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Impact of Patient Safety Indicators on Readmission Following Abdominal Aortic Surgery

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Abstract

Objective: Patient safety is a critical component of health care quality and measures created by the Agency for Healthcare Research and Quality (AHRQ) to identify hospitalizations with potentially preventable adverse events. This analysis evaluated whether Patient Safety Indicator (PSI) events following open (OSR) or endovascular (EVAR) repair of abdominal aortic aneurysm (AAA) were associated with increased risk of readmission.

Methods: Patients undergoing elective repair of non-ruptured AAA from 2009 to 2012 were selected in the Medicare Provider Analysis and Review (MedPAR) files using the ICD-9-CM codes. To identify PSI events, we utilized the AHRQ Patient Safety Indicator ICD-9-CM numerator codes. Chi-square test, multivariable logistic regression analysis, non-parametric Wilcoxon rank sum test, and Kaplan-Meier survival analysis were used for statistics.

Results: 66,923 patients undergoing elective AAA repair were evaluated: 9,315 with OSR and 57,608 with EVAR. The most frequent PSI events after OSR vs. EVAR were: postoperative respiratory failure (PSI 11; 17.7% vs. 1.8%, $p<.0001$); perioperative hemorrhage/hematoma (PSI 9; 3.6% vs. 2.6%, $p<.0001$); postoperative sepsis (PSI 13; 3.5% vs. 0.4%, $p<.0001$); accidental puncture or laceration (PSI 15; 2.1% vs. 0.6%, $p<.0001$); and postoperative acute kidney injury requiring dialysis (PSI 10; 1.4% vs. 0.2%, $p<.0001$). The overall 30-day readmission rate was 10.5%. The occurrence of any PSI event overall significantly increased 30-day readmission compared with no event cases (OR =1.71; 95% CI 1.57–1.86). Likelihood of 30-day readmission was greater for postoperative acute kidney injury requiring dialysis (OR=1.66; 95% CI 1.28–2.15), postoperative respiratory failure (OR=1.36; 95% CI 1.22–1.52), perioperative hemorrhage (OR=1.34; 95% CI 1.18–1.52), and postoperative pressure ulcer (OR=CI, 1.68–3.05). Occurrence of any PSI event was associated with an increased total hospital and ICU (Intensive Care Unit) length of stay and total hospital charges (all $p<0.001$).

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Conclusions: AHRQ PSI events may be used to identify patients at greatest risk for readmission after AAA repair. The risk for 30-day readmission was 71% higher when a PSI event occurred and was not associated with a type of repair. Minimizing preventable PSI events may be beneficial to reducing hospital readmissions after open and endovascular AAA repair and to improving hospital resource utilization.

Keywords

Readmission; aneurysm; patient safety indicators

INTRODUCTION

Readmission has been targeted as an area for healthcare outcome improvement and is a significant cause of patient morbidity and cost for healthcare systems. Since the sentinel Institute of Medicine report, "To Err is Human,"^{1,2} patient safety and medical error have been a focus of attention for healthcare providers, patient groups, and hospital systems. The measures of safety events identified by the Agency for Healthcare Research and Quality (AHRQ) Patient Safety Indicators (PSI)² provide a means to identify potentially preventable adverse events^{3,4} occurring during a hospitalization, which have been standardized to allow comparisons in care quality and related metrics (e.g. inpatient costs, length of stay and mortality) between hospital systems.⁵⁻⁷ Hospital readmission within thirty-days following the previous hospital discharge has been labeled by The Centers for Medicare and Medicaid Services as a surrogate measure of the quality of healthcare delivery by a hospital system and has been targeted as a healthcare quality and cost-saving improvement measure.

