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ORIGINAL INVESTIGATIONS

National Trends in the Utilization of Short-Term Mechanical Circulatory Support

Incidence, Outcomes, and Cost Analysis

Robert Stretch, MD,* Christopher M. Sauer, MD, MBA,* David D. Yuh, MD,† Pramod Bonde, MD†‡

ABSTRACT

BACKGROUND The number of alternatives to intra-aortic balloon counterpulsation in the treatment of anticipated and established acute circulatory failure is growing. Despite the clinical importance and significant cost of short-term mechanical circulatory support (MCS) devices, the state of their present use has not been analyzed on a national scale.

OBJECTIVES The purpose of this study was to characterize the demographics, treatment practices, survival rates, and cost of short-term MCS.

METHODS In this serial cross-sectional study, we analyzed all adult patients receiving short-term MCS in the United States from 2004 to 2011 by using the Nationwide Inpatient Sample from the Healthcare Cost and Utilization Project.

RESULTS From 2007 to 2011, use of percutaneous devices for short-term MCS increased by 1,511% compared with a 101% increase in nonpercutaneous devices. Mortality rates declined over this period (p for trend = 0.027) from 41.1% in 2004 to 2007 to 33.4% in 2008 to 2011. A similar trend was observed for the subset of patients with cardiogenic shock, decreasing from 51.6% to 43.1% (p for trend = 0.012). Hospital costs also declined over this period (p for trend = 0.011). Multivariable analysis revealed balloon pumps (odds ratio [OR]: 2.00; 95% confidence interval [CI]: 1.58 to 2.52), coagulopathy (OR: 2.35; 95% CI: 1.88 to 2.94), and cardiopulmonary resuscitation (OR: 3.50; 95% CI: 2.20 to 5.57) before short-term MCS were among the most significant predictors of mortality.

CONCLUSIONS Use of short-term MCS in the United States has increased rapidly, whereas rates of in-hospital mortality have decreased. These changes have taken place in the context of declining hospital costs associated with short-term MCS. (J Am Coll Cardiol 2014;64:1407–15) © 2014 by the American College of Cardiology Foundation.

Acute circulatory collapse is a broad term referring to failure of the pumping mechanism of the heart and an inability to maintain adequate organ perfusion. The most common situation in which it is encountered is cardiogenic shock. However, similar circulatory collapse can be anticipated during procedures that may compromise hemodynamic stability, including high-risk percutaneous coronary intervention (PCI), ablation for arrhythmias, and transcatheter valvular interventions.

Historically, institution of short-term mechanical circulatory support (MCS) was largely reserved for patients exhibiting significant circulatory compromise requiring cardiac output augmentation, with a

From the *Bonde Artificial Heart Laboratory, Yale University School of Medicine, New Haven, Connecticut; †Section of Cardiac Surgery, Yale University School of Medicine, New Haven, Connecticut; and the ‡Center for Advanced Heart Failure and Transplantation, Yale University School of Medicine, New Haven, Connecticut. This work was supported by the William W. Glenn Research Foundation, New Haven, Connecticut. The authors have reported that they have no relationships relevant to the contents of this paper to disclose.

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ABBREVIATIONS AND ACRONYMS

AMI = acute myocardial infarction

CAD = coronary artery disease and other heart disease

CCS = Clinical Classification Software

CHF = congestive heart failure

ECMO = extracorporeal membrane oxygenation

HCUP = Healthcare Cost and Utilization Project

HVD = heart valve disorder

IABP = intra-aortic balloon pump

LVAD = left ventricular assist device

MCS = mechanical circulatory support

PCI = percutaneous coronary intervention

PCPS = percutaneous cardiopulmonary support

bias toward supporting patients perceived as eligible for transplant or left ventricular assist device (LVAD) implantation (either bridge or destination therapy). More recently, the availability of rapidly deployable percutaneous MCS has led to a paradigm shift in the field that is characterized by growing use of these devices in an anticipatory or prophylactic fashion that was previously uncommon. Although the intra-aortic balloon pump (IABP) is not a true circulatory support device because it does not contribute directly to cardiac output, it was the only rapidly deployable support device available for decades. Reliable circulatory devices including the Thoratec PVAD (Thoratec Corporation, Pleasanton, California), AB5000 and BVS 5000 (both Abiomed, Inc., Danvers, Massachusetts), and various centrifugal pumps usually require a median sternotomy. Venoarterial extracorporeal membrane oxygenation (ECMO) delivered through peripheral cannulation with a centrifugal pump driver is another option but has always been reserved for emergency near-arrest situations. The morbidity and mortality associated with these devices are significant and restricted their use to potential transplant candidates.

