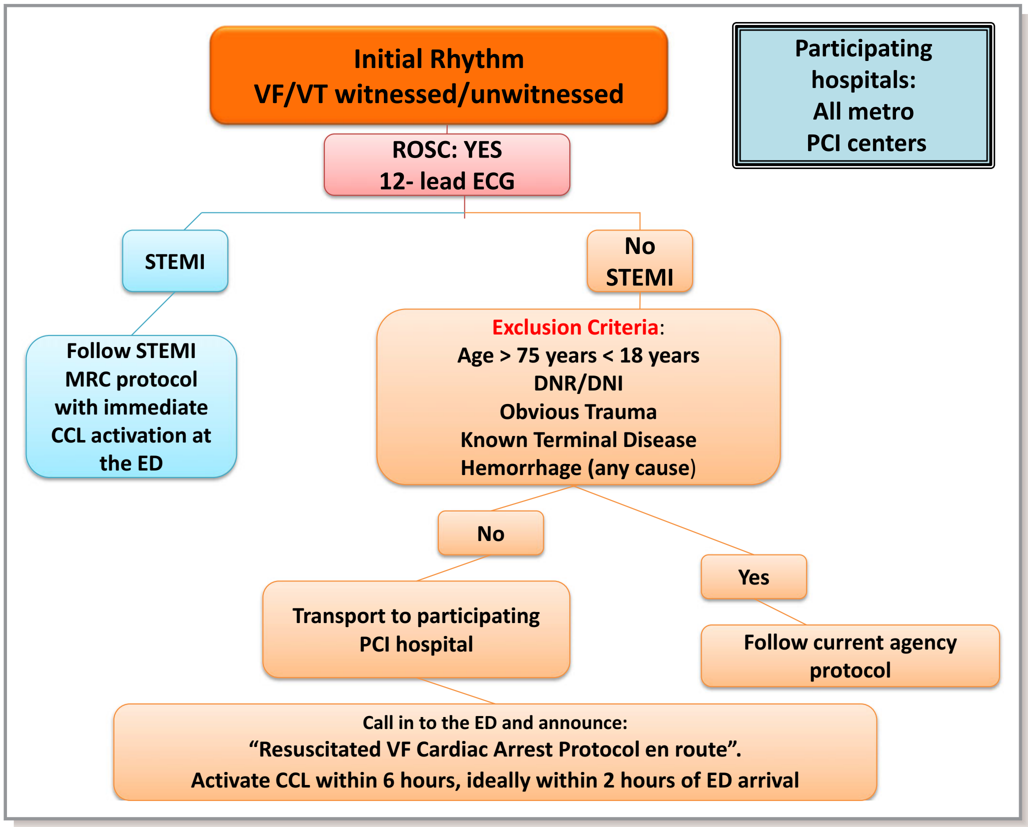


**Figure 1.** The Minnesota Resuscitation Consortium (MRC) protocol for the treatment of out-of-hospital cardiac arrest (OHCA) due to shockable rhythms. CCL indicates cardiac catheterization lab; DNR/DNI, do not resuscitate/do not intubate; ED, emergency department; PCI, percutaneous coronary intervention; ROSC, return of spontaneous circulation; STEMI, ST-segment elevation myocardial infarction; VF/VT, ventricular fibrillation/ventricular tachycardia.

Neurological functional status (CPC) at baseline and at hospital discharge was assessed by review of medical records. CPC assessments were not performed by a blinded independent neurologist. In the state of Minnesota, every survivor of cardiac arrest receives a comprehensive neurological assessment from the treating physician at the point of hospital discharge that is then converted into a CPC score. The CPC score is then imported to the state CARES registry that is housed in MRC. Although treating physicians are not blinded to study interventions, they are not part of MRC.