Vascular surgery, specifically, has been linked with a readmission rate of almost 24%, much higher than the overall readmission rate for other types of surgery, when all diagnoses and procedures are considered.⁸⁻¹⁰ Resources have been directed to identifying and potentially mitigating preventable readmission, which in vascular surgery has been demonstrated to be a substantial cost-burden to hospital systems when compared with other types of surgery.¹¹

Complications such as an unplanned return to the operating room are routinely captured in administrative datasets such as the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) and has been considered a potentially preventable postoperative complication, which has been previously described as a risk-factor for readmission.¹² There exists, therefore, considerable value to identifying and lowering costly readmission within vascular surgery.

Abdominal aortic aneurysm repair is a major vascular operation with a well-described trend between surgical volume and patient outcome,^{13,14} but little has been studied with respect to the factors predisposing to readmission. This present study focusses on risk factors for all-cause hospital readmission within 30 days following hospital discharge after abdominal aortic aneurysm repair and seeks to examine the role of Patient Safety Indicators as possible predictors of readmission.

METHODS

Data Source

The CMS (Centers for Medicare & Medicaid Services) MedPAR (Medicare Provider Analysis and Review) files from 2009 to 2012 were used for analysis. Merging the CMS POS (Provider of Services) files to MedPAR files has allowed us to identify the hospital characteristics that were used in the analysis, such as the hospital's census region, location (urban/rural), and teaching status. Patient demographic characteristics (age, gender, and race) are the data elements of the MedPAR file. To identify comorbid diseases in the study patients we used the AHRQ (Agency for Healthcare Research and Quality) HCUP (Healthcare Cost and Utilization Project) Elixhauser Comorbidity Software, version 3.7.¹⁵ It was applied to the MedPAR file and created 29 various comorbidity measures. Patient safety indicators were recognized using the ICD-9-CM codes for numerators in the AHRQ Patient Safety Indicators Technical Specifications Updates, version 6.0.¹⁶ AHRQ PSI software allows clustered ICD-9 CM codes to be grouped into discrete PSI, in this way, multiple ICD-9 codes describing similar processes can be captured under the overarching broad clinical descriptor, e.g. postoperative respiratory failure. In the analysis, we used the following indicators: PSI 03 Pressure ulcer, PSI 06 Iatrogenic pneumothorax, PSI 09 Perioperative hemorrhage or hematoma, PSI 10 Postoperative acute kidney injury requiring dialysis, PSI 11 Postoperative respiratory failure, PSI 12 Perioperative pulmonary embolism or deep vein thrombosis, PSI 13 Postoperative sepsis, PSI 15 Unrecognized abdominopelvic accidental puncture or laceration, and PSI 16 Transfusion reaction. To calculate the rates of these PSIs in various groups, we used the number of observations in these groups as a denominator.

Study Population

Patients with non-ruptured abdominal aortic aneurysm who were electively hospitalized for AAA repair were selected with the ICD-9-CM (International Classification of Diseases, Ninth Revision, Clinical Modification) diagnosis code 441.4 for the principal diagnosis. Type of surgical procedure for AAA repair was identified with the following ICD-9 procedure codes: 39.71 for endovascular repair (EVAR) and 38.34, 38.44, and 38.64 for open surgery (OSR). Patients were excluded from the study if they had admissions during which both endovascular and open procedures were performed, had admissions flagged as emergent or urgent, or died in the hospital during the index hospitalization. In order to capture 30-day readmissions, for each patient with an index hospitalization we evaluated the following hospitalization and calculated the time interval between the date of the patient readmission and the date of the previous hospital discharge. Patients who were discharged in December 2012 were also excluded from the analysis because of lack of follow-up data.

Analysis

Data analysis and statistics were performed with SAS 9.4 software (SAS Institute, Cary, NC). The difference between categorical variables was evaluated by Chi-square test with calculating OR (odds ratio) and 95% CI (confidence interval) and the following multivariable logistic regression analysis with control for patient demographic and hospital characteristics, comorbidities, type of surgical procedure (EVAR or OSAR), and PSIs. The

freedom from readmission within 30 days after index hospital discharge was assessed by Kaplan-Meier survival analysis. Numeric variables were tested for normality of distribution and compared with the Student's t-test or Wilcoxon rank sum test as appropriate. A two-sided $P < 0.05$ was considered statistically significant.