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The Impella 2.5 (Abiomed, Inc., Danvers, Massachusetts) and TandemHeart (CardiacAssist, Inc., Pittsburgh, Pennsylvania) are percutaneous MCS devices that can be deployed in the catheterization laboratory. The CentriMag (Thoratec Corporation, Pleasanton, California) and the Impella 5.0/CP have greatly increased ease of cannulation and device placement. These developments, among others, have theoretically made possible early deployment of short-term MCS before the downward spiral and inflammatory cascade associated with circulatory collapse can develop. Irrespective of surgical or percutaneous deployment, all temporary MCS devices share similar functional characteristics in terms of augmentation of cardiac output in liters per minute.

In U.S. and European guidelines for acute heart failure, the mainstays of therapy remain intravascular volume control, inotropes, and IABP (1,2). The combination of revascularization, antithrombotic therapy, and intensive care management has only modestly affected the mortality of cardiogenic shock in the last decade (3,4). Despite a paucity of randomized trials, recent guidelines have recommended the use of short-term MCS for profound hemodynamic compromise (1,5); these recommendations reflect the growing impact of short-term MCS on clinical practice and the lack of viable alternatives.

Unlike the Interagency Registry for Mechanically Assisted Circulatory Support (INTERMACS) and Extracorporeal Life Support Organization (ELSO) registries, which track outcomes and adverse events in patients receiving long-term MCS and ECMO, no such registry exists for short-term MCS. To begin addressing the existing deficit of information on patients receiving short-term MCS, we examined national trends in utilization.

METHODS

DATA SOURCE. The Nationwide Inpatient Sample, Healthcare Cost and Utilization Project (HCUP), under the auspices of the Agency for Healthcare Research and Quality (6), is the largest database of all-payer inpatient hospital stays in the United States. It approximates a 20% stratified sample of all nonfederal hospitals. All discharges from sampled hospitals are included, thus enabling the generation of national estimates. This study was deemed exempt by Yale University's Institutional Review Board.

INCLUSION CRITERIA. We included all adults ≥18 years old who were receiving short-term MCS between 2004 and 2011. Short-term MCS was defined by the International Classification of Diseases-ninth revision-Clinical Modification (ICD-9-CM) codes for percutaneous (37.68) or nonpercutaneous (37.60, 37.62, and 37.65) MCS in any procedure position (Online Figure 1). Nonpercutaneous devices included the Thoratec PVAD, AB5000, BVS 5000, and CentriMag. Percutaneous devices included the TandemHeart and Impella devices. IABP (37.61), ECMO (39.65), and percutaneous cardiopulmonary support (PCPS) (39.66) were excluded from our definition of short-term MCS. Permanent devices (37.52 and 37.66) included the HeartMate XVE and HeartMate II (Thoratec Corporation). Earlier years were not analyzed because ICD-9-CM codes do not distinguish short-term from permanent MCS devices before 2004.

DEMOGRAPHICS. Elixhauser comorbidities were generated from ICD-9-CM diagnosis codes using the HCUP Comorbidity Software (7). The sum of comorbidities for each record was reclassified as 0, 1, 2, or ≥3. Comorbidities present in ≥5% of all patients were reported.

HOSPITAL COURSE. We defined the indication for a hospital stay as the diagnosis listed in the primary position and categorized each using HCUP Clinical Classification Software (CCS). Level 3 CCS diagnoses constituting ≥5% of all indications for hospital stays were classified as discrete categories, whereas remaining diagnoses were merged into a single category of other miscellaneous indications. Mortality rates were defined as the percentage of patients who died before discharge.

COST ANALYSIS. We used HCUP cost-to-charge ratios for each hospital, based on information from the Centers for Medicare and Medicaid Services, to adjust the total charges for each patient and to estimate costs. When a hospital-specific cost-to-charge ratio was not available, we used the corresponding state-level ratio. These estimates were then adjusted for inflation by using the Consumer Price Index Inpatient Hospital Services inflation multiplier (8), with 2011 as the base year. Hospital costs incurred by permanent device implantation or heart transplantation were included in all calculations.

STATISTICAL ANALYSIS. An abrupt change in utilization pattern was observed in 2008. Based on this finding, weighted means for demographic and hospital course characteristics were calculated and presented as illustrative data for 2004 to 2007 and for 2008 to 2011 in aggregate. To test for linear and curvilinear trends in disease characteristics and outcomes over time, we adopted a method of variance-weighted regression (9,10). This methodology incorporates the standard errors associated with the estimates of each year but does not assume homogeneity of variance. The threshold for including yearly estimates was a relative standard error <30%.

Data from 2005 were excluded from the mortality trend analysis because 2 of 53 hospitals caused a significant downward distortion of overall mortality in a manner inconsistent with all other years examined. Trend analyses for hospital costs and length of stay were performed before and after removing the top 1% of values, with similar results (latter data not shown).

