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Variation in readmission expenditures after high-risk surgery: A population based study using all-payer data*

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ABSTRACT

Objectives: The Hospital Readmissions Reduction Program reduces payments to hospitals with excess readmissions for three common medical conditions and recently extended its readmission program to surgical patients. We sought to investigate readmission intensity as measured by readmission cost for high-risk surgeries and examine predictors of higher readmission costs.

Methods: We used data from the Healthcare Cost and Utilization Project's State Inpatient Database to perform a retrospective cohort study of patients undergoing major chest (aortic valve replacement, coronary artery bypass grafting, lung resection) and major abdominal (abdominal aortic aneurysm repair [open approach], cystectomy, esophagectomy, pancreatectomy) surgery in 2009 and 2010. We fit a multivariable logistic regression model with generalized estimation equations to examine patient and index admission factors associated with readmission costs.

Results: The 30-day readmission rate was 16% for major chest and 22% for major abdominal surgery ($p<0.001$). Discharge to a skilled nursing facility was associated with higher readmission costs for both chest (OR 1.99; 95% CI 1.60-2.48) and abdominal surgeries (OR 1.86; 95% CI 1.24-2.78). Comorbidities, length of stay, and receipt of blood or imaging was associated with higher readmission costs for chest surgery patients. Readmission >3 weeks after discharge was associated with lower costs among abdominal surgery patients.

Conclusions: Readmissions after high-risk surgery are common, affecting about one in six patients. Predictors of higher readmission costs differ among major chest and abdominal surgeries. Better identifying patients susceptible to higher readmission costs may inform future interventions to either reduce the intensity of these readmissions or eliminate them altogether.

INTRODUCTION

On October 1, 2012, the Centers for Medicare and Medicaid Services (CMS) enacted the Hospital Readmissions Reduction Program, which reduces payments to hospitals with excess readmissions for three common medical conditions (acute myocardial infarction, heart failure, and pneumonia).[1] CMS recently extended its readmissions program to surgical patients and plans to include high-risk procedures, such as cardiac surgery, in the near future.[2,3] Currently, excess readmissions are calculated by accounting for patient factors, such as age, gender, and comorbidities, in its risk adjustment.[4]

However, the Hospital Readmissions Reduction Program does not account for differences in the readmission intensity (i.e., the cost associated with the readmission), which may be important to consider when assessing readmissions after high-risk surgery. Recent work has demonstrated that the quality of hospital care is only marginally associated with surgical readmission rates.[5] The inability to detect a relationship between quality and readmissions after surgery may be due to the fact that not all surgical readmissions are the same. On the one hand, readmissions for acute complications may save lives by averting a catastrophic "failure to rescue" event. On the other hand, readmissions for inadequate social support may be avoided with better allocation of resources.[6] Yet, the current Hospital Readmissions Reduction Program does not account for these differences in hospital readmissions; the program focuses on whether or not a readmission occurs without considering the context of the readmission. In part, this may be attributed to the limited information regarding the intensity of the readmission, especially for patients undergoing high-risk surgery.

For these reasons, we performed a study to evaluate readmission intensity as measured by readmission costs for patients undergoing major chest (aortic valve replacement (AVR), coronary artery bypass grafting (CABG), lung resection) and abdominal surgery (abdominal aortic aneurysm (AAA) repair, cystectomy, esophagectomy, pancreatectomy). A better understanding of the variation in readmission cost associated with these high-risk surgeries may help inform policies aimed at improving the quality and cost of surgical care.

METHODS

Data source and study population

We used the Healthcare Cost and Utilization Project's State Inpatient Database for New York, Iowa, North Carolina, and Washington to identify adult men and women (18 years or older) who underwent one of seven high-risk surgeries in 2009 or 2010. The State Inpatient Database provides information about hospital inpatient stays and patient-level discharge data for 97% of all United States' community hospital discharges.[7] We chose these four states because they comprise diverse patient and geographic populations and because they have data available to characterize readmissions. The seven high-risk surgery types included AAA repair (open as opposed to endovascular approach), CABG, AVR, esophagectomy, pancreatectomy, lung resection, and cystectomy. We chose these surgeries because they represent complex operations with high readmission rates (all >10%).[5,8,9]

We identified patients undergoing these seven high-risk surgery types using their respective *International Classification of Diseases, 9th Revision, Clinical Modification* (ICD-9-CM) codes (appendix). Patients who underwent two or more of the designated surgeries were excluded unless they received both a CABG and an AVR, in which case they were identified as having an AVR; 46% of patients undergoing an AVR had a concomitant CABG. Using these criteria, our study consisted of 69,321 patients.

