Operational Implications of Utilizing 2 Advanced Technologies for Rendering Short-term Hemodynamic Support to Patients Presenting With Cardiogenic Shock: A View Through the Lens of Hospital Readmissions

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ABSTRACT

Purpose: Reducing hospital readmissions for critically ill patients is of concern to payers and providers alike. Patients in cardiogenic shock are often treated with devices to help support the functions of the heart while the patient undergoes treatment. This study compares the readmission experience of Medicare beneficiaries treated for cardiogenic shock (CS) using percutaneous ventricular assist devices (pVADs) vs. extracorporeal membrane oxygenation (ECMO), two types of advanced cardiac support devices. Hospital readmission is a surrogate for quality and cost.

Design and methodology: A retrospective comparison of readmission patterns of patients treated for CS using two advanced cardiac support devices during calendar years 2011 and 2012 was captured via the Medicare Inpatient Standard Analytic File (100% census file). A total of 649 eligible cases (pVAD, 517; ECMO, 132) with 90 days of follow-up documentation were included in this analysis. Baseline characteristics were compared, including demographics, admission type, and severity of illness, with the 2 groups generating clinically similar baseline profiles. Primary outcomes include 30- and 90-day readmissions, associated length of stay (LOS), and costs.

Results: At 90 days after initial hospitalization, the readmission rates in the pVAD and ECMO cohorts were 38.7% (200/517) and 53.0% (70/132), respectively. Overall, pVAD was associated with a 27.1% reduction in readmission (*P*=.004). With the use of pVAD, 90-day readmission costs were lower by $12,294 ($32,736 vs $20,442, a reduction of 37.6%, *P*=.02) and readmission LOS was shorter by approximately 8 days, (20.5 vs. 12.7 days, a 37.9% reduction, *P*=.002). Similar trends were observed at 30 days; however, only LOS was significantly reduced, by 7.0 days (*P*<.001).

Conclusion: In clinically comparable cohorts, pVADs were associated with reduced risk of rehospitalization, lower cost, and shorter LOS, resulting in cost savings for payers and providers. Increased adoption of pVAD, as a technology to support patients in cardiogenic shock, may help hospitals deliver greater value to both government and commercial payers.

(Key Terms) Hospital readmissions, costs, length of stay, cardiogenic shock, hemodynamic support, pVAD, ECMO, Medicare

INTRODUCTION

At an estimated cost to the American public of over $17 billion in 2010, hospital readmissions for Medicare beneficiaries represent a major national priority (Hickman 2012). A recent study showed that up to 20% of all Medicare beneficiaries are readmitted within 30 days of discharge (Bradley 2013). Moreover, although some of these readmissions are part of the course of treatment, the vast majority are unplanned and therefore represent an opportunity for cost savings (Jencks 2009). For example, a recent report by the Medicare Payment Advisory Commission (MedPAC) concluded that three quarters of readmissions within 30 days were preventable, representing $12 billion in additional Medicare spending during fiscal year (FY) 2005 (James 2013). Despite the need to reduce the cost of preventable readmissions, the 19% average rate for all-cause, 30-day readmissions (2007–2011) has remained intractably high (Gerhardt 2013).

Recognizing the need to reduce hospital readmissions, Section 3025 of the Affordable Care Act (ACA) added Section 1886(q) to the Social Security Act, establishing the Hospital Readmissions Reduction Program (HRRP). This section requires the Centers for Medicare & Medicaid Services (CMS) to reduce payments to Inpatient Prospective Payment System hospitals with excess readmissions, effective for discharges beginning on Oct. 1, 2012. The first three conditions the HRRP focused on were pneumonia and two of the most prevalent forms of cardiovascular disease, acute myocardial infarction (AMI) and heart failure (HF).

Reducing readmissions and their associated costs are not the concern only of Medicare policymakers. Most

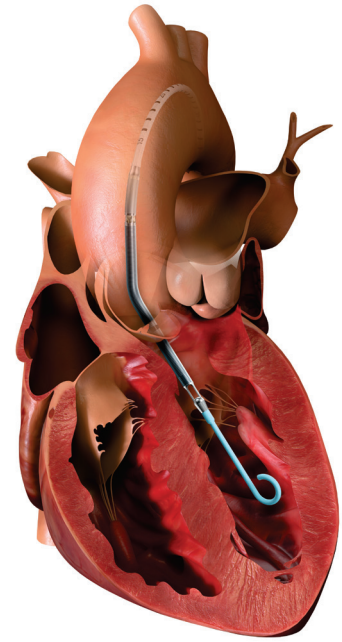
large commercial payers are taking action as well by requiring metrics from hospitals showing their rates of readmission for high-priority conditions. Major commercial payers, including WellPoint and Aetna, have announced payment initiatives encouraging hospitals to reduce readmissions.