The study was approved by the Health Sciences Institutional Review Board.

RESULTS

A total of 66,923 patients who met our selective criteria were included in the analysis. Open repair occurred in 9,315 (13.9%) patients; EVAR was performed in 57,608 (86.1%) cases. Demographic characteristics and comorbidities in patients of both surgical groups are reported in Table 1. Patients who underwent EVAR compared to those with OSR were older, with greater proportion of males ($P < 0.0002$). They had higher rates of hypertension, diabetes and obesity but lower rates of congestive heart failure (CHF), chronic pulmonary disease and renal failure.

Overall, 5,292 (7.9%) patients developed any PSI event during the index hospitalization. In the multivariable analysis, likelihood of any PSI increased with aging (OR=1.015; 95% CI 1.011–1.019), was greater in females compared to males (OR=1.29; 95% CI 1.22–1.38). Among all studied PSI events, the most frequent event was postoperative respiratory failure (3.99%) followed by perioperative hemorrhage/hematoma (2.72%), abdominopelvic accident puncture or laceration (0.84%), postoperative sepsis (0.78%), postoperative acute kidney injury requiring dialysis (0.37%), perioperative pulmonary embolism or deep vein thrombosis (0.30%), pressure ulcer (0.25%), and iatrogenic pneumothorax (0.13%). We did not find cases with transfusion reaction.

As shown in Table 2, crude rates of all studied PSIs in patients with open AAA repair were significantly higher than in patients with EVAR. The greatest difference was found in the rates of iatrogenic pneumothorax, postoperative respiratory failure, postoperative sepsis, and postoperative acute kidney injury requiring dialysis. In multivariable logistic regression analysis, patients with OSR were 5.6 times as likely to develop any PSI as patients with EVAR (95% CI 5.22–5.96).

Among 66,923 patients who were discharged from the hospital after AAA repair, 7,051 (10.5%) were readmitted to the hospital within 30 days after index discharge. This rate was significantly greater in patients who underwent open surgery (12.5%) than in those with EVAR (10.2%; $P < 0.0001$). In bivariate analysis, patients who developed any PSI during the index hospitalization for AAA repair were more likely to be readmitted than their counterparts without PSI (OR=2.02; 95% CI 1.88–2.18). This was confirmed in the multivariable analysis, controlling for patient demographics, comorbidities and hospital characteristics (OR=1.71; 95% CI 1.57–1.86).

Table 3 demonstrates how various PSIs affected 30-day readmission. Among those studied, pressure ulcer was the strongest predictor of hospital readmission, followed by postoperative acute kidney injury with hemodialysis, perioperative PT/DVT, postoperative sepsis, postoperative respiratory failure, abdominopelvic accidental puncture or laceration, and

perioperative hemorrhage/hematoma. The other predictors of 30-day readmission are advanced age, female gender, and such comorbidities as CHF, renal failure, diabetes mellitus, coagulation deficiency, chronic lung disease, and peripheral vascular disease. Figure 1 shows significantly greater freedom from readmission within 30 days after index hospital discharge in patients without any PSI compared to those who developed them.

Finally, we analyzed the impact of PSIs after AAA repair on hospital resource utilization during the index stay. Because of the abnormal distribution of the results obtained, they are presented in Table 4 as median with interquartile range (IQR 25–75 percentiles) in parentheses. As shown in this table, PSIs significantly extend total hospital and ICU length of stay with substantial increase of total hospital and ICU costs.