Multivariable logistic and linear regression was used to calculate the association among independent variables, in-hospital mortality, and the total cost of hospital stay. Hierarchical models were used to account for clustering of cases by hospital. Length of stay and total cost of hospital stay were both log-transformed to achieve less positively skewed distributions. Elixhauser comorbidities affecting ≥5% of patients were included as independent variables if they were significantly associated with outcomes on bivariate analysis. The significance level was set a priori at a p value ≤0.05. Statistical analyses were performed using SPSS version 21.0 (IBM Corporation, Armonk, New York) (Online Methods).

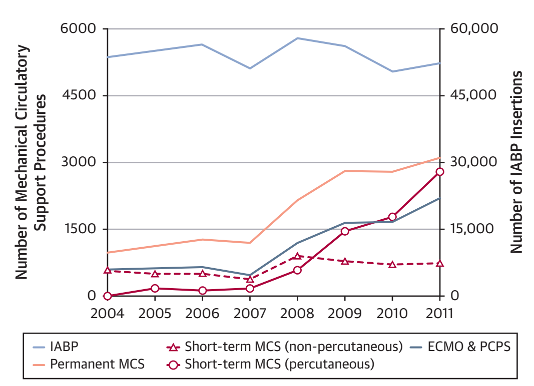

FIGURE 1 Use of MCS Devices Between 2004 and 2011

Use of percutaneous devices, permanent devices, extracorporeal membrane oxygenation (ECMO), and percutaneous cardiopulmonary support (PCPS) has grown considerably, whereas relatively little change in use has been observed for intra-aortic balloon pump (IABP) and nonpercutaneous devices. MCS = mechanical support device.

TABLE 1 Sample Patient and Hospital Demographics

	2004–2007	2008–2011
Female	33.5	28.6
Age, yrs		
18–34	5.7	4.7
35–49	15.8	12.5
50–64	38.9	35.7
65–79	33.4	35.3
≥80	6.2	11.9
Race		
White	75.6	70.4
Black	8.8	11.9
Other	15.6	17.7
Primary payer		
Medicare	42.5	50.2
Medicaid	9.4	9.8
Private insurance	39.3	33.3
Other*	8.8	6.7
Median household income		
0–25th percentile	21.3	27.8
26th–50th percentile	23.8	23.5
51st–75th percentile	24.3	23.1
76th–100th percentile	30.7	23.7
Teaching hospital	79.1	77.3
Urban location	99.0	96.0
Large hospital by bed size	76.6	80.8
Region		
Northeast	31.8	24.4
Midwest	22.9	23.7
South	27.9	29.7
West	17.4	22.2

Values are %. *Includes self-pay, no charge, or other.

RESULTS

UTILIZATION. An estimated 11,887 patients received short-term MCS between 2004 and 2011. Whereas use of temporary nonpercutaneous devices increased 101% from 2007 to 2011, percutaneous device use increased by 1,511%. Indeed, percutaneous devices exhibited the fastest growth of all forms of MCS in this period (**Figure 1**, Online Table 2).

DEMOGRAPHICS. Most patient-related and hospital characteristics remained similar over time (**Table 1**). Approximately two-thirds of patients were male and white. In 2008 to 2011, approximately one-half of patients were ≥65 years of age. Large urban teaching hospitals were the predominant setting.

HOSPITAL COURSE AND DISEASE CHARACTERISTICS. Acute myocardial infarction (AMI) was the most common primary diagnosis (**Table 2**, Online Table 3), and this predominance increased linearly over time (p for trend = 0.003), whereas other miscellaneous diagnoses (Online Table 4) made up a declining proportion of patients (p for trend = 0.024). Approximately one-half of all patients carried a diagnosis of cardiogenic shock. There was an increase in the proportion of patients with ≥3 Elixhauser comorbidities over time (p for trend = 0.001).

LENGTH OF STAY AND DISPOSITION. The mean duration of stay for congestive heart failure (CHF) decreased substantially over time (p for trend = 0.002) (**Table 3**). Trends in length of stay for AMI and coronary artery disease (CAD) did not reach statistical significance. The proportion of patients discharged home increased over time (p for trend = 0.001). This

TABLE 2 Trends in Hospital Course and Disease Characteristics

	2004-2007	2008-2011	p Value
Elective admission	32.5	24.7	0.001
Admission type*			
Not a transfer	–	61.9	–
Transfer from an acute care hospital	–	34.2	–
Transfer from another health facility	–	3.9	–
Primary diagnosis			
AMI	32.0	37.8	0.003
CAD	20.0	22.2	0.91
CHF	11.9	14.4	0.055
HVD	11.0	4.8	0.17
Other	25.0	20.7	0.024
Cardiogenic shock	51.8	49.4	0.38
Hospital course			
Vasopressor use†	3.8	3.7	–
IABP use	41.7	31.0	0.13
Intubation	15.3	21.3	0.006
CPR administration†	4.7	6.8	–
Heart transplant†	3.8	3.5	–
Permanent device†	5.2	8.8	–
Number of comorbidities			
0	16.6	7.5	0.002
1	25.7	16.6	0.004
2	27.2	20.5	0.017
≥3	30.5	55.5	0.001
Comorbidities			
Hypertension	38.4	51.3	0.003
Fluid and electrolyte disorders	28.0	41.6	0.002
Coagulopathy	24.6	28.2	0.07
Diabetes, uncomplicated	18.2	28.4	<0.001
Renal failure	11.5	24.0	<0.001
Deficiency anemias	10.2	18.8	0.012
Chronic pulmonary disease	13.0	17.0	0.23
Peripheral vascular disorders	7.9	16.1	0.004
Obesity†	5.7	10.4	–
Weight loss†	5.5	10.6	–
Hypothyroidism†	4.1	6.8	–
CHF†	6.1	7.3	–

