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Assessing Readmission After General, Vascular, and Thoracic Surgery Using ACS-NSQIP

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Abstract

Objective—In 2012, Medicare began cutting reimbursement for hospitals with high readmission rates. We sought to define the incidence and risk factors associated with readmission after surgery.

Methods—A total of 230,864 patients discharged after general, upper gastrointestinal (GI), small and large intestine, hepatopancreatobiliary (HPB), vascular, and thoracic surgery were identified using the 2011 American College of Surgeons National Surgical Quality Improvement Program. Readmission rates and patient characteristics were analyzed. A predictive model for readmission was developed among patients with length of stay (LOS) 10 days or fewer and then validated using separate samples.

Results—Median patient age was 56 years; 43% were male, and median American Society of Anesthesiologists (ASA) class was 2 (general surgery: 2; upper GI: 3; small and large intestine: 2; HPB: 3; vascular: 3; thoracic: 3; $P < 0.001$). The median LOS was 1 day (general surgery: 0; upper GI: 2; small and large intestine: 5; HPB: 6; vascular: 2; thoracic: 4; $P < 0.001$). Overall 30-day readmission was 7.8% (general surgery: 5.0%; upper GI: 6.9%; small and large intestine: 12.6%; HPB: 15.8%; vascular: 11.9%; thoracic: 11.1%; $P < 0.001$). Factors strongly associated with readmission included ASA class, albumin less than 3.5, diabetes, inpatient complications, nonelective surgery, discharge to a facility, and the LOS (all $P < 0.001$). On multivariate analysis, ASA class and the LOS remained most strongly associated with readmission. A simple integer-based score using ASA class and the LOS predicted risk of readmission (area under the receiver operator curve 0.702).

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Conclusions—Readmission among patients with the LOS 10 days or fewer occurs at an incidence of at least 5% to 16% across surgical subspecialties. A scoring system on the basis of ASA class and the LOS may help stratify readmission risk to target interventions.

Keywords

complications; length of stay; outcomes; readmissions; surgery

Nearly 1 in 5 Medicare beneficiaries is readmitted after discharge,[1] and rates vary widely between hospitals.[2] As many as three out of four readmissions may be preventable through better inpatient care and discharge planning. Readmissions can be costly and, in most instances, represent an unplanned adverse patient event. To reduce preventable admissions, the Centers for Medicare and Medicaid Services (CMS) initiated the Hospital Readmissions Reduction Program in 2012, as authorized by the Affordable Care Act. The overall hospital reimbursement was reduced by up to 1% at hospitals with above-average risk-adjusted readmissions for myocardial infarction, congestive heart failure (CHF), and pneumonia, conditions that represent a high percentage of readmissions. These penalties may increase to 3% in 2014. There are preliminary plans to expand covered conditions in 2014, including coronary artery bypass graft and other vascular procedures.[3] It is likely that more conditions will be added in the future.

Prior studies have sought to identify predictive factors for readmission, as it would be ideal to target readmission prevention interventions to high-risk patients. Most efforts have focused on medical rather than surgical conditions. A recent review of prediction models for medical readmission has found that most models have only modest predictive ability, with area under the receiver operator curve (AUC) of 0.56 to 0.72.[4] Some surgical studies on readmission have been done, focusing on general[5–9] bariatric,[10–13] colorectal,[14–18] hepatopancreatobiliary (HPB),[19,20] cancer,[21] and heart surgery.[22] These studies were largely focused on very specific procedures, and most were single-institution series. Furthermore, with one exception, these studies only identified risk factors for readmission and did not formally create prediction models. The one prediction model identified was specific to readmission after open lower extremity bypass graft.[23]

The American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP), a large, nationally representative risk-adjusted surgical outcomes registry, began collecting readmission data in 2011. No study has broadly examined surgical readmission using the entire national ACS-NSQIP cohort. This study attempts to define the rate of readmission after general, vascular, and thoracic surgery using this large national sample. Furthermore, we sought to identify factors associated with readmission and develop a generalizable predictive model to define readmission risk for individual patients.

