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Association between percutaneous hemodynamic support device and survival from cardiac arrest in the state of Michigan☆

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ABSTRACT

Introduction: The role of circulatory support in the post-cardiac arrest period remains controversial. Our objective was to investigate the association between treatment with a percutaneous hemodynamic support device and outcome after admission for cardiac arrest.

Methods: We performed a retrospective study of adult patients with admission diagnosis of cardiac arrest or ventricular fibrillation (VF) from the Michigan Inpatient Database, treated between July 1, 2010, and June 30, 2013. Patient demographics, clinical characteristics, treatments, and disposition were electronically abstracted based on ICD-9 codes at the hospital level. Mixed-effects logistic regression models were fit to test the effect of percutaneous hemodynamic support device defined as either percutaneous left ventricular assist device (pLVAD) or intra-aortic balloon pump (IABP) on survival. These models controlled for age, sex, VF, myocardial infarction (MI), and cardiogenic shock with hospital modeled as a random effect.

Results: A total of 103 hospitals contributed 4393 patients for analysis, predominately male (58.8%) with a mean age of 64.1 years (SD 15.5). On univariate analysis, younger age, male sex, VF as the initial rhythm, acute MI, percutaneous coronary intervention, percutaneous hemodynamic support device, and absence of cardiogenic shock were associated with survival to discharge (each $p < 0.001$). Mixed-effects logistic regressions revealed use of percutaneous hemodynamic support device was significantly associated with survival among all patients (OR 1.8 (1.28–2.54)), and especially in those with acute MI (OR 1.95 (1.31–2.93)) or cardiogenic shock (OR 1.96 (1.29–2.98)).

Conclusion: Treatment with percutaneous hemodynamic support device in the post-arrest period may provide left ventricular support and improve outcome.

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1. Introduction

The benefit of circulatory support in the post-cardiac arrest period remains controversial. Historically, intra-aortic balloon pumps (IABP) have been used as the primary circulatory support device for myocardial infarction (MI) complicated by cardiogenic shock [1]. However, a contemporary prospective, randomized controlled trial has revealed no mortality benefit with this therapy at one month or one year for patients in cardiogenic shock after MI [2]. While use of IABP for cardiogenic shock in the setting of acute MI was once a level 1b recommendation in America, it has recently been downgraded to a level 2b

recommendation [1,3]. Advances in technology have allowed for mechanical support using percutaneous left ventricular assist devices (pLVAD). While numerous studies have shown improved hemodynamics with these devices, no randomized controlled trial has been performed to assess overall mortality benefit [4,5,6]. Furthermore, studies assessing both IABP and pLVAD use in patients resuscitated from out-of-hospital cardiac arrest (OHCA) are limited given the difficulty in studying this patient population [7].

Data from IABP use to treat post-cardiac arrest cardiogenic shock are more readily available than data from other pLVADs. Two studies retrospectively studying the subject have found that IABP use was strongly associated with neurologically intact survival [8,9]. However, a further prospective study found IABP use associated with increased mortality in MI patients complicated by cardiac arrest [10]. There have been promising porcine studies evaluating the use of pLVAD during cardiac arrest resuscitation, doubling the rate of return of spontaneous circulation (ROSC) compared to standard care [11]. In human subjects, studies

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assessing pLVAD use in cardiac arrest have been limited to case series. These series showed that pLVAD use was associated with a sicker patient populations but found no difference in neurologically intact survival [12,13].

It is clear that little literature exists studying pLVAD and IABP use in post cardiac arrest patients across larger populations. The objective of this study was to investigate whether, in a statewide cohort of post cardiac arrest patients, use of percutaneous hemodynamic support device was associated with survival.

2. Methods

We performed a retrospective study of adult (age ≥ 18 years) patients with an admission diagnosis of cardiac arrest (ICD-CM 427.5) or ventricular fibrillation (ICD-9 CM 427.41) from the Michigan Inpatient Database (MIDB), treated between July 1, 2010, and June 30, 2013. This definition of cardiac arrest includes both OHCA patients that survived to hospital admission, as well as those who arrested in the ED and survived to admission. No patient with CPR in progress is included in this cohort of patients. The MIDB is run by the Michigan Health & Hospital Association and has been collecting data on patients requiring inpatient admission since the 1980s. It currently collects data on 1.3 million admitted patients annually from > 100 hospitals across Michigan [14,15]. This database collects information on all patients who survived to admission into an acute care hospital, including patient demographics, receiving facility, discharge diagnoses, procedures performed, and patient outcomes. Patient outcomes recorded included survival to hospital discharge and discharge destination (home, short term rehabilitation, skilled nursing facility, hospital). For this study we defined surviving to hospital discharge as any patient discharged from the hospital to home or another facility other than hospice. Data on patient demographics (age, sex), clinical characteristics (arrest rhythm of ventricular fibrillation (VF), cardiogenic shock (ICD-9 CM 98551), myocardial infarction (ICD-9 CM, 41000–41010)), procedures performed (e.g. percutaneous coronary intervention (PCI), percutaneous hemodynamic support device placement), and outcome (survived to discharge) were electronically abstracted based on ICD-9 codes at the hospital level. Percutaneous hemodynamic support device was defined as either IABP or pLVAD (Impella 2.5). Duplicate cases, patients < 18 years old, and cases with missing data were excluded.