Values are %. *Data not available before 2008. †Relative standard error exceeded validity threshold in >1 year.

AMI = acute myocardial infarction; CAD = coronary atherosclerosis and other heart disease; CHF = congestive heart failure; CPR = cardiopulmonary resuscitation; HVD = heart valve disorder; IABP = intra-aortic balloon pump.

TABLE 3 Trends in Short-Term Mechanical Circulatory Support Outcomes

Outcome	2004-2007	2008-2011	p Value
Length of stay, days			
AMI	18.5 ± 27.3	14.3 ± 19.5	0.09
CAD	10.3 ± 10.4	7.2 ± 10.4	0.06
CHF	58.7 ± 65.5	32.3 ± 35.9	0.002
HVD	11.6 ± 12.7	17.2 ± 22.4	0.44
Other	25.4 ± 41.2	25.6 ± 31.0	0.81
Disposition			
Routine (home or self-care)	31.7	47.5	0.001
Home health care	23.0	18.4	0.22
Transfer*	45.3	34.1	0.019
Mortality	41.1	33.4	0.027
AMI	41.4	33.5	0.09
CAD†	37.1	15.4	–
CHF	29.6	34.2	0.54
HVD†	43.3	55.3	–
Other	48.2	46.8	0.17
Mortality with cardiogenic shock	51.6	43.1	0.012
Cost	$150,187	$116,858	0.011
AMI	$142,176	$97,134	0.015
CAD	$120,699	$66,277	0.015
CHF	$217,144	$190,612	0.010
HVD	$143,606	$133,733	0.82
Other	$157,726	$162,811	0.86
Cost with cardiogenic shock	$171,509	$146,942	0.034

Values are mean ± SD, %, or mean. *Includes short-term hospital, skilled nursing facility, or intermediate care. †Relative standard error exceeded validity threshold in >1 year.

Abbreviations as in **Table 2**.

TABLE 4 Management by Indication for Hospital Stay From 2008 to 2011

	AMI	CAD	CHF	HVD	Other
Cardiogenic shock	59.5	18.6	56.5	56.0	57.6
Hospital course					
Vasopressor use	4.2	1.1	3.7	4.4	5.2
IABP use	39.9	17.4	26.8	51.2	27.7
Intubation	24.3	7.2	27.0	24.6	26.1
CPR administration	7.4	2.2	7.3	8.6	9.8
Permanent device	5.9	1.5	24.8	4.3	11.9
Disposition					
Routine	39.7	70.7	37.4	19.4	40.2
Home health care	18.7	11.3	26.8	25.6	20.8
Transfer*	41.6	18.0	35.8	55.0	39.0
Mortality rate	33.5	15.4	34.2	55.3	46.8

Values are %. *Includes short-term hospital, skilled nursing facility, or intermediate care.
Abbreviations as in Table 2.

increase was accompanied by a concomitant decline in transfers to other facilities (p for trend = 0.019). In 2008 to 2011, patients with AMI, CHF, or other miscellaneous diagnoses were discharged home in approximately 40% of cases, compared with 70.7% of those with CAD (Table 4). Patients with CAD also had the lowest incidence of cardiogenic shock of all groups.

MORTALITY. As illustrated in Figure 2, mortality rates of short-term MCS recipients have decreased over

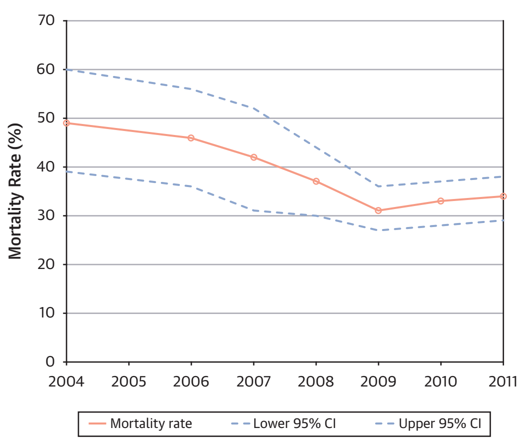

FIGURE 2 Mortality Rate Associated With Short-Term Mechanical Circulatory Support (2004 to 2011)

A trend toward decrease in mortality was observed over time for recipients of short-term circulatory assist devices. CI = confidence interval.

