Research Article

In-Hospital Cardiac Arrest in the Cardiac Catheterization Laboratory: Effective Transition from an ICU- to CCU-Led Resuscitation Team

Rajat Sharma,1,2 Hilary Bews,1 Hardeep Mahal,1 Chantal Y. Asselin,3 Megan O’Brien,1 Lillian Koley,1 Brett Hiebert,1 John Ducas,1 and Davinder S. Jassal1,3,4,5

1Section of Cardiology, Department of Internal Medicine, Max Rady College of Medicine, Rady Faculty of Health Sciences, University of Manitoba, Winnipeg, Manitoba, Canada
2Section of Critical Care, Department of Internal Medicine, Max Rady College of Medicine, Rady Faculty of Health Sciences, University of Manitoba, Winnipeg, Manitoba, Canada
3Institute of Cardiovascular Sciences, St. Boniface Albrechtsen Research Centre, University of Manitoba, Winnipeg, Manitoba, Canada
4Department of Radiology, Max Rady College of Medicine, Rady Faculty of Health Sciences, University of Manitoba, Winnipeg, Manitoba, Canada
5Department of Physiology and Pathophysiology, Max Rady College of Medicine, Rady Faculty of Health Sciences, University of Manitoba, Winnipeg, Manitoba, Canada

Correspondence should be addressed to Davinder S. Jassal; djassal@sbgh.mb.ca

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Objectives. (1) To examine the incidence and outcomes of in-hospital cardiac arrests (IHCA) in a large unselected patient population who underwent coronary angiography at a single tertiary academic center and (2) to evaluate a transitional change in which the cardiologist is positioned as the cardiopulmonary resuscitation (CPR) leader in the cardiac catheterization laboratory (CCL) at our local tertiary care institution. Background. IHCA is a major public health concern with increased patient morbidity and mortality. A proportion of all IHCA occurs in the CCL. Although in-hospital resuscitation teams are often led by an Intensive Care Unit- (ICU-) trained physician and house staff, little is known on the role of a cardiologist in this setting. Methods. Between 2012 and 2016, a single-center retrospective cohort study was performed examining 63 adult patients (70 ± 10 years, 60% males) who suffered from a cardiac arrest in the CCL. The ICU-led IHCA included 19 patients, and the Coronary Care Unit-led (CCU-led) IHCA included 44 patients. Results. Acute coronary syndrome accounted for more than 50% of cardiac arrests in the CCL. Pulseless electrical activity was the most common rhythm requiring chest compression, and cardiogenic shock most frequently initiated a code blue response. No significant differences were observed between the ICU-led and CCU-led cardiac arrests in terms of hospital length of stay and 1-year survival rate. Conclusion. In the evolving field of Critical Care Cardiology, the transition from an ICU-led to a CCU-lead code blue team in the CCL setting may lead to similar short-term and long-term outcomes.

1. Introduction

In-hospital cardiac arrest (IHCA) is a major public health burden with increased patient morbidity and mortality. Data from large registries within the United States and United Kingdom report that the incidence of an IHCA ranges from 0.6 to 2.7 per 1000 hospital admissions [1–3]. Despite improvements in survival over the last decade, outcomes from IHCA remain poor with less than 40% of individuals surviving to hospital discharge [4–7]. Approximately 1.3% of all patients who undergo coronary angiography experience an IHCA, with 3.0% of all IHCA occurring in the cardiac catheterization laboratory (CCL) [8, 9]. Advanced cardiac life support (ACLS) in the CCL has advantages and challenges that include the following: (i) complex coordinated team approach between the
in-hospital resuscitation and catheterization lab teams with selection of a single team leader; (ii) availability of continuous physiological monitoring including ECG parameters, pulse oximetry, and invasive hemodynamics; (iii) working around fluoroscopic imaging equipment while shielding resuscitation team members from ionizing radiation; and (iv) immediate access to a mechanical LUCAS device for uninterrupted chest compressions [9–11]. Most IHCA s in the CCL resolve with brief cardiopulmonary resuscitation (CPR) and defibrillation, resulting in high procedural survival [8].