DISCUSSION

Readmission occurs frequently following vascular surgery with a rate of up to 24% in a Medicare beneficiary study.¹⁰ There are specific vascular procedures that carry a higher rate of readmission than others; examining thirty-day readmissions rates for lower extremity bypass, there was a significant readmission rate of 24.4% with the most common reason being wound infection in the index leg (39.8%) with additional procedures to the index leg driving readmission in 20.8%.¹⁷ Furthermore, regarding lower extremity endovascular procedures, high body mass index, unplanned return to the operating room, diabetes and emergency operation have also been identified as significant risk factors for hospital readmission.¹⁸ Similarly in carotid endarterectomy surgery and stenting, older age, renal failure and congestive heart failure contributed to a much higher chance of being readmitted.¹⁹ This high readmission rate has also been described for aneurysm repair in a Center for Medicare and Medicaid Services (CMS) Chronic Conditions Warehouse database study.²⁰ The authors reported 26.1% of all aneurysm repairs (13.3% of EVAR and 12.8% of open repairs) were readmitted within thirty days; with wound complications, pneumonia and respiratory complications, AAA and graft-related complications, congestive heart failure and sepsis being the primary readmission diagnoses.

As a directed quality improvement measure, a higher than expected readmission rate has been targeted by the Center for Medicare and Medicaid Services (CMS) as an area for improvement²¹ and has been linked with possible reduced reimbursement. There has been little published, however, regarding the effect of the PSI on readmissions and outcomes although a recent study examining the impact of these indicators on the readmission rates on the Veteran's Health Administration demonstrated a 23% odds of readmission when an index hospitalization was complicated by any PSI.²²

Patient safety indicators were introduced in 2003 by the Agency for Healthcare Research and Quality (ARHQ) as a method of monitoring and reporting preventable adverse events during a hospitalization.² The identification of a PSI event has been studied as a marker of overall risk of readmission in different populations.^{22–24} The association of PSI events and readmission, however, has not been extensively studied in a vascular population. Hernandez-Boussard *et al.* (2012) report one of the larger studies of adverse events in vascular surgery by examining eight vascular procedures in the Nationwide Inpatient Sample.²⁵ PSI events

were seen in 5.2% of patients overall with amputations and open aneurysm repair experiencing the highest risk-adjusted PSI and carotid endarterectomy and EVAR the lowest adjusted rate. Interestingly, the authors describe a relationship between the severity of symptoms (e.g. claudication to rest pain to gangrene) and higher PSI risk-adjusted rates.

In this study, we demonstrated similar findings of a higher risk of safety events for open versus endovascular aneurysm repair for ten of the thirteen identified PSI. The overall PSI rate for patients undergoing aneurysm repair was 1.8%, which is consistent with previous reports.²⁵ Traditionally-described risk factors for readmission, such as female gender, diabetes, chronic renal insufficiency and chronic lung disease were borne out in the study to be associated with higher readmission rates. Furthermore, there was a correlation between overall PSI events and readmission and a relationship between the type of PSI encountered and the risk of readmission. Pressure ulceration predicted the highest risk for readmission (HR 2.88) with postoperative acute kidney injury requiring dialysis the next highest (HR 1.88). There are few published reports evaluating the accuracy of individual PSI events in predicting outcome, but clearly some PSI events have greater clinical significance than others. Borzecki *et al* (2011) studied the validity of the AHRQ patient safety indicator postoperative hemorrhage or hematoma (PHH) in a Veteran's Health Administration population.²⁶ The authors identified 112 possible cases of PHH and reviewed the medical records to ascribe a true positive or false positive designation to each of the identified PHH cases. Eighty-four cases were identified as true positive and most of these returned to the operating room for hemorrhage/hematoma management (82%) with a 7% in-hospital mortality rate.