TABLE 5 Multivariable Analysis of Mortality

	Odds Ratio	Lower 95% CI	Upper 95% CI	p Value
Age, yrs				
18–34	Ref			
35–49	1.41	0.85	2.33	0.19
50–64	2.13	1.33	3.41	0.002
65–79	2.41	1.49	3.88	<0.001
≥80	1.51	0.85	2.70	0.16
Female	1.44	1.17	1.79	0.001
Hospital characteristics				
Teaching hospital*	1.13	0.87	1.47	0.37
Urban location	1.02	0.57	1.84	0.94
Year				
2004	Ref			
2005	0.30	0.16	0.54	<0.001
2006	0.70	0.39	1.25	0.23
2007	0.43	0.23	0.79	0.007
2008	0.43	0.26	0.71	0.001
2009	0.31	0.19	0.51	<0.001
2010	0.36	0.22	0.58	<0.001
2011	0.30	0.19	0.48	<0.001
Primary diagnosis				
AMI	Ref			
CAD	0.64	0.47	0.88	0.005
CHF	0.92	0.67	1.27	0.61
HVD	1.49	0.98	2.28	0.07
Other	1.56	1.19	2.05	0.001
Cardiogenic shock	1.42	1.14	1.77	0.002
Before heart assist†				
CPR administration	3.50	2.20	5.57	<0.001
IABP use	2.00	1.58	2.52	<0.001
Intubation	1.71	1.27	2.30	<0.001
Vasopressor use	1.39	0.75	2.58	0.30
Comorbidities				
Coagulopathy	2.35	1.88	2.94	<0.001
Fluid and electrolyte disorders	1.82	1.47	2.25	<0.001
Deficiency anemias	0.44	0.33	0.59	<0.001
CHF	1.38	0.96	1.99	0.08
Diabetes, uncomplicated	0.81	0.64	1.03	0.08

*As classified in the American Heart Association Annual Survey of Hospitals. †Performed or administered up to 7 days before short-term mechanical circulatory support.
CI = confidence interval; Ref = reference; other abbreviations as in Table 2.

time (p for trend = 0.027) (Table 5). This trend was also observed in the subset of patients with cardiogenic shock (p for trend = 0.012). Detailed outcome data for this subgroup are presented in Online Table 1. Patients 65 to 79 years of age had the highest odds of mortality. Comorbidities conveying the greatest risk were coagulopathies and fluid and electrolyte disorders. Other predictors of death included a diagnosis of cardiogenic shock and use of IABP or cardiopulmonary resuscitation before short-term MCS. After adjusting for all other variables, later calendar years remained predictive of lower mortality.

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TABLE 6 Multivariable Analysis of Total Hospital Costs

	Change in Cost (%)	p Value
Age, yrs		
18–34	Ref	
35–49	−14.4	0.007
50–64	−16.3	0.001
65–79	−22.0	<0.001
≥80	−28.5	<0.001
Female	−2.1	0.35
Primary payer		
Medicare	Ref	
Medicaid	−2.3	0.58
Private insurer	7.9	0.015
Other	−0.4	0.93
Median household income		
0–25th percentile	Ref	
26th–50th percentile	0.1	0.97
51st–75th percentile	4.9	0.14
76th–100th percentile	2.9	0.39
Hospital characteristics		
Teaching status	4.7	0.31
Urban location	9.4	0.41
Year		
2004	Ref	
2005	5.9	0.48
2006	−0.3	0.97
2007	−12.1	0.11
2008	−2.7	0.71
2009	−6.4	0.34
2010	−8.1	0.23
2011	−16.4	0.012
Primary diagnosis		
AMI	Ref	
CAD	9.7	0.002
CHF	8.7	0.021
HVD	24.6	<0.001
Other	12.1	<0.001
Length of stay, per 20% increase	8.4	<0.001
Died during hospital stay	28.5	<0.001
Hospital course		
Use of IABP	25.2	<0.001
Intubation	−5.8	0.027
Vasopressor use	−10.2	0.07
CPR administration	−3.4	0.42
Comorbidities		
Coagulopathy	17.7	<0.001
Weight loss	12.7	0.002
Hypertension	−5.1	0.022
Fluid and electrolyte disorders	3.7	0.13
Chronic pulmonary disease	−3.3	0.23
Hypothyroidism	−4.4	0.29
CHF	−1.7	0.70

Abbreviations as in Table 2.

HOSPITAL COSTS. The mean cost of hospital stays declined from 2004 to 2011 (p for trend = 0.011) (Table 6). Stratifying by diagnosis, costs declined over time for all groups except patients with heart valve disorders and other miscellaneous diagnoses. A patient's age was found to have a strong inverse correlation with hospital costs. IABP use and in-hospital death were associated with cost increases of 25.2% ($p < 0.001$) and 28.5% ($p < 0.001$), respectively.