In academic centers across North America, in-hospital resuscitation teams are often led by an Intensive Care Unit (ICU-) trained physician and house staff with the rare involvement of a cardiologist. Similarly, in the setting of an IHCA in the CCL, cardiologists are infrequent members of the CPR team [12]. In a nationwide Denmark study, cardiologists only attended 27% of all IHCA s and were the resuscitation team leader in 12% of the cases [12]. In a complementary study from Italy, cardiologists participated in only 16% of hospital resuscitation teams [13]. As a member of the cardiac arrest team, a cardiologist may possess a unique skillset, which includes cardiac rhythm analysis, bedside focus echocardiography, pericardiocentesis, and/or temporary pacing.

Given the paucity of data on the role of a dedicated cardiologist in the management of IHCA s, the objective of the current study was 2-fold: (1) to examine the incidence and outcomes of IHCA s in a large unselected patient population who underwent coronary angiography at a single tertiary academic center and (2) to compare a transitional change in which the cardiologist is positioned as the CPR leader in the CCL at our local tertiary care institution.

2. Methods

2.1. Study Population. Between 2012 and 2016, a single-center retrospective cohort study was performed, examining adult patients who suffered from a cardiac arrest while admitted to the CCL. The ICU was responsible for responding to all cardiac arrests in the CCL from 2012 to 2014. The Coronary Care Unit (CCU) assumed this role from 2015 to 2016. We identified a total of 63 patients between 2012 and 2016 who suffered an IHCA in the CCL. The ICU-led IHCA s (February 2012–December 2014 inclusive) included 19 patients, while the CCU-led IHCA s (January 2015–August 2016) included 44 patients. Only the IHCA s where resuscitation responded to a code blue were included in the study.

2.2. Definitions. A cardiac arrest was defined as a sudden cessation of cardiac function, precipitated by ventricular tachycardia (VT), ventricular fibrillation (VF), pulseless electrical activity (PEA), or asystole requiring CPR. ICU-led IHCA team members included a critical care specialist and critical care fellow, 2–3 residents (postgraduate trainees with surgical, medical, or anesthesia backgrounds), 2–3 registered ICU nurses, and a respiratory therapist. The CCU-led IHCA team included a cardiologist and cardiology fellow, 1 resident (postgraduate trainee with surgical, medical, or anesthesia background), an anesthesia specialist, 2–3 registered ICU nurses, and a respiratory therapist. During the study span of 2012–2016, the 2010 and 2015 AHA guidelines for CPR were utilized [14, 15].

2.3. Demographics. Demographic information including age, sex of patient, cause of presentation, and comorbidities were collected using a detailed chart review. Resuscitation details included cause and total duration of IHCA, standard CPR (<15 minutes), prolonged CPR (≥15 minutes), use and duration of manual or mechanical compressions, initial rhythm, procedure performed during/after cardiac arrest, and associated laboratory parameters. Primary outcomes included CCL survival, length of hospital stay, and 1-year survival rate. The secondary outcome of neurological recovery was recorded for all patients surviving the initial arrest.

2.4. Statistics. Baseline characteristics were listed as mean values ± standard deviation (SD) or median values (quartile 1–quartile 3) for continuous variables and percentages (absolute numbers) for categorical variables. Baseline characteristics, resuscitation results, and clinical outcomes were compared between the ICU-led and CCU-led IHCA s. Continuous variables were compared using an independent Student’s t-test or Mann–Whitney U-test where appropriate. Categorical variables were compared using the Fisher exact test. Kaplan–Meier survival curves were generated to visualize the 1-year survival rate of each cohort and compared using a log-rank test. Version 9.3 of SAS was used for the statistical analysis, and p < 0.05 was considered statistically significant.

3. Results

At our single tertiary care centre, a total of 63 (0.5%) out of 13,112 patients who underwent a coronary angiogram in the CCL suffered from an IHCA between February 2012 and August 2016. ACLS was led by the ICU team in 19 cases (2012–2014) and the CCU team in 44 cases (2015–2016). Baseline demographics of the study population are outlined in Table 1. The mean age of the study population was 67 ± 10 years in the ICU-led cohort and 70 ± 11 years in the CCU-led cohort. Cardiac risk factors including hypertension, diabetes, and hypercholesterolemia were prevalent in both groups. A significantly higher proportion of patients had a history of smoking exposure in the ICU-led cohort than in the CCU-led cohort (53% vs. 18%; p < 0.01). ST-elevation myocardial infarction (STEMI) was a common indication for coronary angiography in up to 1/3 of the study population (Figure 1). Non-STEMI (NSTEMI) or unstable angina constituted the second most common indication for coronary angiography, representing 37% and 16% of the ICU-led and CCU-led cohorts, respectively (p = 0.07). Other indications for coronary angiography...
included cardiogenic shock, out-of-hospital cardiac arrest (OHCA), congestive heart failure (CHF), stable angina, right heart catheterization, and noncardiac indications (Figure 1).