The predictive power of PSI 09 (postoperative hemorrhage or hematoma) for risk of mortality has been previously described in a Nationwide Inpatient Sample study.²⁷ In a population of elective lower extremity procedures, PSI 09 was associated with an almost threefold risk of death. Additional findings were that the severity of lower extremity symptoms was positively associated with an increase in PSI events from claudication (lowest) to rest pain to gangrene (highest), echoing the findings of other described reports.²⁵

In this present study, and others before, any identified PSI event leads to an increased risk of poor outcome when looking at overall metrics of increased ICU stay, length of hospital stay, hospital cost, mortality and readmission.²³ The PSI events are different in their associated risk of readmission and there may be value in identifying events at particular risk for readmission – such as pressure ulceration or postoperative acute kidney injury requiring dialysis. Given increasing data that is able to distinguish patients at higher risk of readmission, we suggest that the thrust of further research should focus on strategies to prevent readmission in vulnerable populations. A diverse range of interventions have been implemented ranging from enhanced discharge protocols, telemedicine, home visits and remote monitoring with some success in lowering thirty-day readmission.²⁸ Other reports have described a lowering of risk-standardized 30-day readmission rates (RSRRs) in heart failure patients by employing resource-heavy strategies such as increased community physician partnering, partnering with local hospitals to reduce readmission, having nurses responsible for medication reconciliation, arranging follow-up appointments prior to

discharge, electronic or paper discharge summaries directly to primary care physicians and assigning staff to follow-up on testing after patient discharge.²⁹

Despite these multi-faceted interventions, the overall rate of readmissions has been slow to change (19% in 2011 to 17.5% in 2013), even in the face of penalties imposed by CMS as part of the Medicare Hospital Readmissions Reduction Program (HRRP).³⁰

There is a high likelihood that complications surrounding a procedure are associated with increased readmission. Of the PSI which are considered never events, the ones most likely associated with a complication in this analysis were perioperative hemorrhage.³¹ Similarly, the association of pressure ulcers with readmission may be a marker for patients that are debilitated or may be a reflection of long lengths of stay leading to this complication. Patients with increased lengths of stay have been previously described as a potential marker for readmission.³²

Limitations

This study has limitations secondary to relying on the ICD-9-CM codes, as coding practices may vary between institutions. Because the procedure type was not randomly assigned, confounding could affect the differences between surgical groups, and this was addressed with a multivariable logistic regression analysis.

CONCLUSIONS

Readmission remains a significant issue for complex patient populations such as those with vascular disease. Following elective abdominal aortic aneurysm repair, the presence of any PSI event was associated with a significantly higher readmission rate. Furthermore, the power of this association varied in different PSI events with the highest risks of readmission for pressure ulceration, postoperative acute kidney injury requiring hemodialysis, and perioperative PE/DVT. While minimizing PSI events would likely lead to reduced readmission rates and is already a focus for hospital quality metrics, some PSI events may be markers of a more vulnerable population in need of more healthcare resources. PSI events may be used to identify these patients and potentially mitigate early readmission for this susceptible group.

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Figure 1.
Freedom from readmission within 30days after index discharge.

Table 1.

Characteristics of the study population [N (percent) unless otherwise indicated].

Characteristics	Procedure		p-value
	EVAR	OSR	
Age, years (<i>mean ± SD</i>)	75.9 ± 7.3	73.8 ± 6.7	<0.0001
Age groups (years)			<0.0001
70	14,410 (25.0)	3,040 (32.6)	
71–75	13,303 (23.1)	2,487 (26.7)	
76–80	13,511 (23.5)	2,216 (23.8)	
>80	16,384 (28.4)	1,572 (16.9)	
Gender			<0.0001
Male	45,979 (79.8)	6,437 (69.1)	
Female	11,629 (20.2)	2,878 (30.9)	
Race			0.0054
White	53,803 (93.4)	8,642 (92.7)	
Black	2,109 (3.7)	349 (3.8)	
Hispanic	350 (0.6)	51 (0.6)	
Other	1,346 (2.3)	273 (2.9)	
Comorbidities			
Chronic pulmonary disease	17,799 (30.9)	3,260 (35.0)	<0.0001
Congestive heart failure	13 (0.02)	19 (0.2)	<0.0001
Diabetes	10,812 (18.8)	1,449 (15.6)	<0.0001
Hypertension	42,577 (73.9)	6,388 (68.6)	<0.0001
Obesity	4,047 (7.0)	550 (5.9)	<0.0001
Renal failure	6,551 (11.4)	1,227 (13.2)	<0.0001
Total patients	57,608	9,315	66,923

SD, standard deviation; EVAR, endovascular aneurysm repair; OSR, open surgical repair

Table 2.