METHODS

Inclusion Criteria

The ACS-NSQIP collects a sample of surgical patient data from member hospitals for quality improvement purposes. Variables include demographics, indications, preoperative risk factors, procedural details, and 30-day outcomes. Data are collected in a standardized format from clinical records. These methods are described elsewhere.[24,25] The ACS-NSQIP makes de-identified data available to researchers as the Participant Use File. The 2011 Participant Use File was used, which contains data from 316 hospitals. General, vascular, and thoracic cases were selected.

These cases were then categorized into subspecialties using Current Procedural Terminology codes and surgical specially. As procedural overlap between specialties was common, data were categorized by the procedure rather than by the type of surgeon. General surgery included cholecystectomy, appendectomy, and cases performed by a general surgeon not included in other categories—largely breast and hernia. Upper gastrointestinal (GI) included esophageal and gastric cases. Hepatopancreatobiliary included all liver, pancreatic, and biliary cases except cholecystectomy. Small and large intestine included small intestinal, colorectal, and anal cases but excluded appendectomy. Vascular included all vascular cases as well as cases performed by a vascular surgeon not included in other categories. Thoracic included all lung, mediastinal, and chest wall cases as well as cases performed by a thoracic surgeon not included in other categories.

Patients who died before discharge, who were transferred to another acute care hospital, or who were not discharged during the 30-day follow-up period were excluded, as these patients were not at risk of readmission.

Readmission Ascertainment

ACS-NSQIP variables for readmission and unplanned readmission were added in 2011, which include readmission to any hospital within 30 days of the index procedure. This information was gathered from chart review and patient or family contact. Unplanned readmission is defined narrowly in the ACS-NSQIP, excluding unplanned readmission for unrelated causes, in contrast to the more inclusive all-cause CMS definition.[26] Also, only a small proportion of readmissions in this sample were designated “planned” (7.7%), so “any readmission” was used as a more sensitive measure. The variable for readmission had 12% missing data, which were excluded.

Counting 30-day readmissions starting from the day of operation rather than the day of discharge creates 2 problems. First, the CMS uses 30-day postdischarge readmission as the standard, creating a difference in case definition. Second, this introduces immortal person-time bias. Patients are not at risk of readmission (“immortal”) until they are discharged. Calculating a crude readmission rate includes immortal person-time equal to the length of stay after surgery (LOS), which results in an underestimate of the true 30-day postdischarge readmission rate. For example, patients discharged on postoperative day 29 after multiple complications are likely to have a very high risk of readmission, due to the fact that the ACS-NSQIP only follows them for 1 additional day, their observed rate of readmission is artificially low. Exploratory data analysis demonstrated this (Fig. 1). Other studies have found increased readmission with longer LOS,[4,8,14,19,21] but in the ACS-NSQIP the crude readmission rate increases and then decreases as the LOS increases. This is consistent with shortened follow-up for longer hospital stays. To address this problem, all cases with LOS over 10 days were excluded (6% of the total). This allowed for most 30-day postdischarge readmissions to accrue, especially as readmission has been found to be front-loaded in the first week after discharge.[14]

Exploratory analysis, compared with those included in the study, revealed that patients who stayed longer than 10 days had a much higher rate of complications (65.0% vs 10.5%; $P < 0.001$), mortality (3.25% vs 0.45%; $P < 0.001$), and readmission (16.1% vs 7.8%; $P < 0.001$). Even this high readmission rate is underestimated because of the immortal person-time bias at higher LOS. As such, patients who remained in the hospital longer than 10 days should be considered at very high risk of readmission but are not the focus of this study. However, this group was small and if they had been included in the study, the overall readmission rate would have been 8.3%, only marginally higher than the rate for those who stayed 10 days or fewer.