Outcomes

The objective of this study was to assess readmission costs among patients undergoing high-risk surgery. First, we defined a readmission as a hospital admission within 30 days of the index surgery. We used a 30-day time period to be consistent with the readmission definition used by the Hospital Readmissions Reduction Program.[1] Then, we examined readmission cost as our primary outcome. Specifically, we calculated readmission costs using an established method[10,11] based on total readmission charges and hospital-specific cost-to-charge ratios developed by the Healthcare Cost and Utilization Project.[7] The cost-to-charge ratio provides a way to estimate the cost of hospital services, as opposed to the charges put forth by hospitals. Readmission costs were then ranked and sorted into quartiles.

Statistical analysis

We first compared patient demographics and index admission characteristics among patients undergoing one of the seven major surgery types, according to whether or not they were subsequently readmitted. Continuous variables were compared using Student-t-tests. Nominal and ordinal categorical variables were compared using general chi-square and Mantel-Haenszel chi-square tests, respectively. Next, we focused on the patients who were readmitted and compared characteristics related to their readmission, such as time to readmission, length of stay, discharge disposition, and cost. For this part of the analysis, we distinguished chest (CABG, AVR, lung resection) from abdominal (AAA, esophagectomy, pancreatectomy, cystectomy) surgery to account for the different sets of risks and convalescence periods expected between the two anatomical sites. Readmission costs were compared using the nonparametric Wilcoxon rank-sum test.

Next, we fit a multivariable logistic regression model with generalized estimation equations to examine factors associated with readmission costs. This model accounts for the clustering of patients within hospitals. Covariates in our model included time to readmission, age, gender, race, comorbidity, length of stay, discharge disposition, resource utilization (i.e., blood transfusion, imaging, intensive care unit stay, dialysis during the index admission), state, and type of surgery. Race was examined because it has been associated with readmission rates[12] (although it is not incorporated into the Hospital Readmissions Reduction Program's risk adjustment methods[13]). Race was not reported in North Carolina. Comorbidity was measured using the adaptation of the Charlson index by Deyo and colleagues in which ICD-9 diagnosis and procedure codes were used to identify the presence or absence of 16 comorbid conditions.[14] State was included to adjust for geographic differences in cost. All analyses were performed using SAS v9.3 (Cary, NC). The probability of a type I error was set at 0.05, and all testing was two-sided. Because patients cannot be identified, our Institutional Review Board exempted this study from review.

RESULTS

Index admission characteristics of patients not readmitted and readmitted are demonstrated in Table 1. Readmitted patients were more likely to have Medicare and less likely to have private insurance ($p<0.001$). In addition, readmitted patients were more like to have comorbidities, have a longer hospital length of stay, and were more likely to be discharged to a skilled nursing facility rather than home (all $p<0.001$). Last, readmitted patients had higher resource utilization during the index admission ($p<0.001$ for blood transfusion, imaging, intensive care unit, and dialysis).

A comparison of readmission characteristics of patients undergoing major chest and abdominal surgery is shown in Table 2. The 30-day readmission rate was 16% for major chest surgery and 22% for major abdominal surgery (p<0.001). The greatest proportion of patients undergoing both major chest and abdominal surgery were readmitted within 1 week, although this occurred more frequently with chest surgery patients (p=0.002). The median length of stay was five days for both chest and abdominal surgery patients, although there were statistical differences in the two groups based on varying ranges (p=0.02). Readmitted chest surgery patients were less likely to be discharged with home care and more likely to be discharged to a skilled nursing facility (p<0.001). Readmission costs for patients who underwent abdominal surgery were higher than for those who underwent chest surgery (p<0.001).