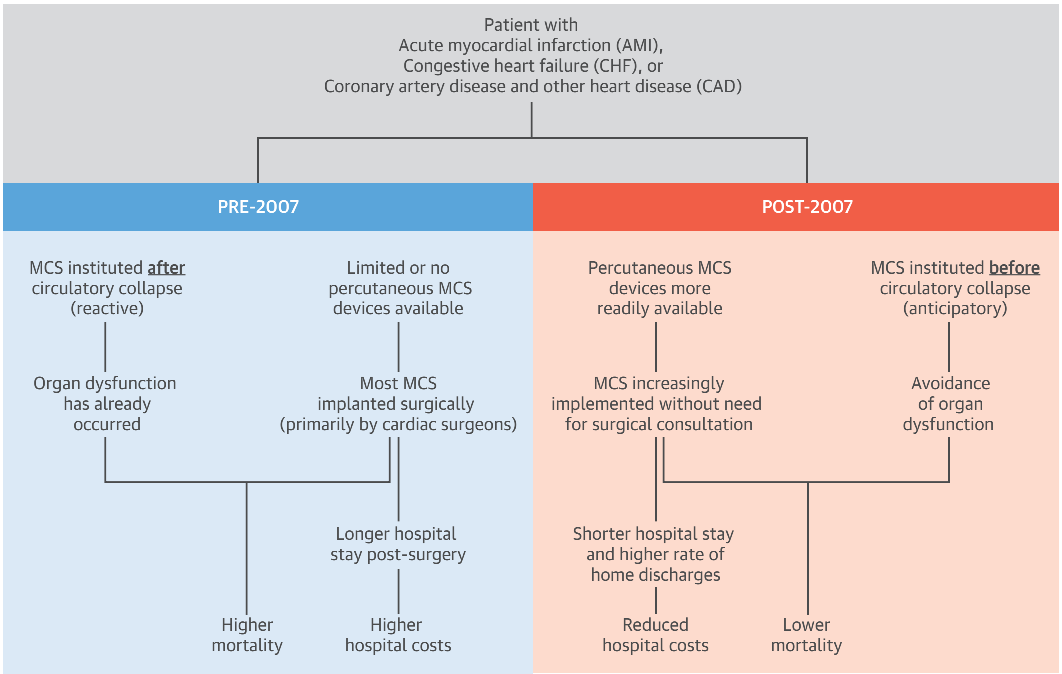
DISCUSSION

These national data demonstrate that use of short-term MCS increased rapidly between 2007 and 2011, accompanied by declining rates of in-hospital mortality. Concomitant reductions in hospital costs were observed during this period.

WHO RECEIVES SHORT-TERM MECHANICAL CIRCULATORY SUPPORT? Recipients of short-term MCS have historically been patients with cardiogenic shock or circulatory collapse who were considered eligible for transplant or LVAD. Accordingly, delivery of short-term MCS most often took place in transplant or LVAD centers and included surgically implanted temporary devices. Providers were primarily cardiac surgeons experienced in transplant and LVAD procedures. Operations to implant these devices are usually associated with significant morbidity; the mortality of these patients has remained similar over time.

The availability of percutaneous devices profoundly changed the field of short-term MCS. The results of this study illustrate a paradigm shift characterized by increased use of short-term MCS in an anticipatory or prophylactic fashion (e.g., during high-risk PCI and ablation procedures carrying a likelihood of impaired cardiac output), as opposed to after the onset of circulatory compromise (Central Illustration). The most striking demonstration of this is the large number of patients with a primary diagnosis of CAD who receive short-term MCS. This change in the use of short-term MCS, particularly the evolution of a "nonshock" group of patients, has had a profound influence on aggregate outcomes.

MORTALITY. Efforts to reduce the mortality rate of cardiogenic shock have had limited success. The SHOCK (Should We Emergently Revascularize Occluded Coronaries for Cardiogenic Shock) trial demonstrated that early revascularization in cardiogenic shock secondary to AMI improves 6- and 12-month survival but does not reduce 30-day mortality (11). The IABP-SHOCK II (Intra-aortic Balloon Pump in Cardiogenic Shock II) trial revealed no effect of IABP on 30-day or 12-month survival (3,12). Indeed, cardiogenic shock in AMI continues to carry an estimated mortality rate of at least 40% to 50% (13,14). Those patients receiving short-term MCS are among the most severely ill.



CENTRAL ILLUSTRATION A Paradigm Shift in the Use of Short-Term MCS

Greater availability of percutaneous mechanical circulatory support (MCS) devices, alongside burgeoning expertise in their use among interventional cardiologists, has resulted in a fundamental change in the approach to patients at risk of acute circulatory collapse.