Death at home after discharge is a competing risk to readmission. Overall, 0.4% (729/162,159) of patients died after initial discharge. Among these patients, 54.7% (399/729) died at home without being readmitted first, but this did not vary between subspecialties ($P = 0.905$). Because of the low incidence of this competing risk, it was not included in the analysis.

Risk Factors, Prediction Modeling, and Statistical Analysis

Key risk factors were selected from the ACS-NSQIP variables. Readmission risk ratio and population attributable risk (PAR) were calculated for each risk factor. The PAR represents the absolute percentage of readmissions that are attributable to exposure to a risk factor. It combines the prevalence and severity of a risk factor into one measure of overall impact on a population. For continuous risk factors, relative risk was calculated as the ratio of the risk for the 95th percentile versus the median, and PAR was calculated by dichotomizing at the median. Multivariable regression analysis was performed in iterative fashion guided by effect size and PAR, with a goal of a parsimonious prediction model. Cases were divided randomly into 70% and 30% samples. The 70% sample was used for all data analysis and generation of a readmission prediction model. The 30% sample was used for model validation. Models were evaluated using AUC and then tested on the validation sample. Statistical analysis was performed with Stata 12.1 (StataCorp).

RESULTS

Baseline Patient Characteristics and Postoperative Course

In the 70% sample, 162,159 patients met inclusion criteria (general surgery: 89,758, upper GI: 16,134, small and large intestine: 25,191; HPB: 4721; vascular: 22,980; thoracic: 3375). Median age was 56 years [interquartile range (IQR): 43–68]; 42.8% of the patients were male. The patients were 70.5% non-Hispanic white, 10.3% black, 7.5% Hispanic, 2.7% Asian, and 11.7% other or unknown. There were differences in the prevalence of clinical risk factors across specialties ($P < 0.001$ for all risk factors; Table 1). Median ASA class was 2 (IQR: 2–3) and varied between specialties (general surgery: 2; upper GI: 3; small and large intestine: 2; HPB: 3; vascular: 3; thoracic: 3; $P < 0.001$). Up to 83.9% of patients had at least 1 preoperative medical condition. Preoperative comorbidities included CHF (0.6%), chronic obstructive pulmonary disorder (4.7%), diabetes (15.8%), and dialysis (1.7%).

Postoperatively, 6.4% of patients experienced a complication before discharge (general surgery: 2.1%; upper GI: 4.1%; small and large intestine: 12.4%; HPB: 21.1%; vascular: 15.0%; thoracic: 9.6%; $P < 0.001$). The median LOS was 1 day (IQR: 0–4) and varied by specialty [general surgery: 1 (IQR: 0–1); upper GI: 2 (IQR: 1–3); small and large intestine: 5 (IQR: 3–7); HPB: 6 (IQR: 4–7); vascular: 2 (IQR: 1–4); thoracic: 4 (IQR: 2–6); $P < 0.001$]. The overall postoperative readmission rate was 7.8% and varied between specialties (general surgery: 5.0%; upper GI: 6.9%; small and large intestine: 12.6%; HPB: 15.8%; vascular: 11.9%; thoracic: 11.1%; $P < 0.001$; Table 2).

Factors Associated With Readmission

A number of factors were associated with the risk of readmission (Table 2). Specifically, there was over a 3-fold variation in the risk of readmission according to surgical subspecialty {general surgery: reference; upper GI: risk ratio [RR]: 1.38 [95% confidence interval (CI): 1.30–1.47]; small and large intestine: RR: 2.51 [95% CI: 2.40–2.62]; HPB: RR: 3.14 [95% CI: 2.93–3.38]; vascular: RR: 2.36 [95% CI: 2.26–2.47]; thoracic: RR: 2.22 [95% CI: 2.01–2.45]}. In addition, there was variability within subspecialty. For example, within HPB, the risk of readmission was higher among patients undergoing a pancreatectomy versus a liver resection (18.9% vs 13.9%; $P < 0.001$). Similarly, within small and large intestine, patients who underwent open colectomy were more likely to be readmitted than those who had a laparoscopic colectomy (14.5% vs 9.4%, $P < 0.001$).