On multivariable analysis, patients undergoing major chest surgery had a greater likelihood of having higher readmission costs (as opposed to lower costs) if they had comorbidities, a longer index length of stay (odds ratio [OR] 1.02; 95% confidence interval [CI], 1.01-1.02), a discharge to a skilled nursing facility as opposed to home (OR 1.99; 95% CI 1.60-2.48), and received either a blood transfusion (OR 1.47; 95% CI 1.23-1.75) or imaging (OR 1.31; 95% CI 1.12-1.53) on their index admission (Figure 1). In addition, patients had lower readmission costs if they lived in Iowa or North Carolina compared with New York or if they underwent an AVR or a CABG as opposed to a lung resection (all p <0.01).

For patients undergoing major abdominal surgery, the likelihood of having higher readmission costs (as opposed to lower costs) was greater if discharged to a skilled nursing facility rather than home (OR 1.86; 95% CI 1.24-2.78), and if they lived in Washington as opposed to New York (OR 2.04; 95% CI 1.16-3.59) (Figure 2). Conversely, readmission costs were lower if admitted greater than three weeks after discharge (OR 0.56; 95% CI 0.33-0.92). Readmission costs did not differ based on type of major abdominal surgery (p=0.35).

DISCUSSION

Readmissions after high-risk surgery are common, affecting about one in six patients. The costs associated with these readmissions vary greatly both within a type of surgery (e.g., chest surgery) and across different types of surgeries (e.g., chest versus abdominal surgery). Moreover, several of the factors that predict higher readmission costs differ among major chest and abdominal surgeries.

The variation in readmission costs suggests that a "one size fits all" approach to surgical readmissions may not be optimal. Although readmission rates are high across all complex chest and abdominal surgeries, factors from the index admission that predict readmission costs vary. For example, with major chest surgery, the time to readmission does not show any association with readmission cost. However, for abdominal surgery, there is a trend towards decreasing readmission costs with increasing time to readmission. This is consistent with the finding that earlier surgical readmissions are associated with increased mortality.[15] As another example, patient comorbidities were associated with increasing readmission costs for chest but not abdominal surgeries.

Despite these differences, discharge to a skilled nursing facility stands out as a strong predictor of readmission costs for patients undergoing both major chest and abdominal surgeries. A discharge destination other than home is a risk factor for readmission across many surgery types, likely due to the patient condition that prevents them from safely being discharged home in the first place.[3,8,16] Critics may argue that these higher readmission rates are evidence that these services are ineffective. However, to the contrary, these facilities may be detecting clinical issues before they become bigger problems.

Earlier recognition of deteriorating clinical conditions earlier can help prevent complications from leading to death, known as failure to rescue. This phenomenon has been reported across a wide range of surgery types.[17-21] Although the variation in failure-to-rescue rates among hospitals is largely unexplained,[18] there are potentially modifiable targets to reduce these rates. For instance, modifying structural components (e.g., experienced staff members in skilled nursing facilities), modifying processes of care components (e.g., communication between hospitals and discharge destinations), and enhancing safety culture (e.g., education to increase awareness)[22,23] may decrease failure-to-rescue rates. Interestingly, hospitals with high-care intensity (adjusted ratios of inpatient days and physician encounters) have lower failure-to-rescue rates, which begs the question as to whether hospitals with higher readmission costs also have lower failure-to-rescue rates.[24]

Factors associated with higher readmission costs may help inform interventions to ultimately reduce failure-to-rescue rates for specific types of surgeries. For instance, since patients with three or more comorbidities undergoing major chest surgery have higher readmission costs, scheduling them a primary care visit within two weeks post-operatively may heighten medical management and reduce the intensity of an unavoidable readmission or prevent a readmission from occurring altogether. In this context, others have shown that follow-up visits with primary care physicians after high-risk surgery, especially among those with higher complications rates, is associated with a lower risk of readmission.[25]

Our findings have important policy implications, especially as the Hospital Readmissions Reduction Program extends to surgical procedures. First, there will be added pressures on surgeons to reduce readmissions due to concerns about performance on quality measures and resulting penalties.[3,26] This pressure may result in unintended consequences through delays in care, such as increased rates of failure to rescue. Early presentations of serious problems may be written off as trivial with subsequent discharge instead of observation in the hospital. Second, the index admission hospital length of stay may increase. Physicians may feel added pressure to observe patients in the hospital longer if they feel it will reduce their chances of incurring a readmission penalty. Third, the readmission program assumes that the majority of readmissions represent inadequate management, inappropriate discharge, or poor care coordination,[13,26] and thus, penalizes all readmissions, regardless of their intensity. Similar to prior recommendations to weight post-surgical readmissions based on the time from discharge to readmission,[26] we feel other predictors of readmission costs (e.g., the use of resources during the index admission) should also be taken into account so that penalties are weighted based on the likelihood of readmission.