We identified high mortality in short-term MCS recipients with AMI or valvular heart disease but low mortality among patients with CAD. This difference is consistent with their respective prevalence of cardiogenic shock. The growing number of patients with CAD undergoing percutaneous MCS-assisted PCI resulted in a decline in overall MCS mortality over time.

Early identification of impending circulatory collapse coupled with rapid implementation of MCS may contribute to mortality reductions (15). Newer MCS devices have reduced the time between decision and implementation compared with earlier pulsatile devices that required expertise restricted to centers with heart transplant or LVAD programs. Guidelines need to be developed to help enable early identification of patients for whom IABP is likely to be insufficient.

UTILIZATION. The observed growth in MCS use likely results from a reduced treatment threshold. The shift from predominantly surgical to percutaneous device delivery has minimized procedural invasiveness and enhanced ease of delivery. It also has expanded availability because devices can be implanted in the catheterization laboratory without the need for surgical consultation. Ongoing technologic advances continue to increase the absolute additional output (l/min) achievable and help to obviate escalation to surgically implanted devices.

QUALITY OF LIFE AND COST. The proportion of patients discharged home, without need for home health care, increased over time. Furthermore, the fraction of patients receiving permanent heart-assist devices during their hospital stay increased. From 2008 to 2011, 24.8% of the patients with a primary diagnosis of CHF received permanent devices, which have been shown to confer both a survival benefit and an improved quality of life (16).

These improved outcomes have been achieved in the context of declining hospital costs. Shorter durations of stay are likely a major factor driving this decline. The reduced proportion of patients discharged to other facilities suggests these shorter stays reflect more rapid recoveries rather than increased use of rehabilitation facilities. Implantation of permanent devices and heart transplants are associated with higher hospital costs and lengths of stay.

UNEXPECTED FINDINGS. A somewhat surprising finding of our study was the 25.2% increase in the cost of hospital stay associated with IABP use. One possible explanation is that IABP use is associated with a delay in instituting more aggressive forms of circulatory support in patients who require it. Such delays could escalate the severity of cardiogenic shock and ultimately increase the intensity and cost of the care required by those patients.

LIMITATIONS OF PERCUTANEOUS SHORT-TERM MECHANICAL CIRCULATORY SUPPORT DEVICES. The technology of short-term MCS continues to evolve. Some devices may be insufficient to augment cardiac output, whereas others need specialized skills rare among even skilled interventional cardiologists. The amount of myocardial support required by patients in cardiogenic shock is subject to rapid fluctuation. However, the ability to escalate the degree of cardiac assistance provided by current-generation percutaneous devices remains limited. Prompt and repeated assessments to identify cannula positions, malfunctions, and changes in flow as a result of volume status are paramount to patients' survival and reduction of adverse events.

Perhaps the most crucial aspects of management are assessments for signs of recovery and for subsequent withdrawal of short-term MCS. Understanding that extended support may be needed before adequate recovery can occur is critical to management and is a major limitation of prior randomized trials (17–19).

STUDY LIMITATIONS. This study has several limitations inherent to a retrospective analysis. First, the use of ICD-9-CM codes to identify short-term MCS procedures did not allow an analysis of outcomes for individual devices. In addition, a substantial proportion of the study population (21.6%) was assigned a miscellaneous indication for hospital stay.

In terms of mortality, it is difficult to differentiate and estimate the impact of short-term MCS evolution from other concurrent changes during the study period, including efforts to reduce door-to-balloon times and length of inpatient stays. Length of stay and home healthcare requirements were higher in patients with CHF, although the higher rate of permanent device implantation in these patients may be a confounder. Finally, our analysis was limited to hospital costs. Increased use of permanent devices will confer downstream costs to the healthcare system, whereas reduced need for home health care and intermediate facilities at discharge will achieve cost savings.

CONCLUSIONS

Short-term MCS therapy has witnessed rapid growth since 2007, with concomitant reductions in both mortality rates and hospital costs. Systematic and longitudinal collection of data pertaining to short-term MCS therapy is warranted to ensure improved outcomes in the future.

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REPRINT REQUESTS AND CORRESPONDENCE: Dr. Pramod Bonde, Section of Cardiac Surgery, Center for Advanced Heart Failure and Transplantation, Yale University School of Medicine, 330 Cedar Street, Boardman 204, New Haven, Connecticut 06510. E-mail: pramod.bonde@yale.edu.

PERSPECTIVES

COMPETENCY IN MEDICAL KNOWLEDGE: Percutaneous heart-assist devices are increasingly used to prevent circulatory compromise in patients at risk of acute hemodynamic decompensation.

TRANSLATIONAL OUTLOOK: Future advances in percutaneous mechanical circulatory assist technology should address the need for bedside deployment and reduced levels of hemolysis that currently limit the duration of support.

REFERENCES

1. Yancy CW, Jessup M, Bozkurt B, et al. 2013 ACCF/AHA guideline for the management of heart failure: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines. J Am Coll Cardiol 2013;62:e147–239.