Patient comorbidities were associated with readmission. The risk of readmission increased with ASA class [ASA 1: reference; ASA 2: RR: 2.02 (95% CI: 1.82–2.24); ASA 3: RR: 3.92 (95% CI: 3.55–4.33); ASA 4: RR: 6.66 (95% CI: 5.99–7.42); ASA 5: RR: 5.40 (95% CI: 3.02–9.66)]. Specific comorbidities such as history of CHF (RR: 3.02; 95% CI: 2.69–3.39), dialysis (RR: 2.75; 95% CI: 2.55–2.96), poor nutritional status (albumin: <3.5 g/dL; RR: 2.07; 95% CI: 1.99–2.16), and corticosteroid use (RR: 2.24: 95% CI: 2.10–2.39) were also highly associated with an increased risk of readmission.

In addition to preexisting patient comorbidities, several hospital course factors impacted the risk of readmission. Patients who had initially been transferred from another facility were at a 2-fold increased risk of readmission after discharge (RR: 2.03; 95% CI: 1.91–2.16). Similarly, patients who experienced any postoperative inpatient complication (RR: 2.67; 95% CI: 2.55–2.79) and those patients with a prolonged LOS (RR: 3.50 for the 95th percentile of the LOS compared with the median; 95% CI: 3.38–3.62) were more likely to be readmitted. Furthermore, patients who were discharged to a facility rather than to home had a greater chance of readmission (RR: 2.82; 95% CI: 2.68–2.96).

Risk factors with the highest PAR included ASA class (66.1 %), the LOS (47.9%), surgical subspecialty (35.6%), age (18.2%), albumin less than 3.5 g/dL (12.6%), and nonelective surgery (10.3%).

Prediction Model for Readmission

As a baseline model, factors associated with readmission were identified using multiple logistic regression on the basis of a large number of ACS-NSQIP variables (Supplemental Data Table 1, Supplemental Digital Content 1, available at http://links.lww.com/SLA/A417). Coefficients were used to generate a predicted probability model of readmission. When assessing the 70% cohort irrespective of surgical subspecialty, the complex prediction model performed well on receiver operating characteristics (ROC) analysis (AUC: 0.721). The model performed slightly less well, however, when used to predict readmission among certain surgical subspecialties (range: 0.650–0.713; Table 3).

In an attempt to identify a more parsimonious readmission prediction model, iterative multiple regression guided by RR and PAR was performed. ASA class and the LOS were found to have the greatest predictive power. A regression model with these 2 risk factors found an absolute risk increase for readmission of 3.0% for each additional ASA class point (95% CI: 2.8%–3.2%) and an increase of 1.5% for each additional inpatient day after surgery (95% CI: 1.5%–1.6%).

Given that specific surgical subspecialty may impact readmission risk, a prediction model that included surgical subspecialty, in addition to the LOS and ASA class, was examined. Interestingly, some subspecialties were independently associated with differences in absolute readmission risk [reference, general surgery: 0%; upper GI: −1.2% (95% CI: −1.7% to −0.8%), small and large intestine: 1.3% (95% CI: 0.8%–1.7%), HPB: 2.8% (95% CI: 2.0%–3.7%), vascular: 2.2% (95% CI: 1.8%–2.6%), thoracic: 0.1% (95% CI: −0.8% to 1.0%)]. Of note, the coefficients for the association of ASA class and the LOS with readmission remained unchanged when subspecialty was added. Given that the risk difference associated with surgical subspecialty was small compared with the LOS and ASA class, operation type was not included in the final model.