Our findings should be interpreted in the context of several limitations. First, we examined readmissions after high-risk surgery in four states (New York, Iowa, North Carolina, and Washington), and thus, our findings may not be generalizable to other parts of the country. However, these states contain diverse patient and geographic populations that are, in many ways, representative of the population as a whole. In addition, the State Inpatient Database contains adult patients of all ages with all types of health insurance, which further generalizes our findings. Second, we used a 30-day period to assess readmissions. There is evidence to suggest that a 90-day period may provide a more complete story of the morbidity associated with high-risk surgeries.[27] However, we are most interested in readmissions that occur in the acute post-operative period. Further, assessing 30-day readmission rates is aligned with the Hospital Readmissions Reduction Program.

Despite these limitations, our study merits consideration for three reasons. First, readmissions are different for patients who have undergone major chest and abdominal surgery and a "one size fits all" approach to assessing them is unlikely the best approach to post-surgical readmissions. Second, this study demonstrates that predictors of readmission costs vary based on the type of surgery, which may inform the timing and the nature of interventions to either reduce the intensity of readmissions or prevent them altogether. Third, the Hospital Readmission Reduction Program should consider characteristics from the index admission that predict readmission costs when assessing their penalties to hospitals.

ABBREVIATIONS AND ACRONYMS

AAA = abdominal aortic aneurysm

AVR = aortic valve replacement

CABG = coronary artery bypass graft

CMS = Centers for Medicare and Medicaid Services

ICD-9-CM = International Classification of Diseases, 9th Revision, Clinical Modification

Max = maximum

Min = minimum

MRI = magnetic resonance imaging

NA = not applicable

AUTHOR CONTRIBUTIONS

Study concept and design: Jacobs, He, Li, Helfand, Krishnan, Borza, Ghaferi, Hollenbeck, Helm, Lavieri, Skolarus

Acquisition of data: He, Skolarus

Jacobs, He, Li, Helfand, Krishnan, Borza, Ghaferi, Hollenbeck, Helm, Lavieri, Skolarus
Readmission expenditures after surgery

Analysis and interpretation: Jacobs, He, Li, Helfand, Krishnan, Borza, Ghaferi, Hollenbeck, Helm, Lavieri, Skolarus