Compelling logic underlies the selection of cardiovascular disease, especially HF and AMI, as a target for reducing hospital readmissions. Advanced HF is the leading cause for hospital readmissions among both Medicare and commercial insureds (Desai 2012). A review of the claims of over 11 million Medicare beneficiaries from the MedPAR database found HF to be the leading cause of hospital readmissions, with a 30-day rehospitalization rate of 26.9% (Jencks 2009).

A particularly challenging clinical complication of HF and AMI is cardiogenic shock (CS). CS is a state of end-organ failure and is the leading cause of death in patients experiencing an AMI (Maini 2014). In 2013, the annual incidence of AMI was projected to be 635,000 cases (Go 2013); approximately 7% to 10% of AMI cases are complicated by CS (Thiele 2007). Although AMI patients whose condition is complicated by CS constitute a relatively small group of hospital admissions, these patients frequently experience adverse clinical and economic outcomes and approximately 25% of these cases require hemodynamic support (Lloyd-Jones 2010, Whellan 2010, Thiele 2007). In

KEY POINTS

- Cardiovascular disease is leading cause of hospital readmission among Medicare beneficiaries and people with commercial insurance coverage.
- Physicians are increasingly reliant on advanced technologies to treat patients in cardiogenic shock after less-costly conventional drug therapy and mechanical cardiac support prove unsuccessful.
- Previous studies have suggested that percutaneous ventricular assist devices (pVADs) are more cost-effective than extracorporeal membrane oxygenation (ECMO) devices for treating patients with refractory cardiogenic shock.
- This study, which focused on hospital readmissions, showed that 90 days after their initial hospitalization, the readmission rate for patients treated with pVADs was lower than those treated with ECMO devices (38.7% vs. 53%).
- Readmission costs were also lower ($20,442 vs. $32,736) and the readmission LOS were shorter (12.7 days vs 20.5 days) for those treated with pVADs compared with those treated with ECMO devices.
- With the exception of length of stay, many of the differences between pVADs and ECMO devices 30 days after initial hospitalization did not reach statistical significance.



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PVAD inside the heart

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Extracorporeal membrane oxygenation (ECMO) with intraaortic balloon counterpulsation in ICU

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Funding source: The funding source for this article is Abiomed (Danvers, Mass.).

Conflict disclosures: Scotti discloses that he is a paid consultant to Abiomed as a technical advisor and receives indirect support from Abiomed for secondary database acquisition. Gregory and Buck disclose that they are paid advisors of Abiomed and also receive indirect support from Abiomed for secondary database acquisition.

Acknowledgements: Christina Cool of Baker Tilly helped prepare the manuscript.

addition to lengthy hospital stays with prolonged confinements in intensive care units, these hemodynamic support devices and their management are costly; all of these factors contribute to the overall costs of patients with cardiogenic shock. Accordingly, both payers and providers are searching for treatment options that improve quality and lower costs, which include reducing the incidence of hospital readmission (Jencks 2009).

Historically, intraaortic balloon pump (IABP) has been one of a limited number of mechanical hemodynamic support options when treatment of CS with inotropic and vasopressor drugs has failed. Although relatively inexpensive, IABPs have not made great strides in altering the clinical outcomes of CS patients (Romeo 2013, Thiele 2012). More advanced devices for rendering short-term percutaneous cardiac support — such as extracorporeal membrane oxygenation (ECMO) and more recently introduced percutaneous ventricular assist devices (pVADs) — may be used as an alternative to IABP or to escalate therapy for refractory CS.

pVADs, such as Impella 2.5 (Abiomed Inc., Danvers, Mass.) and TandemHeart (CardiacAssist, Pittsburgh), are minimally invasive, short-term mechanical pumps used to help hearts that no longer can pump blood effectively. These mechanical devices permit physicians to determine how much hemodynamic support is needed, ranging from 2.5 to 5.0 liters of forward blood per minute. Several recent studies have shown that these devices are effective in providing urgent, systemic circulatory support, thereby preventing additional cardiac and organ damage, expediting recovery time, and reducing subsequent major adverse events, including mortality (Liu 2013, Maini 2012, O'Neill 2014, Lemaire 2014). By comparison, ECMO also facilitates enhanced flow of oxygenated blood but has been associated with high rates of periprocedural complications and mortality rates exceeding 50% (Zangrillo, 2013) when used to treat patients in CS. The devices and clinical terms referred to in this discussion are defined in the glossary.