A simple integer-based “readmission score” was created on the basis of the multiple regression coefficients for ASA class and the LOS (risk difference of 3.0% for each additional ASA class point and 1.5% for each additional day in the hospital; weighted readmission score = LOS/2 + ASA class, rounded up to the nearest integer). This parsimonious readmission score model performed nearly as well as the complex all-variable model (AUC: 0.696 vs 0.721; Table 3). Similar to the complex model, the simple readmission score performed variably well across the surgical subspecialties. For example, although the risk model maintained predictive ability for general surgery (AUC: 0.687) and upper GI (AUC: 0.659), it performed poorly for thoracic surgery (AUC: 0.507).

Prediction Model Validation

The complex all-variable model and final parsimonious readmission score were then validated using the 30% random sample (n = 68,705). The complex model performed well in predicting readmission when applied to the 30% validation subset (AUC: 0.724). For the subspecialties, the complex model again had a variable performance on the basis of the surgical subspecialty examined (Table 3). In examining the parsimonious readmission score model that included only ASA class and the LOS, the AUC was similar (AUC: 0.702).

Performance of the model stratified by subspecialty tended to be lower (AUC ranging from 0.591 to 0.697), but values were largely similar to those obtained from the larger generation sample (Table 3).

The incidence of readmission increased in a stepwise fashion as the readmission score increased (Table 4). Specifically, among patients who had a score of 1, the incidence of readmission was 1.2%; in contrast, patients with a score of 5 and 9 had an incidence of readmission of 11.8% and 22.2%, respectively. Although there was some variation among surgical subspecialties, patients with risk scores of 5 to 6 had an incidence of readmission of more than 10%, and patients with a score of 7 to 10 had an incidence of readmission of more than 15%—irrespective of surgical subspecialty (Fig. 2).

On ROC analysis, a score of 4 maximized sensitivity and specificity, and resulted in a low positive predictive value but a high negative predictive value (Table 4). The distribution of readmission scores was plotted for all patients and compared with readmitted patients (Fig. 3). Interestingly, although readmitted patients had higher readmission scores on average than patients who were not readmitted, most readmissions occurred at intermediate readmission scores, as there were many more patients with these scores. For example, a score of 4 or higher identified almost 80% of readmissions, but included about half of all patients.

DISCUSSION

Readmission to the hospital after a medical or surgical stay has been identified as an area for quality improvement. Readmission may be associated with increased hospital-related patient morbidity and mortality, as well as higher costs to the health care system.[27] As such, the CMS has described readmissions as an “expensive, adverse event for patients” and has begun public reporting of some risk-adjusted readmission rates.[3,23] In spite of the interest in readmission, as well as these policy initiatives, relatively little is known about the incidence and factors predisposing to readmission after most surgical procedures. Several groups have reported on readmission after abdominal surgery in general surgery,[5] colorectal surgery,[14] complex HPB surgery,[19] and vascular surgery.[28] These studies were largely focused, however, on very specific procedures and many were single-institution series. Furthermore, these studies identified risk factors but largely did not seek to create prediction models for readmission. Defining the incidence of readmission in a large national cohort of general, vascular, and thoracic surgery, as well as better defining which factors are associated with readmission, may be critical to improve outcomes and define areas for intervention. This study is important because it demonstrated that the overall incidence of readmission after a surgical procedure was relatively common at about 1 in 13 (7.8%). Furthermore, readmission varied significantly among surgical subspecialties, with readmission being as high as 1 in 8 for small and large intestine surgery and 1 in 6.5 for HPB surgery. Perhaps more importantly, we identified a number of patient and hospital course factors associated with an increased risk of readmission. In turn, using a simple integer-based model consisting of ASA class and the LOS, a prediction model for higher risk of readmission was defined. Although a score of 4 had a relatively high specificity, it had a poor sensitivity. These data collectively suggest that “predicting” readmission remains a challenge.