## Statistical Analysis

Variables are presented as mean$\pm$SD or as percentages. Continuous variables were compared with *t* test when normally distributed and nonparametric test (Mann–Whitney) when skewed. Categorical variables were compared with $\chi^2$ test or Fisher's exact test. Multivariable logistic regression analysis adjusting for age (treated as continuous variable), sex (female versus male), race (white versus all others), location of arrest (home versus all others), bystander cardiopulmonary resuscitation (yes versus no), ST-segment elevation myocardial infarction on ECG, witnessed arrest (yes versus no) and prior history of percutaneous coronary intervention, coronary artery bypass graft (CABG) surgery, previous myocardial infarction, diabetes mellitus, congestive heart failure, hyperlipidemia, and tobacco use was used to assess whether early access to the CCL was a predictor of survival with favorable neurological function. Clinical and demographic variables were obtained from medical records and defined according to the American College of Cardiology Foundation/American Heart Association 2011 Key Data Elements and Definitions of a Base Cardiovascular Vocabulary for Electronic Health Records.[15] Predictors of survival to discharge were assessed using logistic regression models. Both unadjusted and adjusted odds ratios are presented. Adjusted models included the same covariates described above. A prespecified subgroup analysis was conducted among patients with No ST-segment elevation on their postresuscitation ECG. Since these patients have a less well-defined treatment pathway after ROSC,[9] a separate logistic regression analysis, using the same variables as listed above but without ST elevation on ECG, was performed in this subset of patients to determine whether early access to the CCL resulted in survival with favorable neurological function.

All statistical tests are 2-sided and a *P*-value of <0.05 was considered statistically significant. All analyses were performed using the Statistical Analysis System (SAS, version 9.3, 2011; SAS Institute, Cary, NC). Statistical analysis was performed at the University of Minnesota.

## Results

From January 1, 2013 to December 30, 2014, 431 patients were admitted after cardiac arrest to MRC participating hospitals. Of these, 331 patients had cardiac arrest due to shockable rhythms and 315 had complete data sets available combining CARES and hospital records that included hospital outcomes. A complete flow diagram of the study design is presented in Figure 2.

Coronary angiography within 6 hours of arrival to the emergency department was performed in 231 (73.3%) patients, with the majority of patients gaining access to the CCL within 2 hours of presentation (Figure 3). The mean age (±SD) of this group was 55 (±11) years and 177 (77%) were male. Most arrests occurred at home (56%) and were witnessed 152 (66%). Baseline demographic characteristics, prearrest comorbidities, and resuscitation efforts are described in Table 1. Baseline prearrest neurological function was not different between groups.

A total of 84 (26.6%) patients did not undergo urgent angiography within 6 hours and were considered MRC protocol deviations. Of those 84 patients, 32 patients also gained access to the CCL after 6 hours. Six of those 32 patents gained access after 6 hours but within the first day and the other 26 patients after 24 hours. The mean age (±SD) of this group was 53 (±2) years and 65 (77%) were male. Likewise, most arrests in the protocol-deviation group occurred at home (58%) and were witnessed 53 (63%). Patients in this group were more likely to have a past medical history of previous CABG surgery (11% versus 4%, *P*=0.02) and congestive heart failure (20% versus 8%, *P*=0.003). Otherwise, there were no significant intergroup differences in key baseline characteristics (Table 1). The most common reason for deviating from the MRC protocol was the early concern for poor neurological function. Other reasons for MRC protocol deviation are stated in Table 2 and Appendix S1.

## Survival to Hospital Discharge With Favorable Neurological Function

### *All patients*

Patients who were treated according to the MRC protocol had an absolute 10% higher survival to hospital discharge with favorable neurological function compared to protocol failure patients. Using a logistic regression model adjusted for covariates, early access to the CCL was associated with improved survival with favorable neurological outcome with an adjusted odds ratio of 1.99 (1.07–3.72) *P*=0.03 (Table 3). Overall survival was not statistically different. Time to death (in hours) among those patients who did not survive (median: 25–75%) was as follows: access to CCL within 6 hours: 84.3 (8.6–182.6) and no access to CCL: 84.3 (25.7–163.9).