In addition to its clinical utility, pVAD was dominant in a cost-effectiveness analysis during initial hospitalization when compared with other circulatory support systems (Maini 2014). Further, published budget impact models have linked use of pVADs with nominal per-member, per-month expenditures for payers and a reduction in costs over time after the initial hospitalization (Gregory 2013).

As clinical practice patterns evolve, both physicians and managed care professionals need to better understand the economic consequences of reliance on advanced cardiac support devices as adjunct to or as substitutes for use of IABPs in the treatment of CS. This study provides a comparative economic analysis of readmissions stemming from the use of ECMO and pVADs as advanced technologies for providing mechanical hemodynamic support in the broad context of CS.

GLOSSARY

Cardiac output: The amount of blood the heart pumps through the circulatory system in 1 minute.

Cardiogenic shock (CS): A condition in which the heart muscle cannot get enough oxygen or nutrients to sustain itself, leading to diminished ability to pump enough blood to support proper circulation to the body's vital organs. Typically, cardiogenic shock is associated with a heart attack and can be fatal if not treated right away.

Extracorporeal left ventricular assist devices (eLVAD): A temporary mechanical pump used to help hearts that can no longer pump blood effectively due to heart failure. Ventricular assist devices (VADs) may be used as a bridge to recovery or as a bridge to a permanent implantable VAD.

Extracorporeal membrane oxygenation (ECMO): A support system that circulates blood through an external oxygenation system.

Hemodynamic support: The function performed by circulatory assist devices by increasing blood flow through various mechanisms of action.

Intraaortic balloon pump (IABP): A pump connected to a balloon device that is inserted into the descending aorta to provide temporary assistance to the heart in the management of left ventricular heart failure.

Percutaneous ventricular assist device (pVAD): A short-term minimally invasive mechanical pump that is implanted through a blood vessel and is used to help hearts that can no longer pump blood effectively due to heart failure.

Subendocardial infarction: A heart attack that involves the inner most layer and, in some cases, the middle layer of the heart muscle (myocardium).

METHODS

Study design

This study was designed as a retrospective comparison of readmission dynamics related to patients surviving treatment for CS supported by two advanced cardiac assist devices during calendar years 2011 and 2012. Primary outcomes included 30- and 90-day readmissions and associated length of stay (LOS) and costs for

all survivors of the initial CS event. Readmissions within 30 days of the initial ("index") stay were included in both measures. As secondary analyses, these variables were examined in a subgroup of cases where CS was present on admission, and the relationship between readmissions and discharge disposition was explored.

Data source and study population

The primary source of data for this retrospective analysis is the Medicare Standard Analytic File (SAF) of inpatient fee-for-service claims. The SAF contains all such records collected by Medicare from institutions and noninstitutional providers and contains claim-level detail on diagnosis, procedures, diagnosis-related groups (DRGs), dates of services, reimbursement and cost amounts, providers, and patient demographic detail. Our study population was compiled from the SAF data sets ranging between Jan. 1, 2011, and Dec. 31, 2012.

Demographic and clinical information for the patients analyzed in this study were identified using the *International Classification of Diseases–Ninth Revision* (ICD-9) coding system. Eligible candidates for this study included all patients in the inpatient SAF file who were discharged alive with an ICD-9 diagnosis code of 785.51 (cardiogenic shock) and a ICD-9 procedure code of 37.68 (insertion of percutaneous external heart assist device with or without the use of IABP) or procedure code 39.65 (extracorporeal membrane oxygenation [ECMO] with or without the use of IABP) appearing on a single claim (defined as the index hospitalization). A total of 901 discharged patients were identified as having the diagnosis code of interest and at least one of the procedure codes across the 2 years of claims data. Of these, 136 patients with discharge dates after Oct. 1, 2012, were excluded from the sample given that insufficient time remained to measure 90-day readmissions within the study period. An additional 60 patients were removed because of the presence of multiple procedures (devices) of interest on a single date or claim. A total of 705 patients were eligible for inclusion.