ACLS was initiated in the CCL for PEA more frequently than ventricular arrhythmias and/or hypotension (Table 1). In the ICU-led group, a total of 3/19 (16%) patients received standard CPR and 16/19 (84%) patients received prolonged CPR (≥ 15 minutes). In the CCU-led group, a total of 12/44 (27%) patients received standard CPR and 32/44 (73%) patients received prolonged CPR (≥ 15 minutes). Although the total length of CPR was similar in both groups, standard CPR (< 15 minutes duration) was shorter in the CCU-led cohort. The majority of patients received chest compressions, including mechanical chest compressions via a LUCAS device in over 25% of the patient population. The duration of manual and mechanical CPR was similar between the ICU-led and CCU-led cohorts (Table 1). Nearly 2/3 of patients required further respiratory support and were subsequently intubated. Mechanical circulatory support (MCS) using an Impella ventricular assist device was frequently employed in both the ICU-led and CCU-led cohorts (39% versus 21%; p = 0.13).

The cause of hemodynamic deterioration was most commonly attributed to cardiogenic shock in the ICU-led cohort as compared to the CCU-led cohort (84% vs. 23%; p < 0.01) as shown in Table 1. Conversely, an arrhythmic cause for cardiovascular collapse was more frequent in the CCU-led cohort as compared to the ICU-led cohort (39% vs. 5%; p < 0.01). The rate of coronary dissection was similar between the two cohorts. Finally, a minority of patients in the CCU-led cohort suffered from a left ventricular free wall rupture, pulmonary embolus, or pulmonary arterial rupture.

Approximately 50% of the study population received emergent revascularization by percutaneous coronary intervention (PCI). In the ICU-led cohort, 10/19 (53%) patients underwent simultaneous PCI during the IHCA, of which 3 (16%) individuals received mechanical compressions with a LUCAS device. In the CCU-led cohort, 21/44 (48%) patients underwent simultaneous PCI during...
resuscitation, of which 3 (7%) individuals also received mechanical compressions. A greater proportion of patients in the ICU-led cohort, as compared to the CCU-led cohort, was surgically revascularized by coronary artery bypass surgery (22% vs. 7%; \( p = 0.18 \)). Emergent pericardiocentesis or valvular surgery was necessary in a minority of cases (Table 1).

With respect to primary outcomes, a significantly greater proportion of patients survived the IHCA in the CCU-led cohort as compared to the ICU-led cohort (75% vs. 47%; \( p = 0.18 \)). Emergent pericardiocentesis or valvular surgery was necessary in a minority of cases (Table 1).

![Figure 1: Indication for cardiac catheterization. CCU, Coronary Care Unit; ICU, Intensive Care Unit; STEMI, ST elevated myocardial infarction; NSTEMI, non-ST elevated myocardial infarction; UA, unstable angina; CHF, congestive heart failure; TAVI, transcatheter aortic valve implantation.](image)

### Code blue indication

| Code blue indication                  | Intensive Care Unit lead (2012–2014; \( n = 19 \)) | Coronary Care Unit lead (2015–2016; \( n = 44 \)) | \( p \)-value |
|--------------------------------------|--------------------------------------------------|--------------------------------------------------|--------------|
| STEMI                                | 36.8% (7)                                        | 34.1% (15)                                      | 0.83         |
| NSTEMI/UA                            | 36.8% (7)                                        | 15.9% (7)                                       | 0.07         |
| Shock                                | 5.3% (1)                                         | 4.5% (2)                                        | 1.00         |
| Non-cardiac                          | 0.0% (0)                                         | 2.3% (1)                                        | 1.00         |
| Out of hospital arrest               | 5.3% (1)                                         | 15.9% (7)                                       | 0.42         |
| CHF                                  | 5.3% (1)                                         | 11.4% (5)                                       | 0.66         |
| Stable angina                        | 10.5% (2)                                        | 4.5% (2)                                        | 0.58         |
| Constrictive pericarditis            | 0.0% (0)                                         | 2.3% (1)                                        | 1.00         |
| TAVI                                 | 0.0% (0)                                         | 6.8% (3)                                        | 0.55         |