Although a number of factors were associated with a higher risk of readmission, increasing ASA class and the LOS were the most predictive risk factors for readmission (Tables 1 and 2). The association of ASA and readmission is consistent with previous studies, essentially all of which identified comorbidity as a risk factor for readmission.[4] For example, Silverstein et al[29] noted that the magnitude of increased risk of readmission was similar for most comorbid conditions, with a relative risk ranging from 1.12 to 1.53, corresponding to a 1.3 to 6.9 percentage point increase in the probability of readmission. In a separate study, Mudge and colleagues[30] noted that chronic comorbid conditions were one of the strongest predictors of increased risk of readmission among medical patients. Similarly, several other studies have found that increasing LOS is associated with increased readmission. In previous work, our group noted that an LOS greater than 7 to 10 days was associated with a higher incidence of readmission among patients undergoing both small and large intestine as well as HPB procedures.[14,19] The fact that the longer LOS associated with increased risk of readmission is probably related to how this factor may be a surrogate for both increased surgical complexity and complications during the index hospital stay.

Using ASA class and the LOS, we defined a simple readmission score. The risk of readmission increased incrementally with the readmission score. On the basis of ROC analysis, a score of 4 seemed to be the optimal cutoff value to predict readmission. The score performed moderately well when applied to the validation subset with an overall AUC of 0.702. In their systematic review of risk prediction for hospital readmission among medical patients, Kansagara et al[4] noted that most prediction models to identify high-risk medical patients for readmission had AUCs ranging from 0.56 to 0.72. As such, our readmission score for surgical patients seems comparable in terms of accuracy to previous models proposed for medical patients. It is important to note that among patients with the highest scores, the incidence of readmission was about 20%. Overall, the score had good specificity and negative predictive value, but the sensitivity and positive predictive values were more modest. In other words, the score was better at predicting who would *not* be readmitted, rather than who *would* be readmitted. In fact, many patients who were readmitted had a low-to-moderate readmission score—partly attributable to the fact that there were far more patients in this category. Although more accurate identification of those patients at the highest risk of readmission is ideal, even partial identification of high-risk groups can improve the cost efficiency of expensive case management resources.[31] On the basis of our data, a readmission score of 4 seemed to be the most applicable clinical cutoff value, as patients with a score of 4 or more accounted for nearly 80% of readmissions.

Surgical subspecialty contributed only somewhat to the risk of readmission compared with other factors on multivariate analysis. It was true that the incidence of readmission varied among surgical subspecialties, as well as even within subspecialties on the basis of the specific procedure type. Indeed, the simple readmission score performed worse in certain subspecialties—suggesting that different risk factors may have varying weights in different subspecialties. One particular example was thoracic surgery, where the readmission score performed poorly (AUC: 0.591). Risk factors for readmission among patients undergoing thoracic surgery may be very different than general, HPB, or vascular surgery. It is also important to note that in this study we classified esophageal cases in the upper GI group, not the thoracic group. As such, reclassification of these cases into the thoracic group could impact the performance of the readmission score. Although the readmission score proposed herein represents an initial attempt to identify those patients at the highest risk of readmission, specialty- or procedure-specific models may be of benefit in the future. Notwithstanding this possibility, it is also likely that ward-based nursing and discharge planners will play a large role in readmission prevention interventions. Given that many patients recover in mixed-specialty surgical units, a simple, generalizable readmission score such as the one proposed might be more useful than a slightly more accurate, but much more complex one tailored to specific operations.

This study has several limitations. Because of reporting 30-day postoperative rather than postdischarge readmissions, the ACS-NSQIP introduces an immortal person-time bias. We addressed this by excluding patients with an LOS of longer than 10 days. As such, the current data are only generalizable to patients with an LOS of 10 days or less, which is fortunately the overwhelming majority of patients. The ACS-NSQIP could improve the study of readmission, as well as other important postdischarge metrics, by reporting 30-day postdischarge data instead of only data within the first 30 days after surgery. Alternatively, NSQIP could report the day on which readmission occurred, as they do for other complications. This would allow for a Kaplan–Meier time to event analysis. In addition, another important limitation to this study is that our estimates for readmission probably underrepresent readmissions, as the data likely do not fully account for outside readmissions to hospitals where the index procedure did not take place. Although we used a complex as well as simple model to predict readmission, we were still limited by the variables available in the ACS-NSQIP dataset. In reality, factors associated with readmission might include the following: (1) preadmission factors such as patient demographics, comorbidities, as well as biological characteristics such as extent of disease; (2) health care factors and hospital course such as transfer from another hospital, perioperative complications, and the LOS; and (3) postdischarge factors such as social characteristics like socioeconomic status, the discharge environment, availability of caregivers, and health care self-efficacy (Table 5). The ACS-NSQIP, however, has minimal information about characteristics on discharge setting, postdischarge social support, family caregiver characteristics, and other possible social determinants of readmission.[4,5,12] Given this, perhaps it is not surprising that our prediction model, as well as those of others, did not better predict readmission.[4]