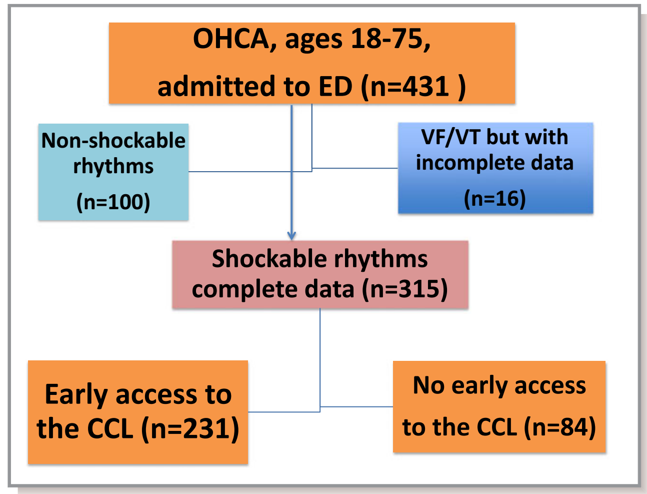


**Figure 2.** Flow diagram of the Minnesota Resuscitation Consortium study cohort 2013–2014. This study comprised 315 patients with shockable rhythms that had complete data. CCL indicates cardiac catheterization lab; ED, emergency department; OHCA, out-of-hospital cardiac arrest; VF/VT, ventricular fibrillation/ventricular tachycardia.

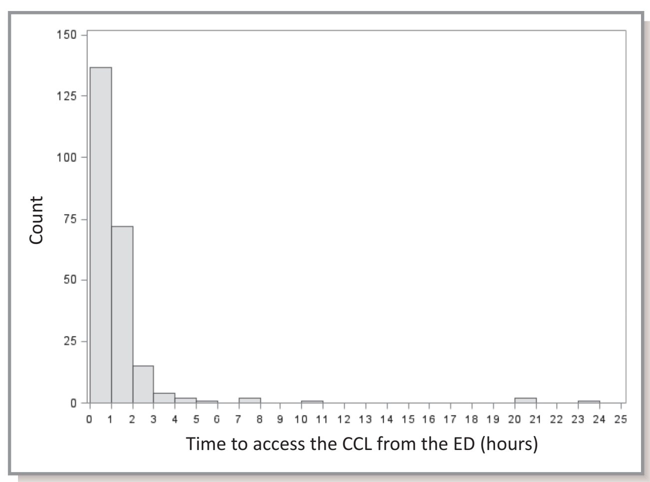


**Figure 3.** Histogram depicting time to access the cardiac catheterization laboratory (CCL) after arrival to the emergency department (ED) (N=231). The majority of patients gained access to the CCL within 2 hours.

**Table 1.** Baseline Characteristics of the Study Population

| | Overall (N=315) | MRC Protocol (N=231) | Protocol Deviations (N=84) | *P* Value |
|---|---|---|---|---|
| Age in y, mean (SD) | 55.0 (11.7) | 55.6 (10.8) | 53.5 (1.93) | 0.21 |
| Sex, N (%) | | | | |
| Female | 73 (23) | 54 (23) | 19 (23) | 0.89 |
| Male | 242 (77) | 177 (77) | 65 (77) | |
| Race, N (%) | | | | |
| White | 259 (85) | 190 (86) | 69 (84) | 0.75 |
| All others | 45 (15) | 32 (14) | 13 (16) | |
| Past medical history, N (%) | | | | |
| PCI | 38 (12) | 28 (12) | 10 (12) | 0.96 |
| CABG | 18 (6) | 9 (4) | 9 (11) | 0.02 |
| MI | 31 (10) | 21 (9) | 10 (12) | 0.46 |
| DM | 58 (18) | 39 (17) | 19 (23) | 0.25 |
| HTN | 139 (44) | 98 (42) | 41 (49) | 0.31 |
| CHF | 36 (11) | 19 (8) | 17 (20) | 0.003 |
| HLD | 89 (28) | 65 (28) | 24 (29) | 0.94 |
| Tobacco use | 114 (36) | 85 (37) | 29 (35) | 0.71 |
| 911 witnessed, N (%) | 40 (13) | 30 (13) | 10 (12) | 0.80 |
| Bystander witnessed, N (%) | 205 (65) | 152 (66) | 53 (63) | 0.67 |
| Bystander CPR, N (%) | 137 (43) | 100 (43) | 37 (44) | 0.90 |
| Amiodarone used, N (%) | 95 (30) | 66 (29) | 29 (35) | 0.31 |
| Epinephrine used, N (%) | 190 (60) | 139 (60) | 51 (61) | 0.93 |
| Advance airway, N (%) | 191 (61) | 143 (62) | 48 (57) | 0.44 |
| AED, N (%) | 173 (55) | 126 (55) | 47 (56) | 0.82 |
| Location of arrest, N (%) | | | | |
| Home | 175 (56) | 126 (55) | 49 (58) | 0.55 |
| All others | 140 (44) | 105 (45) | 35 (42) | |
| Time from event to ED arrival in minutes, mean (SD) | 41.7 (24.3) | 41.9 (25.5) | 41.0 (20.6) | 0.73 |