Study supervision: Ghaferi, Hollenbeck, Helm, Lavieri, Skolarus

Acknowledgments: None

CONFLICTS OF INTEREST

Dr. Jacobs is a consultant for ViaOncology

Dr. Hollenbeck is an Associate Editor of *Urology*

Dr. Skolarus is a consultant for ArborMetrix

REFERENCES

1. Readmissions Reduction Program. http://www.cms.gov/Medicare/Medicare-Fee-for-Service-Payment/AcuteInpatientPPS/Readmissions-Reduction-Program.html. Accessed June 5, 2014.
2. Medicare Payment Advisory Commission. Report to Congress: promoting greater efficiency in Medicare. http://www.medpac.gov/documents/jun07_entirereport.pdf. Accessed June 5, 2014.
3. Merkow RP, Ju MH, Chung JW, et al. Underlying reasons associated with hospital readmission following surgery in the United States. *Jama.* Feb 3 2015;313(5):483-495.
4. Gu Q, Koenig L, Faerberg J, Steinberg CR, Vaz C, Wheatley MP. The medicare hospital readmissions reduction program: potential unintended consequences for hospitals serving vulnerable populations. *Health Serv Res.* Jun 2014;49(3):818-837.
5. Tsai TC, Joynt KE, Orav EJ, Gawande AA, Jha AK. Variation in surgical-readmission rates and quality of hospital care. *N Engl J Med.* Sep 19 2013;369(12):1134-1142.
6. Graham KL, Wilker EH, Howell MD, Davis RB, Marcantonio ER. Differences between early and late readmissions among patients: a cohort study. *Ann Intern Med.* Jun 2 2015;162(11):741-749.
7. Healthcare Cost and Utilization Project (HCUP). Overview of the State Inpatient Databases. http://www.hcup-us.ahrq.gov/sidoverview.jsp. Accessed October 16, 2014.
8. Stitzenberg KB, Chang Y, Smith AB, Nielsen ME. Exploring the burden of inpatient readmissions after major cancer surgery. *J Clin Oncol.* Feb 10 2015;33(5):455-464.
9. Jacobs BL, Zhang Y, Tan HJ, Ye Z, Skolarus TA, Hollenbeck BK. Hospitalization trends after prostate and bladder surgery: implications of potential payment reforms. *J Urol.* Jan 2013;189(1):59-65.
10. Yu HY, Hevelone ND, Lipsitz SR, Kowalczyk KJ, Hu JC. Use, costs and comparative effectiveness of robotic assisted, laparoscopic and open urological surgery. *J Urol.* Apr 2012;187(4):1392-1399.
11. Sachs T, Pomposelli F, Hamdan A, Wyers M, Schermerhorn M. Trends in the national outcomes and costs for claudication and limb threatening ischemia: angioplasty vs bypass graft. *Journal of vascular surgery.* Oct 2011;54(4):1021-1031.e1021.
12. Tsai TC, Orav EJ, Joynt KE. Disparities in surgical 30-day readmission rates for Medicare beneficiaries by race and site of care. *Ann Surg.* Jun 2014;259(6):1086-1090.
13. Shih T, Ryan AM, Gonzalez AA, Dimick JB. Medicare's Hospital Readmission Reduction Program in Surgery May Disproportionately Affect Minority-Serving Hospitals. *Ann Surg.* May 30 2014.
14. Deyo RA, Cherkin DC, Ciol MA. Adapting a clinical comorbidity index for use with ICD-9-CM administrative databases. *J Clin Epidemiol.* Jun 1992;45(6):613-619.
15. Gonzalez AA, Abdelsattar ZM, Dimick JB, Dev S, Birkmeyer JD, Ghaferi AA. Time-to-Readmission and Mortality After High-Risk Surgery. *Ann Surg.* Sep 10 2014.
16. Hu M, Jacobs BL, Montgomery JS, et al. Sharpening the focus on causes and timing of readmission after radical cystectomy for bladder cancer. *Cancer.* May 1 2014;120(9):1409-1416.
17. Tan HJ, Wolf JS, Jr., Ye Z, Wei JT, Miller DC. Complications and failure to rescue after laparoscopic versus open radical nephrectomy. *J Urol.* Oct 2011;186(4):1254-1260.

18. Ghaferi AA, Osborne NH, Birkmeyer JD, Dimick JB. Hospital characteristics associated with failure to rescue from complications after pancreatectomy. *J Am Coll Surg.* Sep 2010;211(3):325-330.
19. Ghaferi AA, Birkmeyer JD, Dimick JB. Hospital volume and failure to rescue with high-risk surgery. *Med Care.* Dec 2011;49(12):1076-1081.
20. Ghaferi AA, Birkmeyer JD, Dimick JB. Variation in hospital mortality associated with inpatient surgery. *N Engl J Med.* Oct 1 2009;361(14):1368-1375.
21. Ghaferi AA, Birkmeyer JD, Dimick JB. Complications, failure to rescue, and mortality with major inpatient surgery in medicare patients. *Ann Surg.* Dec 2009;250(6):1029-1034.
22. Ghaferi AA, Dimick JB. Understanding failure to rescue and improving safety culture. *Ann Surg.* May 2015;261(5):839-840.
23. Johnston M, Arora S, Anderson O, King D, Behar N, Darzi A. Escalation of care in surgery: a systematic risk assessment to prevent avoidable harm in hospitalized patients. *Ann Surg.* May 2015;261(5):831-838.
24. Sheetz KH, Dimick JB, Ghaferi AA. The association between hospital care intensity and surgical outcomes in medicare patients. *JAMA surgery.* Dec 2014;149(12):1254-1259.
25. Brooke BS, Stone DH, Cronenwett JL, et al. Early primary care provider follow-up and readmission after high-risk surgery. *JAMA surgery.* Aug 2014;149(8):821-828.
26. Girotti ME, Shih T, Dimick JB. Health policy update: rethinking hospital readmission as a surgical quality measure. *JAMA surgery.* Aug 2014;149(8):757-758.
27. Stimson CJ, Chang SS, Barocas DA, et al. Early and late perioperative outcomes following radical cystectomy: 90-day readmissions, morbidity and mortality in a contemporary series. *J Urol.* Oct 2010;184(4):1296-1300.