In addition to the standard information contained in the SAF, we utilized *severity of illness* (SOI) and *service intensity weights* (SIW) from the All-Patient Refined DRG Classification System (APR-DRG, Version 29, 3M Co.) to assess clinical differences between the cohorts. Using claim-level detail, each APR-DRG is subdivided into four levels of illness severity: *minor* (level 1), *moderate* (level 2), *major* (level 3), or *extreme* (level 4), with a specific SIW assigned to each SOI level based on age and primary and secondary diagnoses. For purposes of this study, all procedure codes, including device-specific codes, were removed from the claim-level detail prior to APR-DRG and severity assignment to establish baseline clinical profiles of the cohorts prior to treatment intervention.

Upon preliminary examination of SOI characteristics, we identified 56 cases that mapped to APR-DRG 200 "Cardiac Congenital and Valvular Disorders," 53 of which were categorized as extreme, with an SIW of 5.3761 (whereas others ranged from 0.7238 to 4.1402). Further examination revealed that these were predominantly scheduled/elective procedures. Clinical members of the research team agreed that the congenital and structural pathology of these cases was not clinically aligned with the typical CS profile. Therefore, all 56 cases were removed, resulting in 649 patients being included in the analysis. Of the 649 patients, 517 were treated with pVAD based on the presence of ICD-9 procedure code 37.68 upon index admission, while 132 were treated with ECMO on the basis of the presence of ICD-9 procedure code 39.65.

Variables

The claims containing the first instance of CS during the study period were considered the index hospitalization and served as the source for describing the baseline characteristics of research subjects (Table 1). Characteristics of the patients included in the study, including race, gender, age, and diagnoses present on admission (POA), were evaluated to assess the level of clinical comparability between the cohorts. For diagnoses POA, the ICD-9 appropriate diagnosis codes were extracted from each claim and the top 10 were compared across the pVAD and ECMO cohorts.

The type of admission at index hospitalization also was identified to assess the existence of noteworthy differences among these subgroups. As defined by CMS, inpatient admission types include, but are not limited to the following:

Emergent: The patient required immediate medical intervention as a result of severe, life threatening, or potentially disabling conditions. Generally, the patient was admitted through the emergency room.

Urgent: The patient required immediate attention for the care and treatment of a physical or mental disorder. Generally, the patient was admitted to the first available and suitable accommodation.

Elective: The patient's presenting condition permitted adequate time to schedule the availability of suitable accommodations (this type was by far the least frequent admission type for this population).

For statistical analysis purposes, 30- and 90-day readmissions were treated as dichotomous ("yes" or "no") occurrences. Patients with more than one readmission in each readmission category (30 and 90 days) were counted only once.

Readmission LOS was determined by taking the difference of the admission date for the rehospitalization and the discharge date. Admissions and discharges occurring on the same day were deemed as 1-day stays. Readmission cost was determined by calculating the total cost associated with the readmission claim as reported in the Inpatient SAF file. When patients had more than one readmission in either the 30- or 90-day timeframe, LOS for the visits were combined and an average cost was calculated for the readmissions.

Subgroup analyses included assessments of 30- and 90-day readmissions for patients who had an admission type of either *urgent* or *emergent*, reflecting index hospitalizations where inadequate time was available to schedule or plan for appropriate resources. For this subgroup analysis, these patients were combined into one group and all other patients were excluded (including elective, trauma, and other). We also conducted a subgroup analysis on only those patients with CS POA.

Additional descriptive analyses included evaluations of 90-day readmissions by discharge disposition, as well as a comparison of admitting and principal diagnoses at readmission. The SAF database assigns a patient's discharge disposition to 1 of 13 distinct settings. Of these, five were combined and recoded as discharged to *institutional* care (293 patients), while two were combined and recoded as discharged to *community* care (315 patients). The six remaining discharge categories were thinly represented (comprising only 41 patients in total) and were therefore excluded from analysis. A comparison of admitting and principal diagnoses for patients rehospitalized at 30 and 90 days was performed by extracting the respective codes for each treatment cohort.