AED indicates automated external defibrillator; CABG, coronary-artery bypass graft surgery; CHF, congestive heart failure; CPR, cardiopulmonary resuscitation; DM, diabetes mellitus; ED, emergency department; HLD, hyperlipidemia; HTN, hypertension; MI, myocardial infarction; MRC, Minnesota resuscitation consortium; PCI, percutaneous coronary intervention.

### *No ST-elevation patients*

Patients who had no ST elevation on the ECG and were treated according to the MRC protocol had an absolute 13% higher survival to hospital discharge with favorable neurological function compared to protocol failure patients with an adjusted odds ratio of 2.77 (1.31–5.85), *P*=0.01 (Table 3). Overall survival was not statistically different.

## Echocardiographic and Angiographic Outcomes

### *All patients*

The MRC protocol did not affect left ventricular function at hospital discharge as evaluated by echocardiography (Table 4). The most common culprit vessel for patients who went to the CCL according to the MRC protocol was the left anterior descending artery (n=84, 36%). PCI with stent placement was performed in 121/231 (52%) patients and 15 (7%) received a CABG procedure for a total revascularization rate of 59% (Table 4).

Among patients who deviated from the MRC protocol, PCI and CABG were seldom performed: n=7 (n=8%) and n=1 (1%), respectively, for a total revascularization rate of 9%.

### *No ST elevation patients*

The MRC protocol did not improve left ventricular function at hospital discharge as evaluated by echocardiography in the no ST elevation subgroup either (Table 5). The most common

**Table 2.** Stated Reasons Why Patients Did Not Go to the Cardiac Catheterization Laboratory Within 6 Hours (Protocol Violations)

| Stated Reason in the Medical Record, n=52 |
|---|
| Patient/family refusal or family informed MD of patient DNR status, n=3 (5.8%) |
| Physician denial, n=42 (80.8%) |
| Concern for poor neurological function (n=14) |
| No ischemic features on ECG (n=11) |
| Cardiology did not recommend catheterization, no clear reason given (n=6) |
| Other nonischemic etiology thought to be more likely (n=10) |
| Patient was receiving other therapies that delayed catheterization laboratory (n=1) |
| No reason n=6 (11.5%) |
| Died prior to arrival at catheterization lab, n=1 (1.9) |

DNR indicates do not resuscitate.

culprit vessel for patients who went to the CCL according to the MRC protocol was the left anterior descending artery (n=39, 30%). PCI with stent placement was performed in 47/130 (36%) patients and 13 (10%) received a CABG procedure for a total revascularization rate of 46% (Table 4). Among patients who deviated from the MRC protocol, PCI and CABG were seldom performed: n=7/73 (10%) and n=1/73 (1%), respectively, for a total revascularization rate of 11%.

## Effect of Coronary Revascularization

Revascularization with PCI and/or CABG was associated with a significant increase in survival to hospital discharge with favorable neurological function (adjusted odds ratio: 3.04 [1.36–5.66] $P<0.001$) (Table 6). Angiographic variables for patients who entered the CCL based on the presence or absence of ST elevation is presented in Table 7.