CONCLUSIONS

In conclusion, on the basis of a population-based dataset, the 30-day incidence of readmission after general, vascular, and thoracic surgery was noted to be at least 7.8% and at a minimum ranged from 5.0% to 15.8%, depending on the surgical subspecialty. Although factors associated with the risk of readmission included both patient-level and hospital course factors, ASA class and the LOS were the two factors with the greatest predictive power on the basis of RR and PAR. Using ASA class and the LOS, a simple integer score was found to predict readmission with a high specificity, but only a moderate sensitivity. Although the readmission score may not precisely predict absolute readmission risk, it may be a useful heuristic tool to identify those patients at the highest risk of readmission to direct prevention interventions. As conditions covered by the Medicare Hospital Readmissions

Reduction Program expand into surgery, further research into the causes and prevention of readmission in this population will become increasingly important.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

References

1. Jencks SF, Williams MV, Coleman EA. Rehospitalizations among patients in the Medicare fee-for-service program. N Engl J Med. 2009; 360:1418–1428. [PubMed: 19339721]
2. Report to the Congress: Promoting Greater Efficiency in Medicare. Medicare Payment Advisory Commission; Jun. 2007 Payment policy for inpatient readmissions; p. 102-120.Available at http://www.medpac.gov/documents/jun07_entirereport.pdf [Accessed December 29, 2012]
3. FY 2013 Final Rule, Inpatient Prospective Payment Systems, Medicare Program. Federal Register. 2012; 77:170.
4. Kansagara D, Englander H, Salanitro A, et al. Risk prediction models for hospital readmission: a systematic review. JAMA. 2011; 306:1688–1698. [PubMed: 22009101]
5. Martin RC, Brown R, Puffer L, et al. Readmission rates after abdominal surgery: the role of surgeon, primary caregiver, home health, and subacute rehab. Ann Surg. 2011; 254:591–597. [PubMed: 22039606]
6. Kiran RP, Delaney CP, Senagore AJ, et al. Outcomes and prediction of hospital readmission after intestinal surgery. J Am Coll Surg. 2004; 198:877–883. [PubMed: 15194068]
7. Goodney PP, Stukel TA, Lucas FL, et al. Hospital volume, length of stay, and readmission rates in high-risk surgery. Ann Surg. 2003; 238:161–167. [PubMed: 12894006]
8. Morris DS, Rohrbach J, Rogers M, et al. The surgical revolving door: risk factors for hospital readmission. J Surg Res. 2011; 170:297–301. [PubMed: 21696766]
9. Kassin MT, Owen RM, Perez SD, et al. Risk factors for 30-day hospital readmission among general surgery patients. J Am Coll Surg. 2012; 215:322–330. [PubMed: 22726893]
10. Saunders JK, Ballantyne GH, Belsley S, et al. 30-day readmission rates at a high volume bariatric surgery center: laparoscopic adjustable gastric banding, laparoscopic gastric bypass, and vertical banded gastroplasty-Roux-en-Y gastric bypass. Obes Surg. 2007; 17:1171–1177. [PubMed: 18074490]
11. Saunders JK, Ballantyne GH, Belsley S, et al. One-year readmission rates at a high volume bariatric surgery center: laparoscopic adjustable gastric banding, laparoscopic gastric bypass, and vertical banded gastroplasty-Roux-en-Y gastric bypass. Obes Surg. 2008; 18:1233–1240. [PubMed: 18452051]
12. Hong B, Stanley E, Reinhardt S, et al. Factors associated with readmission after laparoscopic gastric bypass surgery. Surg Obes Relat Dis. 2011; 8:691–695. [PubMed: 21978746]
13. Dorman RB, Miller CJ, Leslie DB, et al. Risk for hospital readmission following bariatric surgery. PLoS One. 2012; 7:e32506. [PubMed: 22412881]
14. Schneider EB, Hyder O, Brooke BS, et al. Patient readmission and mortality after colorectal surgery for colon cancer: impact of length of stay relative to other clinical factors. J Am Coll Surg. 2012; 214:390–398. [PubMed: 22289517]
15. Wick EC, Shore AD, Hirose K, et al. Readmission rates and cost following colorectal surgery. Dis Colon Rectum. 2011; 54:1475–1479. [PubMed: 22067174]
16. Ozturk E, Kiran RP, Remzi F, et al. Early readmission after ileoanal pouch surgery. Dis Colon Rectum. 2009; 52:1848–1853. [PubMed: 19966631]
17. Lidor AO, Schneider E, Segal J, et al. Elective surgery for diverticulitis is associated with high risk of intestinal diversion and hospital readmission in older adults. J Gastrointest Surg. 2010; 14:1867–1873. [PubMed: 20878256]
18. Azimuddin K, Rosen L, Reed JF, et al. Readmissions after colorectal surgery cannot be predicted. Dis Colon Rectum. 2001; 44:942–946. [PubMed: 11496073]