Statistical analysis

Tests of differences among discrete categorical variables were assessed using the Pearson's chi squared or Fisher's exact test, as appropriate. Differences for normally distributed continuous variables with adequate sample sizes were tested using the *t* test. Logarithmic transformation was used to normalize data where substantial departures from normality were detected and data were positively skewed. When logarithmic transformation was not appropriate, comparisons were performed using the Mann-Whitney test. Data distribution anomalies were identified by standard SPSS diagnostic tests. Statistical analyses were 2-tailed and a value of $P<.05$ was considered statistically significant. All analyses were performed using SPSS Version 20 (IBM SPSS Statistics, Chicago).

RESULTS

Table 1 (see online appendix*) compares the baseline characteristics for the study cohorts. The highest percentage of patients in the pVAD cohort fell in the 65–69-year age category (pVAD=22.8%, ECMO=19.7%, $P=.48$), which is in contrast with the number of patients under age 65 observed in the ECMO cohort (pVAD=20.1%, ECMO=37.1%, $P<.001$). The ECMO cohort is therefore decidedly younger than the pVAD cohort and includes disabled beneficiaries under age 65 in this Medicare claims database. The age disparity between the two groups is statistically significant only in the under-65 category ($P<.001$), which disadvantages pVAD regarding its readmission parameters. There was no difference in gender, with approximately 59% men in the pVAD group as compared with 58% with ECMO. In terms of race, patients identifying themselves as *white* represented the highest percentage among the race categories of *white*, *black*, and *other*. The study cohorts were similar on race (white, $P=.31$, black, $P=.08$, and

TABLE 3
Readmission dynamics in the cardiogenic shock population by treatment cohort[1]

Measures	pVAD		ECMO		Change	% Change	*P* value
	n	%	n	%			
Index admissions (counts)	517	n/a	132	n/a	n/a	n/a	n/a
30-day readmissions (counts)[5]	134	25.9%	45	34.1%	8.2%	24.0%	0.064
30-day readmission LOS (days)[3]	10.5	n/a	17.5	n/a	7.0	39.9%	<0.001
30-day readmission cost (dollars)[2,4]	$28,159	n/a	$46,830	n/a	$18,671	39.9%	0.078
90-day readmissions (counts)[5]	200	38.7%	70	53.0%	14.3%	27.1%	0.004
90-day readmission LOS (days)[3]	12.7	n/a	20.5	n/a	7.8	37.9%	0.002
90-day readmission cost (dollars)[2,4]	$20,442	n/a	$32,736	n/a	$12,294	37.6%	0.022

ECMO=extracorporeal membrane oxygenation, LOS=length of stay, pVAD=percutaneous ventricular assist device.
1. 2011–2012 Medicare SAF 100% sample file.
2. Cost data are limited to 2012 only due to data constraints.
3. Log transformations were performed to address data distribution anomalies identified by standard SPSS diagnostic tests.
4. Mann-Whitney nonparametric tests were used when justified by small sample sizes and/or nonnormally distributed measures.
5. Fisher's exact tests were applied based on the dichotomous nature of the data.

*The online appendix can be found at www.managedcaremag.com/archives/2015/5/pvad-vs-ecmo

other, *P*=.71) and gender (*P*=.80) as well as all age groups over 65. Table 1 also shows that the study groups were not comparable in terms of relative frequency of CS POA. In the pVAD cohort, 58.3% of patients had CS POA compared with 41.7% of the patients in the ECMO cohort, a statistically significant difference of nearly 17% (*P*<.001). Moreover, 1,143 patients who did not survive their index event were excluded prior to any additional analysis, reflecting an overall mortality rate of 56%. Of these cases ECMO was associated with a higher mortality rate (67.4%) when compared with pVAD (50.8%; *P*<.001).

In addition to the key baseline characteristics, we compared the average SOI of our two study cohorts. The range of SOI values by study cohort and by inpatient admission type is shown in Table 2 (see online appendix). Overall, the clinical severity was assumed to be similar due to the fact that the average SOI was not statistically significant between the study cohorts. Appendix A (see online appendix) displays the top ICD-9 codes POA and their frequency of occurrence in both study cohorts. This clinical profile is offered to provide descriptive depth and was not used for matching purposes.