2. McMurray JJV, Adamopoulos S, Anker SD, et al. ESC guidelines for the diagnosis and treatment of acute and chronic heart failure 2012: the Task Force for the Diagnosis and Treatment of Acute and Chronic Heart Failure 2012 of the European Society of Cardiology. Developed in collaboration with the Heart Failure Association (HFA) of the ESC. Eur Heart J 2012;33:1787–847.

3. Thiele H, Zeymer U, Neumann F-J, et al. Intraaortic balloon support for myocardial infarction with cardiogenic shock. N Engl J Med 2012;367:1287–96.

4. de Waha S, Desch S, Eitel I, et al. What is the evidence for IABP in STEMI with and without cardiogenic shock? Ther Adv Cardiovasc Dis 2012;6:123–32.

5. Peura JL, Colvin-Adams M, Francis GS, et al. Recommendations for the use of mechanical circulatory support: device strategies and patient selection. A scientific statement from the American Heart Association. Circulation 2012;126:2648–67.

6. Healthcare Cost and Utilization Project (HCUP). HCUP Nationwide Inpatient Sample (NIS). 2004–2011. Agency for Healthcare

Research and Quality, Rockville, MD. Available at: http://www.hcup-us.ahrq.gov/nisoverview.jsp. Accessed July 26, 2014.

7. Healthcare Cost and Utilization Project (HCUP). HCUP Comorbidity Software. 2004–2011. Agency for Healthcare Research and Quality, Rockville, MD. Available at: http://www.hcup-us.ahrq.gov/toolssoftware/comorbidity/comorbidity.jsp. Accessed July 26, 2014.

8. United States Bureau of Labor. Consumer Price Index (CPI). Available at: http://www.bls.gov/cpi/#data. Accessed July 26, 2014.

9. Healthcare Cost and Utilization Project (HCUP). Using the HCUP Nationwide Inpatient Sample to Estimate Trends. 2011. Agency for Healthcare Research and Quality, Rockville, MD. Available at: http://www.hcup-us.ahrq.gov/reports/methods/2006_05_NISTrendsReport_1988-2004.pdf. Accessed July 26, 2014.

10. Bao Y, Sturm R. How do trends for behavioral health inpatient care differ from medical inpatient care in US community hospitals? J Ment Health Policy Econ 2001;4:55–63.

11. Hochman JS, Sleeper LA, Webb JG, et al. Early revascularization in acute myocardial infarction complicated by cardiogenic shock. N Engl J Med 1999;341:625–34.

12. Thiele H, Zeymer U, Neumann FJ, Ferenc M. Intra-aortic balloon counterpulsation in acute myocardial infarction complicated by cardiogenic shock (IABP-SHOCK II): final 12 month results of a randomised, open-label trial. Lancet 2013;382:1638–45.

13. Goldberg RJ, Spencer FA, Gore JM, Lessard D, Yarzebski J. Thirty-year trends (1975 to 2005) in the magnitude of, management of, and hospital death rates associated with cardiogenic shock in patients with acute myocardial infarction: a population-based perspective. Circulation 2009;119:1211–9.

14. Cheng JM, Corstiaan A, Hoeks SE, et al. Percutaneous left ventricular assist devices vs. intra-aortic balloon pump counterpulsation for treatment of cardiogenic shock: a meta-analysis of controlled trials. Eur Heart J 2009;30:2102–8.

15. Takayama H, Truby L, Koekort M, et al. Clinical outcome of mechanical circulatory support for refractory cardiogenic shock in the current era. J Heart Lung Transplant 2013;32:106–11.

16. Slaughter MS, Rogers JG, Milano CA, et al. Advanced heart failure treated with continuous-flow left ventricular assist device. N Engl J Med 2009;361:2241–51.

17. Dixon SR, Henriques JPS, Mauri L, et al. A prospective feasibility trial investigating the use of the Impella 2.5 system in patients undergoing high-risk percutaneous coronary intervention (the PROTECT I trial): initial U.S. experience. J Am Coll Cardiol Intv 2009;2:91–6.

18. Seyfarth M, Sibbing D, Bauer I, et al. A randomized clinical trial to evaluate the safety and efficacy of a percutaneous left ventricular assist device versus intra-aortic balloon pumping for treatment of cardiogenic shock caused by myocardial infarction. J Am Coll Cardiol 2008;52:1584–8.

19. Thiele H, Sick P, Boudriot E, et al. Randomized comparison of intra-aortic balloon support with a percutaneous left ventricular assist device in patients with revascularized acute myocardial infarction complicated by cardiogenic shock. Eur Heart J 2005;26:1276–83.

KEY WORDS heart failure, left ventricular assist device, percutaneous devices, shock

APPENDIX For the statistical methodology as well as supplemental tables and a figure, please see the online version of this article.