Univariate relationships with outcome were compared using a Welch's two-sample *t*-test for continuous data and a chi-squared test of independence for categorical data. Mixed-effects logistic regression models were fit to test the effect of percutaneous hemodynamic support device on outcome, with hospital modeled as a random effect. In the mixed-effects logistic regression, we controlled for those variables known to have an effect on survival from our univariate analysis (age, sex, VF, MI, and cardiogenic shock), but also attempted to control for specific hospital effect on survival. This study was approved by the William Beaumont Hospital Institutional Review Board. All data cleaning and analysis was performed using R (version 3.2.1) and RStudio (version 0.99.467).

3. Results

A total of 103 hospitals in Michigan contributed 4393 patients for analysis with a mean age of 64.1 years (SD 15.5) and 41% being female. From the total, 1422 patients (32.4%) had a diagnosis of VF, 1174 (26.7%) with MI, and 779 (17.7%) cardiogenic shock. Only 197 (4.5%) patients received a percutaneous hemodynamic support device, of which most were IABP (182 (4.1%)). These were placed in 35 different hospitals, with only 20 hospitals placing them more than once a year. Table 1 and Fig. 1 highlight the results of the univariate analyses, revealing that younger age, male sex, VF initial rhythm, acute MI, PCI, percutaneous hemodynamic support device, and absence of cardiogenic shock were associated with survival to discharge. This effect was most notable

Table 1

Univariate analysis of factors associated with survival to hospital discharge.

Patient variables	Survival (n = 1688)	Deaths (n = 2705)	p-Value
Age, mean (SD)	61.5 (15.3)	65.7 (15.5)	$<0.001^a$
Male sex, n(%)	1083 (64.2)	1499 (55.4)	$<0.001^b$
VF initial rhythm, n(%)	821 (48.6)	601 (22.2)	$<0.001^b$
Acute MI, n(%)	510 (30.2)	664 (24.5)	$<0.001^b$
Cardiogenic shock, n(%)	220 (13.0)	559 (20.7)	$<0.001^b$
Received PCI, n(%)	278 (16.5)	122 (4.5)	$<0.001^b$
Hemodynamic support device, n(%)	103 (6.1)	94 (3.5)	$<0.001^b$

VF-ventricular fibrillation; MI-myocardial infarction; PCI-percutaneous intervention.

^a Compared using Welch's two-sample *t*-test.

^b Compared using chi-squared test of independence.

for an initial rhythm of VF (OR, 3.3, 95% CI, 2.9–3.8) and receiving PCI (OR, 4.2, 95% CI, 3.3–5.2) but was still significant for those receiving a percutaneous hemodynamic support device (OR, 1.8, 95% CI, 1.4–2.4). As would be expected, cardiogenic shock was negatively associated with survival (OR, 0.6, 95% CI, 0.5–0.7).

Fig. 2 shows results of the mixed-effects logistic regression model assessing the association of percutaneous hemodynamic support device on survivability in all patients, acute MI patients, and patients complicated by cardiogenic shock. The mixed-effects logistic regression model attempted to control for variables found in our univariate analysis such as age, sex, VF initial rhythm, cardiogenic shock and presence of MI while also taking into account a theoretical hospital effect towards survivability. While controlling for these variables, use of a percutaneous hemodynamic support device was associated with survival in all patients (OR, 1.8, 95% CI, 1.3–2.5) and even more so when applied to acute MI patients (OR, 1.9, 95% CI, 1.3–2.9) and those in cardiogenic shock (OR, 2.0, 95% CI, 1.3–3.0).

4. Discussion

These data identify that the use of percutaneous hemodynamic support device in post cardiac arrest patients admitted to Michigan hospitals was associated with an improved survival. This was true in all patients, patients who had a diagnosis of MI, and patients with a diagnosis of cardiogenic shock. While an improved outcome was observed for all patients, the association was even stronger with those who had suffered an acute MI or suffered from cardiogenic shock. To our knowledge this is the largest dataset that has evaluated use of percutaneous hemodynamic support device in the post arrest population.

Our findings are important, as the literature specifically evaluating percutaneous hemodynamic support device use in cardiac arrest patients is sparse [7]. While existing literature evaluating IABP use in MI patients suffering from cardiogenic shock found no mortality benefit, there is some data to suggest that IABP use is positively associated with neurologically intact survival in post arrest patients [1,8,9]. In the largest prospective trial assessing IABP use in MI patients complicated by cardiac arrest, IABP was associated with higher mortality [10]. Because IABP was used in a sicker population, and the primary outcome of mortality did not assess for neurologic status, results were likely negatively biased. It is possible that these variables as well as our inclusion of pLVAD use could account for our positive association with survival. Furthermore, this study did not delineate between in hospital and OHCA while our study specifically looked at those admitted for cardiac arrest. In human subjects, very little data exists specifically addressing pLVAD use in OHCA. A single study compared IABP use to pLVAD (Impella 2.5) use in OHCA patients and found no difference in neurologically intact survival at 28 days. However, no comparison was made between patients that received either LVAD device to those that received neither [12,13]. Our findings expand the literature as our patient population represented patients who suffered either OHCA or Emergency

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