4. Discussion

As cardiovascular disease is a leading cause of morbidity and mortality worldwide, the management of individuals who sustain a cardiac arrest in the CCL remains a challenge. In the current study, we demonstrated that (1) the incidence of an IHCA within the CCL is low when acute coronary syndrome (ACS) was the primary indication for cardiac catheterization; (2) PEA was the most common rhythm for ACLS requiring chest compressions, with a mechanical device used in 25% of cases; (3) cardiogenic shock and arrhythmia were the most likely reasons for a code blue response to be initiated in the CCL; (4) neurological recovery among patients who survived an IHCA in the CCL is favourable; and (5) no significant difference was noted in the neurological sequelae (2 delayed recoveries and 1 stroke) as shown in Table 2.
1-year survival rate between the ICU-led and CCU-led cardiac arrest teams.

A review of the literature to date on PubMed/MEDLINE supports that the data on the prevalence of IHCAs in the CCL is limited. Webb et al. previously evaluated the prevalence of IHCAs in patients undergoing PCI at St. Paul’s Hospital in Vancouver, BC, Canada, between 1996 and 1999 [8]. Of the total 4,363 patients (65 ± 13 years old, 61% males) who underwent PCI, only 1.3% suffered an IHCA in the CCL [8]. In addition, Sprung et al. conducted a retrospective analysis of all patients who suffered a cardiac arrest while undergoing coronary angiography or PCI at the Mayo Clinic between 1990 and 2000 [16]. Of the 51,985 coronary angiograms performed during this time frame, only 0.2% of patients suffered a cardiac arrest. Similarly, in our study, we evaluated the prevalence of IHCAs in the CCL from 2012 to 2016, during which time a total of 13,112 coronary angiograms were performed at our single tertiary care academic centre (~2850 angiograms/year). Of this total cohort, only 0.5% suffered an arrest in the CCL necessitating ACLS. Despite the low prevalence of IHCAs in the CCL, patients who require an urgent coronary angiogram for ACS, cardiogenic shock, and/or OHCA may be at an increased risk of developing hemodynamic collapse necessitating ACLS during the invasive procedure [8, 16].

The initial electrical rhythm detected during a cardiac arrest in the CCL is predictive of survival. Previous studies have demonstrated that patients who suffer an IHCA with a shockable rhythm (VF and/or VT) have 3-4-fold improved survival rate, as compared to those patients presenting with a nonshockable PEA rhythm [17–21]. Our study confirmed PEA as the most common rhythm detected prior to the initiation of chest compressions in the CCL. This is likely a consequence of the success in achieving return of spontaneous circulation with the early recognition and defibrillation of ventricular arrhythmias in the CCL, during which time a code blue response was not necessarily activated.

In our study, a mechanical compression device was used in 25% of our patient population. The CCL is an ideal

### Table 2: Comparison of secondary outcomes for patients surviving cardiac arrest in the ICU-led and CCU-led cohorts.

| Outcome                                      | Intensive Care Unit lead (Jan 2012–Dec 2014) (n = 19) | Coronary Care Unit lead (Jan 2015–Mar 2016) (n = 44) | p value |
|----------------------------------------------|-----------------------------------------------------|-----------------------------------------------------|---------|
| Acute kidney injury (survived cath lab)      | 14.3% (1)                                           | 21.1% (4)                                           | 1.00    |
| Neurological Recovery                        |                                                     |                                                     |         |
| Good                                          | 100% (19)                                           | 91.0% (40)                                          | 0.31    |
| Delayed                                       | 0% (0)                                              | 4.5% (2)                                            | 1.00    |
| Poor/stroke                                   | 0% (0)                                              | 4.5% (2)                                            | 1.00    |
| Hospital length of stay in days (survived ICU stay) | 32 (8–42)                                           | 9 (5–14)                                            | 0.32    |

**Figure 2:** Survival rates for the ICU- vs. CCU-led study cohorts. CCU, Coronary Care Unit; ICU, Intensive Care Unit.
5. Conclusion

Although the incidence of an IHCA in the CCL is low, individuals requiring emergent angioplasty for ACS or cardiogenic shock are at greater risk. In the evolving field of Critical Care Cardiology, the transition from an ICU-led to CCU-led code blue team may lead to similar short-term and long-term outcomes. Future clinical studies involving a larger patient population are required to confirm these findings.
Data Availability
The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest
The authors declare that they have no conflicts of interest.

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