## Discussion

Our results suggest that enabling prompt access to the CCL, as part of postresuscitation care of patients with OHCA who present with a shockable rhythm in a large metropolitan area in the United States, is feasible and may improve survival to hospital discharge with favorable neurological function.

Current guidelines emphasize the need for an organized approach to postresuscitation care, including transfer to centers capable of performing therapeutic hypothermia and PCI.[3] The objectives of postresuscitation care are to prevent recurring cardiac arrest and mitigate neurological damage.[3] In the first 2 years of experience with the MRC protocol, we have demonstrated that this organized approach is feasible,

**Table 3.** Survival to Hospital Discharge With Favorable Neurological Outcomes

| Overall Population Outcomes | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Overall (N=315) | MRC Protocol (N=231) | Protocol Deviations (N=84) | Unadjusted OR (95% CI) | *P* Value | Adjusted OR* (95% CI) | *P* Value |
| Discharge alive | 227 (72%) | 170 (74%) | 57 (68%) | 1.31 (0.77, 2.27) | 0.32 | 1.60 (0.83, 3.08) | 0.16 |
| CPC 1 or 2 | 197 (63%) | 151 (65%) | 46 (55%) | 1.56 (0.94, 2.56) | 0.09 | 1.99 (1.07, 3.72)† | 0.03† |
| **No ST-Elevation Population Outcomes** | | | | | | | |
| | All No STE (N=203) | MRC Protocol (N=130) | Protocol Deviations (N=73) | Unadjusted OR (95% CI) | *P* Value | Adjusted OR‡ (95% CI) | *P* Value |
| Discharged alive | 145 (71%) | 95 (73%) | 50 (68%) | 1.25 (0.67, 2.34) | 0.49 | 1.73 (0.80, 3.74) | 0.16 |
| CPC 1 or 2 | 125 (62%) | 86 (66%) | 39 (53%) | 1.70 (0.95, 3.06) | 0.07 | 2.77 (1.31, 5.85)† | 0.01† |
| **STEMI Population Outcomes** | | | | | | | |
| | All STEMI (N=112) | MRC Protocol (N=101) | Protocol Deviations (N=11) | Unadjusted OR (95% CI) | *P* Value | Adjusted OR‡ (95% CI) | *P* Value |
| Discharged alive | 82 (73%) | 75 (74%) | 7 (64%) | 1.65 (0.45, 6.09) | 0.45 | 1.89 (0.48, 7.40) | 0.36 |
| CPC 1 or 2 | 72 (64%) | 65 (64%) | 7 (64%) | 1.03 (0.28, 3.76) | 0.96 | 1.12 (0.30, 4.19) | 0.87 |

CABG indicates coronary artery bypass graft; CHF, congestive heart failure; CPC, cerebral performance category; CPR, cardiopulmonary resuscitation; DM, diabetes mellitus; HLD, hyperlipidemia; HTN, hypertension; MI, myocardial infarction; MRC, Minnesota Resuscitation Consortium; PCI, percutaneous coronary intervention; OR, odds ratio; STE, ST-elevation; STEMI, ST-segment elevation myocardial infarction.

*Adjusted for age, sex, race, history of PCI, CABG, MI, DM, HTN, CHF, HLD, tobacco use, year, location of arrest, bystander CPR, witnessed arrest, STEMI on ECG.

†Statistical significance between the patients that were treated according to the MRC protocol and the protocol deviations.

‡Adjusted for age, sex, race, history of PCI, CABG, MI, DM, HTN, CHF, HLD, tobacco use, year, location of arrest, bystander CPR, witnessed arrest.