Table 3 reports results on the outcome variables of primary interest. Frequency of readmission, costs, and LOS were calculated and analyzed for the subgroups at both 30 days and 90 days post discharge. Although not statistically significant, the 30-day readmission rate was lower for pVAD when compared with ECMO (25.9% vs. 34.1%; *P*=.06). The mean difference in cost of $18,671 between ECMO ($46,830) and pVAD ($28,159) did not reach statistical significance (*P*=.08), but the mean difference in LOS of 7.0 days between ECMO (17.5 days) and pVAD (10.5 days) was statistically significant (*P*<.001).

Trends in frequency, cost, and LOS observed for CS patients readmitted within 90 days were similar to those observed at the 30-day mark (Table 3). The readmission rate was lower for pVAD when compared with ECMO (38.7% vs. 53.0%; *P*=.004). The mean differences in cost and LOS at 90 days were statistically significantly lower for the pVAD cohort by $12,294 (*P*=.02) and 7.8 days (*P*=.002).

The clinical reasons for readmission within 30 and 90 days (as defined by admitting and principal diagnoses) are presented for each cohort in Appendices B and C (see online appendix). Patients in the pVAD cohort were most often rehospitalized with the admitting and principal diagnosis of subendocardial infarction, while patients in the ECMO cohort were most often readmitted with the admitting diagnosis of CS, coronary atherosclerosis, or shortness of breath, and a principal diagnosis of coronary atherosclerosis.

The readmission dynamics of the subset of patients whose index admission was classified as either *urgent* or *emergent* were examined, and the results are displayed in Table 4. As with the overall sample, the pVAD cohort had a lower frequency of admissions at both 30 and 90 days postdischarge when compared with the ECMO cohort. The average LOS and cost of the readmission at both 30 and 90 days also favored the pVAD cohort. The mean differences in the average LOS were statistically significant at 30 days postdischarge (17.1 vs. 10.6 days; *P*=.004) and at 90 days postdischarge (20.9 vs. 14.5 days; *P*=.02). The 90-day readmission mean difference in cost of $13,950 was also statistically significant (*P*=.049).

Because of the clinical importance of cardiogenic shock, a separate subgroup analysis was performed to evaluate differences in readmissions among patients with CS POA across the study groups (Table 5). At 30 days, the profiles of this subgroup revealed a 35.6% reduction in readmissions (pVAD, 24.6% [74/301]; ECMO, 38.2% [21/55]) and a 7.6-day reduction in average LOS between the pVAD cohort and the ECMO cohort (pVAD, 9.0 days; ECMO, 16.5 days), both of which were statistically significant (*P*=.046 and *P*=.02, respectively). Although not statistically significant, the average cost of a 30-day readmission in the ECMO cohort was $51,260 compared with $32,404 in the pVAD cohort, a 36.8% saving in the pVAD group (*P*=.15). Trends in 90-day readmissions for this subgroup paralleled those found at 30 days. Patients treated with pVAD exhibited a 25.6% reduction in readmissions (*P*=.10), a $19,063 average savings in costs (*P*=.16), and a 6.6-day reduction in mean LOS (*P*=.01). While reductions in readmissions did not achieve statistical significance, we believe the magnitude of the observed reductions and average costs (and their respective *P* values) suggest the odds favor positive operational impacts associated with the use of pVADs at 90 days postdischarge for the CS POA subgroup.

To complete our analyses, we compared (post hoc) the differences in discharge disposition between the study groups subsequent to their index hospitalization (Table 6; see online appendix). Over half (54.5%) of the patients in the pVAD cohort were discharged to community care (either with or without medical support). This finding is in direct contrast to the ECMO cohort, where 59% were discharged to another institution, generating a statistically significant difference (*P*=.008) in the rate of discharge to community settings for pVAD.

We also examined the relationship between aggregate 90-day readmissions and postindex discharge disposition (Table 7; see online appendix). It is worth noting that, overall, 46.8% of patients who were discharged to an

institutional setting were readmitted within 90 days compared with 39.0% of patients who were discharged to home, approaching a statistically significant difference of nearly 8% (P=.06).

DISCUSSION

In the present era of healthcare reform, there is increasing pressure to improve quality of care while reducing costs. Recently, federal policymakers have focused on reducing the large and often unnecessary costs of Medicare readmissions by instituting the HRRP as part of ACA. While well intentioned, so far the HRRP has done little to reduce the all-cause, 30-day readmission rate, which has remained at approximately 19% for the past 5 years. This rate has dropped just 0.6%, to 18.4% in 2012 (the first year hospitals were penalized for excess readmissions for certain medical conditions), illustrating the intractable nature of the problem (Gerhardt 2013).