Table 1: Index admission characteristics of patients undergoing major chest and abdominal surgery

Characteristics	**Major chest and abdominal surgery (AVR, CABG, lung resection, AAA, cystectomy, esophagectomy, pancreatectomy) (n=69,321)**		
Readmission status, %	Not readmitted n=57,900 (84)	Readmitted n=11,421 (16)	P value*
Procedure			<0.001
Chest surgery, %	50,687 (88)	9516 (83)	
Abdominal surgery, %	7213 (12)	1905 (17)	
Median age, y (standard error)	67 (0.05)	69 (0.11)	<0.001
Male, %	37,963 (66)	6906 (60)	<0.001
Race, %**			<0.001
White	41,228 (71)	7923 (70)	
Black	2776 (5)	778 (7)	
Hispanic	2389 (4)	585 (5)	
Asian	1257 (2)	269 (2)	
Other	2419 (4)	505 (4)	
Missing	7831 (14)	1361 (12)	
Primary payer, %			<0.001
Medicare	30,068 (52)	7007 (61)	
Medicaid	3991 (7)	918 (8)	
Private	21,623 (37)	3185 (28)	
Other***	2218 (4)	311 (3)	
Median household income quartile, $ (%)			0.09
1 (low)	12,022 (21)	2470 (22)	
2	14,955 (26)	2914 (26)	
3	15,277 (26)	3004 (26)	
4 (high)	15,646 (27)	3033 (26)	
Comorbidity, %			<0.001
0	27,417 (47)	4729 (41)	
1	13,360 (23)	2848 (25)	
2	9194 (16)	2002 (18)	
3 or greater	7929 (14)	1842 (16)	
Population of residence, %			<0.001
1,000,000 or more	29,754 (51)	6469 (57)	
50,000-999,999	17,828 (31)	3101 (27)	
10,000-49,999	6934 (12)	1248 (11)	
< 10,000	3384 (6)	603 (5)	
Year, %			0.01
2009	29,316 (51)	5927 (52)	
2010	28,584 (49)	5494 (48)	
State, %			<0.001
New York	33,213 (58)	7226 (64)	
Iowa	2998 (5)	583 (5)	
North Carolina	11,671 (20)	2106 (18)	
Washington	10,018 (17)	1506 (13)	
Median length of stay, days (min, max)	7 (1,241)	10 (1, 220)	<0.001
Died during admission	1811 (3)	NA	<0.001

Table 1: Index admission characteristics of patients undergoing major chest and abdominal surgery (continued)

Characteristics	**Major chest and abdominal surgery (AVR, CABG, lung resection, AAA, cystectomy, esophagectomy, pancreatectomy) (n=69,321)**		
Readmission status, %	Not readmitted n=57,900 (84)	Readmitted n=11,421 (16)	P value*
Discharge disposition, %			<0.001
Home	25,542 (45)	3134 (27)	
Home care	21,238 (38)	4147 (37)	
Skilled nursing facility****	9307 (17)	4140 (36)	
Resource utilization, index admission (%)			
Blood transfusion	37,648 (65)	8771 (77)	<0.001
Imaging (CT scan, MRI, ultrasound)	17,335 (30)	4887 (43)	<0.001
Intensive care unit	37,812 (65)	7670 (67)	<0.001
Dialysis	1660 (3)	621 (5)	<0.001

Abbreviations: AAA, abdominal aortic aneurysm; AVR, aortic valve replacement; CABG, coronary artery bypass graft; max, maximum; min, minimum; MRI, magnetic resonance imaging; NA, not applicable

*Significant for p-value ≤ 0.05; P-values for continuous variables generated from Student-*t*-tests. P-values for nominal and ordinal categorical variables generated from general chi-square and Mantel-Haenszel chi-square tests, respectively.