**Table 4.** Left Ventricular Function and Angiographic Characteristics of Patients Based on Protocol Compliance

| Overall Population | | | | |
|---|---|---|---|---|
| Echocardiographic and Angiographic Variables | Overall (N=315) | MRC Protocol (N=231) | Protocol Deviations (N=84) | *P* Value |
| % EF at discharge, mean (SD) | 46.1 (15.3) | 45.9 (14.3) | 46.5 (17.9) | 0.81 |
| Location of culprit vessel, N (%) | | | | |
| RCA | 49 (16) | 47 (20) | 2 (2) | |
| LM | 11 (3) | 11 (5) | 0 (0) | |
| LAD | 89 (28) | 84 (36) | 5 (6) | |
| LCX | 35 (11) | 32 (14) | 3 (4) | |
| LIMA | 2 (1) | 2 (1) | 0 (0) | |
| Vein graft | 3 (1) | 2 (1) | 1 (1) | |
| PCI | 128 (41) | 121 (52) | 7 (8) | <0.0001 |
| ECMO, N (%) | 4 (1) | 4 (2) | 0 (0) | 1 |
| Balloon pump, N (%) | 36 (13) | 35 (16) | 1 (2) | 0.005 |
| LVAD, N (%) | 1 (0.3) | 1 (0.4) | 0 (0) | 1 |
| CABG, N (%) | 16 (5) | 15 (7) | 1 (1) | 0.08 |

CABG indicates coronary artery bypass graft; ECMO, extracorporeal circulation membrane oxygenation; EF, ejection fraction; LAD, left anterior descending coronary artery; LCX, left circumflex coronary artery; LIMA, left internal mammary artery; LM, left main coronary artery; LVAD, left ventricular assist device; MRC, Minnesota Resuscitation Consortium; PCI, percutaneous coronary intervention; RCA, right coronary artery.

with 73% of patients gaining access to the CCL within 6 hours and 59% receiving coronary revascularization. More importantly, this approach was associated with a 65% rate of survival to hospital discharge with favorable neurological outcomes. Therefore, our results provide further support to the American Heart Association recommendation to consider interventional treatments after resuscitated OHCA even in the absence of ST-elevation, in the presence of coma, or in conjunction with hypothermia.[3]

The effect observed was sustained regardless of the presence or absence of ST elevation on the post ROSC ECG. For patients with no ST elevation, early access within 6 hours

**Table 5.** Left Ventricular Function and Angiographic Characteristics of Patients Based on Protocol Compliance: No ST-Elevation Population

| Echocardiographic and Angiographic Variables | No STE Population | | | *P* Value |
|---|---|---|---|---|
| | Overall (N=203) | MRC Protocol (N=130) | Protocol Deviations (N=73) | |
| EF postevent, mean (SD) | 47.0 (15.6) | 47.2 (14.1) | 46.6 (18.1) | 0.83 |
| Location of culprit vessel, N (%) | | | | |
| RCA | 23 (11) | 21 (16) | 0 (3) | |
| LM | 8 (4) | 8 (6) | 0 (0) | |
| LAD | 44 (22) | 39 (30) | 5 (7) | |
| LCX | 22 (11) | 19 (15) | 3 (4) | |
| Vein graft | 3 (1) | 2 (2) | 1 (1) | |
| PCI | 54 (27%) | 47 (36%) | 7 (10%) | <0.001 |
| ECMO, N (%) | 2 (1) | 2 (2) | 0 (0) | 1 |
| Balloon pump, N (%) | 17 (10) | 16 (13) | 1 (2) | 0.04 |
| LVAD, N (%) | 1 (0.5) | 1 (0.8) | 0 (0) | 1 |
| CABG, N (%) | 14 (7) | 13 (10) | 1 (1) | 0.02 |

CABG indicates coronary artery bypass graft; ECMO, extracorporeal circulation membrane oxygenation; EF, ejection fraction; LAD, left anterior descending coronary artery; LCX, left circumflex coronary artery; LM, left main coronary artery disease; LVAD, left ventricular assist device; MRC, Minnesota Resuscitation Consortium; PCI, percutaneous coronary intervention; RCA, right coronary artery; STE, ST-elevation.