The challenge of controlling readmission costs is not just a Medicare issue. According to an analysis by *OptumInsight Inc.* of 5.4 million commercial and 900,000 retired covered lives, the average readmission cost to commercial carriers is 37% higher than for the average initial hospitalization (Kilroy 2013). Value-based care organizations, such as ACOs, should put programs in place that will address inpatient readmissions.

Although CS represents a small percentage of all HF patients, the mortality rate can be well over 50% and the cost to treat these patients is often exorbitantly high, with readmission rates well above the all-cause rates for both Medicare and commercial populations. One of the principal methods for restoring hemostasis in CS patients is via mechanical hemodynamic support, which was traditionally achieved with IABP, or if necessary, ECMO. Recent studies have shown pVADs provide effective mechanical hemodynamic support when compared with ECMO, with fewer clinical complications and at a lower index cost.

Unlike previous studies that focused on the initial, or index, hospital stay, this study moved the timeframe of interest to postindex discharge and explored the effect that utilization of these two commonly deployed cardiac support devices (ECMO and pVAD) had on the frequency, cost, and LOS of 30- and 90-day readmissions. As the study results show, the use of pVAD during the index hospitalization was associated with reductions in readmission frequencies, cost, and LOS at both 30 and 90 days when compared with the use of ECMO. Moreover, most of these reductions were statistically significant and were derived from a pVAD study cohort that was decidedly older than the ECMO cohort and well matched in terms of clinical severity.

The use of pVAD was also linked to reductions in the frequency, costs, and LOS of 30- and 90-day readmissions in the subgroup analyses comprising only patients who had CS and were classified as *emergent* or *urgent* on index admission, lending to the durability and credibility of the results observed in the overall study population. Also of note is the finding that pVAD was used more often than ECMO in these patients who were classified as *urgent/emergent* or who presented to the hospital with CS, suggesting the performance of pVAD is preferred to ECMO when time to plan for appropriate resource deployment is not an option.

Although the results of this study were based on the Medicare population, previous studies of commercially insured beneficiaries have shown that the economic impact of pVAD use in younger CS patients was favorable during their index hospitalizations. The authors assume the economics associated with the use of pVAD after discharge may also be similar. Future research should employ a similar study design utilizing a commercial claims database to test this hypothesis.

Our study is not without limitations. The study cohorts were derived from the fee-for-service Medicare claims data contained in the Inpatient SAF file. Restrictions on age and the disproportionate prevalence of disabled beneficiaries in our dataset limit the generalizability of our findings to the total population of those with insurance. Moreover, unlike prospective clinical studies, claims data are limited to administrative coding, including diagnoses and procedure codes that may lack precision and limit the number of variables and measures available for interpretation and analysis. Also, planned readmissions, which are part of the follow-up care and standard treatment protocols for a given condition, could not be filtered out of the study. Additionally, because this is a retrospective analysis, it is more difficult to control for factors that may influence adequate matching cohorts and their associated outcomes.

Finally, all observational studies are subject to the influence of hidden biases beyond the knowledge and control of the investigators. Accordingly, the conclusions from our study are susceptible to variable interpretations, do not imply causality, and should be applied judiciously. We would, therefore, encourage further research to explore the relationship between pVAD deployment and readmission outcomes based on more tightly controlled study designs.

CONCLUSION

The present study examined the readmission profiles of two advanced mechanical devices (pVAD and ECMO) that are increasingly deployed to provide cardiac support in the broad context of cardiogenic shock. The re-

sults of this study show that the use of pVADs are linked with reduced cost and improved operational efficiency, not only during the index stay as previously reported, but also post-discharge. Specifically, pVADs were associated with statistically significant reductions in readmission rates, LOS, and hospital costs. Our study, while limited in scope, does suggest that pVADs may have downstream operational implications that work to the benefit of CS patients after discharge. This research offers providers and managed care professionals an opportunity to better understand the economic consequences of clinical decisions to utilize advanced technologies as they strive to optimize post-acute care, including hospital readmissions. In the current era of health reform, commercial insurers as well as government policymakers should consider these potential operational effects of pVADs, as they attempt to control cost while maintaining quality in this high-risk patient population. MC

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