**Information on race is not reported in North Carolina.

***Other comprises self-pay, no charge, and other.

****Includes intermediate care facility, other facility, or short-term hospital.

Note: Major chest surgery includes AVR, CABG, and lung resection; major abdominal surgery includes AAA, cystectomy, esophagectomy, and pancreatectomy.

Table 2: Readmission characteristics

Characteristics	Major chest surgery (AVR, CABG, lung resection)	Major abdominal surgery (AAA, cystectomy, esophagectomy, pancreatectomy)	P-value*
30-day readmission, %	9516 (16)	1905 (22)	<0.001
Time to readmission, weeks (%)			0.002
≤ 1 week	4809 (51)	899 (47)	
>1 to 2 weeks	2232 (23)	451 (24)	
>2 to 3 weeks	1357 (14)	300 (16)	
> 3 weeks	1118 (12)	255 (13)	
Median length of stay, days (min, max)	5 (<1, 172)	5 (<1, 139)	0.02
Died during readmission	270 (3)	69 (4)	0.07
Discharge disposition, %			<0.001
Home	3624 (39)	728 (40)	
Home care	3309 (36)	770 (42)	
Skilled nursing facility**	2313 (25)	338 (18)	
Source of readmission, %			<0.001
Home	2531 (27)	535 (28)	
Emergency department	3957 (42)	719 (37)	
Direct admission from skilled nursing facility, intermediate care facility, or other facility	422 (4)	53 (3)	
Different hospital	488 (5)	111 (6)	
Clinic	310 (3)	91 (5)	
Other***	379 (4)	37 (2)	
Missing	1429 (15)	359 (19)	
Readmission cost quartile, $. median (min, max)			<0.001
1 (low)	3146 (576, 4500)	3458 (606, 4917)	
2	6001 (4501, 7864)	6493 (4919, 8677)	
3	10,510 (7869, 14,687)	11,514 (8677, 15,966)	
4 (high)	23,420 (14,690, 127,123)	25,870 (15,975, 147,904)	

Abbreviations: AAA, abdominal aortic aneurysm; AVR, aortic valve replacement; CABG, coronary artery bypass graft; max, maximum; min, minimum

*Significant for p-value ≤ 0.05; P-values for continuous, nominal categorical, and skewed categorical variables generated from Student-*t*-tests, general chi-square tests, and Wilcoxon rank-sum test, respectively.

** Includes intermediate care facility, other facility, or short-term hospital.

***Other comprises court/law enforcement, readmission to same home health agency, transfer to different unit within same hospital, ambulatory surgery center, and transfer from another health care facility.

Note: Major chest surgery includes AVR, CABG, and lung resection; major abdominal surgery includes AAA, cystectomy, esophagectomy, and pancreatectomy.

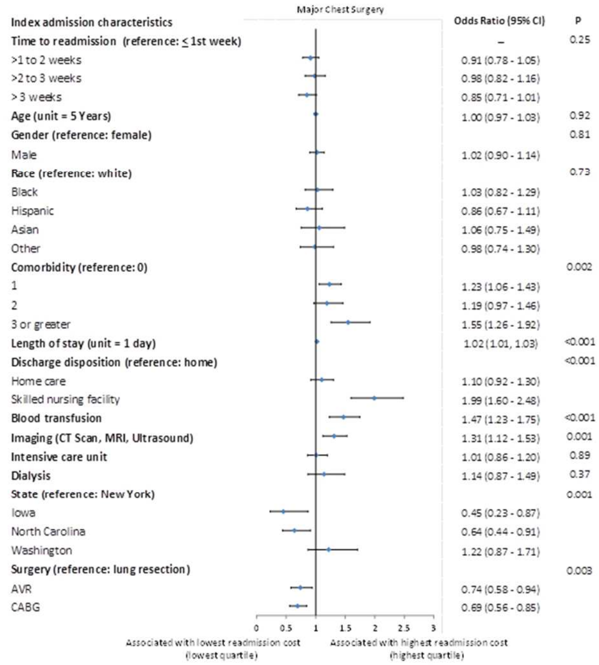

Figure 1: Estimated effect (adjusted odds ratio* and 95% CI) of each predictor on the highest versus lowest readmission costs for patients undergoing major chest surgery: Results of a multivariable logistic regression analysis