**Table 6.** Outcomes Based on the Presence or Absence of Revascularization Regardless of Timing to CCL Access

| | Overall (N=315) | PCI or CABG (N=139) | No PCI or CABG (N=176) | Unadjusted OR (95% CI) | *P* Value | Adjusted OR* (95% CI) | *P* Value |
|---|---|---|---|---|---|---|---|
| Discharged alive | 227 (72%) | 112 (79%) | 115 (66%) | 1.88 (1.13, 3.14) | 0.015 | 2.55 (1.32, 4.93) | 0.005 |
| CPC 1 or 2 | 197 (63%) | 102 (72%) | 95 (55%) | 2.09 (1.31, 3.36) | 0.002 | 3.04 (1.36, 5.66) | 0.0005 |

CABG indicates coronary artery bypass graft; CCL, cardiac catheterization lab; CPC, cerebral performance category; OR, odds ratio; PCI, percutaneous coronary intervention.
*Adjusted for age, sex, race, history of PCI, CABG, myocardial infarction, diabetes mellitus, hypertension, congestive heart failure, hyperlipidemia, tobacco use, year, location of arrest, bystander cardiopulmonary resuscitation witnessed arrest.

to the CCL was associated with a 65% survival rate to hospital discharge with favorable neurological function. The positive association was present after adjusting for measured confounders. Our results are in agreement with previous observations by Strote et al in Seattle, WA[16] and Dumas et al in Paris,[6] France and suggest that an organized approach for the treatment of OHCA due to shockable rhythms, such as MRC, is generalizable to other metropolitan areas.

The primary reason that early angiography was implemented as part of the MRC protocol was to allow for early identification and treatment of myocardial ischemia, which is a known trigger of OHCA.[4] Spaulding et al reported the results of immediate coronary angiography performed in 84 consecutive patients between the ages of 30 and 75 years resuscitated from OHCA, 90% of which had ventricular fibrillation/ventricular tachycardia as the presenting rhythm. Sixty of the 84 patients (71%) had clinically significant coronary disease on angiography and 40/84 (48%) had coronary artery occlusion.[4] In the first 2 years, MRC patients who received coronary revascularization were 3 times more likely to survive to hospital discharge than patients who did not receive revascularization, all of which supports the notion that enabling early access to the CCL to define the coronary anatomy and treat ischemic triggers is safe and associated with improved clinical outcomes. The results of our analysis are in concordance with the only randomized animal study, which showed that in the setting of acute coronary occlusion and cardiac arrest, early revascularization improves neurological intact survival at 24 hours.[17]

**Table 7.** Angiographic Data and Revascularization Details for Patients Who Went to the CCL Regardless of the Time

| | Overall (N=263) | STEMI (N=104) | No-STE (N=159) | *P* Value |
|---|---|---|---|---|
| Multivessel CAD* | 136 (52%) | 56 (54%) | 80 (50%) | 0.58 |
| PCI | 128 (49%) | 74 (71%) | 54 (34%) | <0.0001 |
| CABG | 16 (6%) | 2 (2%) | 14 (9%) | 0.03 |
| PCI and/or CABG | 142 (54%) | 75 (72%)† | 67 (42%)† | <0.0001 |
| Location of stents placed | | | | |
| 1 vessel | 115 (44%) | 69 (66%) | 46 (29%) | |
| 2 vessels | 13 (5%) | 5 (5%) | 8 (5%) | |
| 3 vessels | 1 (0.4%) | 1 (1%) | 0 (0%) | |
| No stents placed | 133 (51%) | 29 (28%) | 1045%) | |

The overall prevalence of disease distribution associated with clinical revascularization is shown for patients presenting with STEMI and with No-ST elevation. All STEMI patients who gained access to the CCL did so within 3 hours and all the No-STE patients within 2 days. CABG indicates coronary artery bypass graft; CAD, coronary artery disease; CCL, cardiac catheterization lab; PCI, percutaneous coronary intervention; STE, ST-elevation; STEMI, ST-segment elevation myocardial infarction.
*Defined as the presence of >70% stenosis in the coronary angiography report by the cardiologist unrelated to the "culprit" lesion.
†Statistical significant difference between the ST and no-ST elevation groups.

