Cardiogenic shock remains an important cause of death in acute ST-segment elevation myocardial infarction (STEMI) (1). Intra-aortic balloon pump (IABP) is widely used for hemodynamic support in cardiogenic shock. The availability of novel mechanical circulatory support (MCS) devices has increased the therapeutic armamentarium of a cardiologist. A recent study from the Nationwide Inpatient Sample (NIS) demonstrated a significant increase in the use of short-term MCS in the United States during the period 2004 to 2011 (2). However, the study was limited secondary to inclusion of a heterogeneous population, providing little insight into MCS use in the setting of STEMI. We, therefore, conducted a study to evaluate the trends and variations in MCS use during the period 2003 to 2012 in the United States in STEMI patients complicated by cardiogenic shock.

Data were obtained from the NIS, which contains discharge-level data from ~8 million hospitalizations annually from ~1,000 hospitals across the United States. All hospitalizations with the principal diagnosis of STEMI, identified using ICD-9-CM codes, were considered for inclusion. Of these patients, we included all patients with an additional diagnosis of cardiogenic shock (ICD-9: 785.51). The use of MCS was determined using ICD-9 procedure codes. These included IABP (ICD-9: 37.61), Impella/Tandem Heart (ICD-9: 37.68), nonpercutaneous devices (ICD-9: 37.60, 37.62, 37.65), extracorporeal membrane oxygenation (ECMO) (ICD-9: 39.65), and percutaneous cardiopulmonary support (ICD-9: 39.66). To evaluate the impact of hospital volume on MCS use, we divided all hospitals into quartiles based on the annual volume of primary percutaneous coronary intervention (PCI) performed. Data from 2003 to 2011 were included in this analysis due to a change in patient sampling strategy and lack of availability of complete hospital data for participating hospitals in 2012. Multivariable hierarchical logistic regression analysis was used to account for the clustered nature of the NIS.

Over a 10-year period (2003 to 2012), 414,367 discharges of STEMI patients were analyzed. Of these patients, 35,944 patients (8.7%) had a diagnosis code corresponding to cardiogenic shock. Figure 1A demonstrates the proportion of patients in cardiogenic shock treated using short-term MCS. We noted a slow increase in IABP use from 48.6% of cardiogenic shock cases during 2003 to 57.1% in 2009, followed by a steady decline in IABP use during recent years (50.6% in 2012). In contrast, there has been a steep increase in the use of percutaneous-assist devices and a small increase in the use of ECMO in cardiogenic shock cases during the period 2003 to 2012.

Comparison of baseline characteristics between cardiogenic shock patients treated using MCS support (n = 16,691) and without MCS support (n = 19,253) revealed important differences. Patients treated with MCS were younger (mean age, 64.9 years vs. 69.8 years) and more likely male (67.3% vs. 56.1%) compared with those not treated with MCS. There was a lower prevalence of chronic renal failure (11.2% vs. 14.9%), chronic pulmonary disease (18.7% vs. 21.4%), peripheral vascular disease (7.3% vs. 10.5%), and hypertension (45.8% vs. 47.0%) among patients treated with MCS compared with those not treated with MCS. Importantly, there was a significant difference in the proportion of patients undergoing PCI on the first day of admission between the 2 groups; 62.6% of patients treated with MCS underwent PCI on the first day of admission compared with only 42.9% of patients not treated with MCS (p < 0.001). As expected, there was an increase in the proportion of cardiogenic shock patients treated with PCI on first day of admission from 35.6% in 2003 to 66.0% in 2012 (p trend < 0.001).

There was a significant variation in MCS use across the institutions in the United States. There was greater use of MCS in cardiogenic shock patients in urban nonteaching (52.1%) and urban teaching (56.5%) hospitals compared with rural hospitals (41.7%, p < 0.001). Similarly, MCS use for cardiogenic shock was greater in the large-sized hospitals (55.3%) and medium-sized hospitals (50.5%) compared with...
small-sized hospitals (45.6%, \( p < 0.001 \)). On stratification of hospitals by geographic location, there were differences noted in MCS use between the northeastern (54.4%), midwestern (56.6%), southern (52.4%), and western (51.8%) United States. Furthermore, on stratification of hospitals into quartiles based on annual primary PCI volume, there was an increase in MCS use in cardiogenic shock with increasing primary PCI volume (Figure 1B).

Mortality in patients with cardiogenic shock has been attributed to hemodynamic deterioration, multiorgan dysfunction, lack of myocardial salvage, remote ischemia, and systemic inflammatory response syndrome (3-6). Although IABP implantation was initially believed to improve hemodynamics in cardiogenic shock after STEMI, placement of an IABP after revascularization in the pivotal IABP-SHOCK II (Intraaortic Balloon Pump in Cardiogenic Shock II) trial failed to demonstrate hemodynamic improvement or improvement in clinical endpoints (6). Our study has evaluated the trend in MCS use in high-risk STEMI patients with cardiogenic shock from a non-trial, contemporary real-world setting. We noted an increase in the IABP use for cardiogenic shock during the period 2003 to 2009, followed by a decline during the period 2010 to 2012. This was partially compensated for by an increase in the use of devices such as the Impella and Tandem Heart. This might be attributable to the ease of implantation, decreasing confidence in the IABP, and the need for added hemodynamic support. A significant proportion of patients treated using other MCS devices underwent IABP implantation concomitantly (47.7%), implying inadequate support with IABP in patients with intractable cardiogenic shock.

An important finding was heterogeneity of MCS use across various institutions. The variation may be explained partly by differences in case mix or hospital characteristics. Hospital size may be an indirect marker of available health care resources, and large-sized hospitals might have access to more resources for patient management. It is also plausible that low-volume centers are more selective in treating patients with STEMI and cardiogenic shock. We noted an interesting association between the annual primary PCI volume and MCS use in U.S. hospitals. This considerable in-hospital variation clearly indicates the lack of guidelines for MCS use during most of the study period. The guidelines for MCS use have recently been published and would potentially serve to reduce some of these discrepancies (7).

Our study has several limitations. First, NIS is an administrative database, which may be subject to errors in coding of diseases or procedures.

Cardiogenic shock was identified using the ICD-9 code reported by the treating hospital and thus may not be uniform across participating institutions. Unlike the IABP-SHOCK II trial, which included all acute myocardial infarction patients, our study was restricted to patients with STEMI. Identification of patients with non-STEMI in an administrative dataset
such as NIS would likely identify a heterogeneous group of patients with multiple different causes for cardiac biomarker elevation. In an administrative dataset, we could probably be most certain of definitive diagnoses such as STEMI; hence, we decided to restrict our analysis to this cohort. In addition, inclusion of non-STEMI patients (with much lower rates of cardiogenic shock) was a criticism of the IABP-SHOCK II trial. Second, because the unit of analysis in the NIS database is “unique admission” rather than “unique patient,” it is possible that a patient might have been represented more than once in case of repeat admission for recurrent STEMI. Third, this is a retrospective observational study, which may be subject to traditional biases of observational studies. However, these limitations might be partially compensated for by the large size of the NIS database and a uniform representation of all regions of the United States.

In conclusion, there was a steady increase in the use of IABP for cardiogenic shock during the period 2003 to 2009, followed by a slow decline in its use during the period 2010 to 2012. This was partially compensated for by a steep increase in the use of short-term percutaneous MCS during recent years. There was significant variability in MCS use among STEMI patients with cardiogenic shock, based on the annual PCI volume of the treating hospital. Increase in annual PCI volume was correlated with an increase in MCS use in STEMI patients complicated by cardiogenic shock.

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