For patients undergoing major chest surgery, comorbidities, increasing length of stay, discharge to a skilled nursing facility, and receipt of a blood transfusion or imaging during the index admission were associated with higher readmission costs. Residing in Iowa or North Carolina and receiving an AVR or CABG (as opposed to a lung resection) were associated with lower readmission costs.

*The effect of each predictor was adjusted for all other predictors in the model.
**Includes intermediate care facility, other facility, or short-term hospital.
Abbreviations: AVR, aortic valve replacement; CABG, coronary artery bypass graft; MRI, magnetic resonance imaging

254x190mm (96 x 96 DPI)

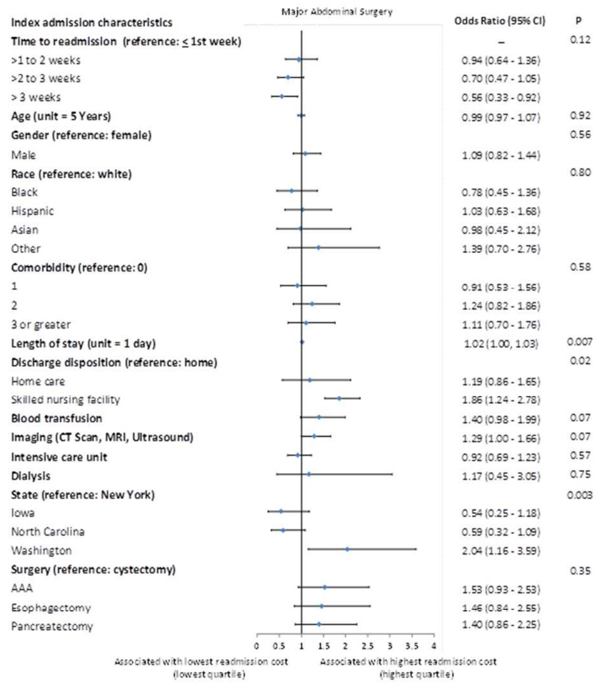

Figure 2: Estimated effect (adjusted odds ratio* and 95% CI) of each predictor on the highest versus lowest readmission costs for patients undergoing major abdominal surgery: Results of a multivariable logistic regression analysis

For patients undergoing major abdominal surgery, discharge to a skilled nursing facility or residing in Washington were associated with higher readmission costs. Conversely, readmission greater than three weeks after discharge was associated with lower readmission costs.

*The effect of each predictor was adjusted for all other predictors in the model.

**Includes intermediate care facility, other facility, or short-term hospital.

Abbreviations: AAA, abdominal aortic aneurysm; MRI, magnetic resonance imaging

254x190mm (96 x 96 DPI)

Appendix: Codes used to define surgery types

Surgery type	**ICD-9-CM codes**
Major chest surgery	
Aortic valve replacement	3511, 3521, 3522
Coronary artery bypass graft	3510, 3512, 3513, 3514, 3515, 3516, 3517, 3518, 3519, 3520, 3523, 3524, 3525, 3526, 3527, 3528, 3529, 3610, 3611, 3612, 3613, 3614, 3615, 3616, 3617, 3618, 3619
Lung resection	323, 3230, 3239, 324, 3241, 3249, 325, 3250, 3259
Major abdominal surgery	
Abdominal aortic aneurysm repair*	3834, 3844, 3864, 3925
Cystectomy	577, 5771, 5779
Esophagectomy	4240, 4241, 4242, 4399
Pancreatectomy	5251, 5253, 526, 527

Abbreviations: ICD9-CM, International classification of diseases, 9th revision, clinical modification

*ICD-9 codes for ruptured and/or thoracic aneurysms were excluded