PSI events by type of aneurysm repair [N (percent) unless otherwise indicated].

PSI events	OSR	EVAR	OR (95% CI)	p-value
03 Pressure ulcer	49 (0.5)	117 (0.2)	2.6 (1.9–3.6)	<0.0001
06 Iatrogenic pneumothorax	65 (0.7)	25 (0.04)	16.2 (10.2–25.7)	<0.0001
09 Perioperative hemorrhage/hematoma	333 (3.6)	1484 (2.6)	1.4 (1.2–1.6)	<0.0001
10 Postoperative AKI with HD	131 (1.4)	116 (0.2)	7.1 (5.5–9.1)	<0.0001
11 Postoperative respiratory failure	1652 (17.7)	1019 (1.8)	11.9 (11.0–12.9)	<0.0001
12 Perioperative PE/DVT	74 (0.79)	126 (0.22)	3.6 (2.7–4.9)	<0.0001
13 Postoperative sepsis	321 (3.5)	200 (0.4)	10.2 (8.6–12.2)	<0.0001
15 Unrecognized AP puncture/laceration	191 (2)	368 (0.64)	3.3 (2.7–3.9)	<0.0001

OSR, open surgical repair; EVAR, endovascular aneurysm repair; OR, odds ratio; CI, confidence interval; AKI, acute kidney injury; HD, hemodialysis; PE, pulmonary embolism; DVT, deep vein thrombosis; AP, abdominopelvic

Table 3.

Multivariable logistic regression analysis of factors associated with thirty-day readmission

Variables	OR	95% CI	p-value
Age (one-year increase)	1.015	1.011–1.019	<0.0001
Female gender	1.29	1.22–1.38	<0.0001
Congestive heart failure	3.01	1.41–6.39	0.004
Coagulation deficiency	1.31	1.17–1.46	<0.0001
Chronic lung disease	1.24	1.17–1.31	<0.0001
Diabetes mellitus	1.68	1.35–2.10	<0.0001
Peripheral vascular disease	1.20	1.14–1.27	<0.0001
Renal failure	1.72	1.60–1.85	<0.0001
PSI 03 Pressure ulcer	2.88	1.99–4.17	<0.0001
PSI 09 Perioperative hemorrhage/hematoma	1.38	1.20–1.59	<0.0001
PSI 10 Postoperative AKI with HD	1.88	1.37–2.57	0.0001
PSI 11 Postoperative respiratory failure	1.44	1.28–1.62	<0.0001
PSI 12 Perioperative PE/DVT	1.56	1.05–2.30	0.028
PSI 13 Postoperative sepsis	1.53	1.20–1.95	<0.001
PSI 15 Unrecognized AP puncture/laceration	1.40	1.09–1.79	0.009

OR, Odds Ratio; CI, confidence interval; AKI, acute kidney injury; HD, hemodialysis; PE, pulmonary embolism; DVT, deep vein thrombosis; AP, abdominopelvic

Table 4.

The impact of PSI after AAA repair on hospital resource utilization [median (interquartile range)].

Parameters	PSI development		p-value
	No	Yes	
Total hospital LOS, days	2 (1–3)	7 (4–12)	<0.0001
ICU LOS, days	1 (0–1)	3 (1–7)	<0.0001
Total hospital cost, \$ \$	77,882 (57,442–106,381)	110,333 (75,916–169,225)	<0.0001
ICU cost, \$ \$	1,674 (0–4,250)	7,652 (1,649–21,219)	<0.0001

LOS, length of stay; ICU, intensive care unit