Even in the context of a well-organized prospective registry, protocol deviations were common (26%). They were most commonly related to cardiologists' concerns for the potential of full neurological recovery at the time of presentation. We have previously shown that neurological recovery can take several days, in particular in the era of widespread use of therapeutic hypothermia.[18] Additional clinical markers (pH <7.2, lactate >7, age >85, initial rhythm non–ventricular fibrillation, >30 minutes to ROSC, end-stage renal disease, or cancer) have been proposed to risk-stratify patients at presentation.[9]

Clinical features such as the occurrence of chest pain and ischemic ECG findings are poor predictors of acute coronary-artery occlusion in the setting of OHCA.[4,9] Since the seminal observation by Spaulding et al, many studies have validated the role of angiography and PCI in survivors of OHCA with ST-segment elevation on their postresuscitation ECG.[6–12,19] The positive results with the MRC protocol are most noticeable in the group without ST elevation because a well-defined postarrest treatment pathway is lacking and early access to the CCL is controversial.[9,10] With an organized and coordinated approach, two thirds of patients gained early access to the CCL and almost 50% underwent coronary revascularization, which is significantly higher than previously reported at 33%.[10]

The association between early access to the CCL and improved survival to hospital discharge may be causal. Most cardiac arrests in the community are due to an acute coronary occlusion.[4] Prompt coronary revascularization has the potential to limit infarct size, improve cardiac function, and reduce arrhythmias and hemodynamic instability postarrest. More importantly, revascularization has the potential to reduce the risk of recurrence of cardiac arrest due to myocardial ischemia.

Public reporting of hospital and CCL mortality rates, along with financial incentives to keep mortality rates low after PCI, might have unintentionally created an adverse environment for patients with OHCA to gain access to the CCL.[20] The American Heart Association has published a scientific statement that describes the obstacles in clinical implementation of early access to the CCL for this patient population.[21] Efforts to keep OHCA mortality rates separate from standard PCI procedures are warranted and ongoing.[21] Additionally, the American College of Cardiology's Interventional Council recently published a treatment algorithm outlining unfavorable resuscitation features at presentation that may assist clinicians in triaging patients with OHCA.[9]

## Limitations

Our study has several important limitations. First, early access to the CCL was part of a multifaceted strategy (ie, early defibrillation, hypothermia, etc) designed to improve outcomes of OHCA survivors with shockable rhythms. The decision to gain early access to the CCL was not randomized and therefore was subject to selection bias, which is a common occurrence in registry data. The reasons for the protocol violations were stated for the majority of patients in our registry, and the most common one was concern for poor neurological function. Multiple factors play a role in the decision of the interventional cardiologist not to take a patient to the CCL including noncardiac comorbidities, duration of resuscitation efforts, family wishes, etc. The question of whether this approach is superior to a strategy of delayed angiography can only be ascertained in a randomized clinical trial. Therefore, our results are encouraging but only hypothesis generating. Second, our experience may not be applicable to other geographic areas or healthcare markets. The Minneapolis-St. Paul area has closely collaborating emergency medical services directors who previously participated in cardiopulmonary resuscitation randomized trials (ResQTrial). In the MRC, emergency medical services directors use unified basic life support and advanced cardiac life support protocols and collectively own 158 LUCAS and Autopulse automated cardiopulmonary resuscitation devices for early transport and transfer of patients with ventricular fibrillation/ventricular tachycardia to participating hospitals. Third, we excluded elderly patients and those presenting with asystole, pulseless electrical activity, or an obvious noncardiac etiology such as trauma. Caution is warranted when extrapolating our results to the broader OHCA population. Fourth, the decision to proceed with coronary revascularization of a potential coronary culprit vessel as well as the modality of revascularization (PCI or CABG) was subjective (ie, left at the discretion of the treating physician). Finally, CPC assessments were not performed by a blinded independent neurologist.

## Conclusions

A clinical protocol of early access to the CCL for patients with OHCA due to a shockable rhythm is feasible and associated with good survival with favorable neurological outcomes. These positive results were also noted in patients without ST elevation on their postresuscitation ECG. A randomized trial evaluating access to the CCL is warranted in this very high-risk population.

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## Disclosures

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