19. Schneider EB, Hyder O, Wolfgang CL, et al. Patient readmission and mortality after surgery for hepato-pancreato-biliary malignancies. J Am Coll Surg. 2012; 215:607–615. [PubMed: 22921328]
20. Ahmad SA, Edwards MJ, Sutton JM, et al. Factors influencing readmission after pancreaticoduodenectomy: a multi-institutional study of 1302 patients. Ann Surg. 2012; 256:529–537. [PubMed: 22868373]
21. Rochefort MM, Tomlinson JS. Unexpected readmissions after major cancer surgery: an evaluation of readmissions as a quality-of-care indicator. Surg Oncol Clin N Am. 2012; 21:397–405. viii. [PubMed: 22583989]
22. Li Y, Cai X, Mukamel DB, et al. Impact of length of stay after coronary bypass surgery on short-term readmission rate: an instrumental variable analysis. Med Care. 2012; 51:45–51. [PubMed: 23032357]
23. McPhee JT, Nguyen LL, Ho KJ, et al. Risk prediction of 30-day readmission after infrainguinal bypass for critical limb ischemia. J Vasc Surg. 2013; 57:1481–1488. [PubMed: 23395204]
24. Henderson WG, Daley J. Design and statistical methodology of the National Surgical Quality Improvement Program: why is it what it is? Am J Surg. 2009; 198:S19–S27. [PubMed: 19874930]
25. ACS-NSQIP. [Accessed October 23, 2012] ACS-NSQIP data collection, analysis, and reporting. Available at http://site.acsnsqip.org/program-specifics/data-collection-analysis-and-reporting
26. Horwitz, L.; Partovian, C.; Lin, Z., et al. Hospital-wide all-cause unplanned readmission measure: final technical report. Centers for Medicare and Medicaid Services; Jul. 2012
27. Jencks SF. Defragmenting care. Ann Intern Med. 2010; 153:757–758. [PubMed: 21135299]
28. Brooke BS, De Martino RR, Girotti M, et al. Developing strategies for predicting and preventing readmissions in vascular surgery. J Vasc Surg. 2012; 56:556–562. [PubMed: 22743022]
29. Silverstein MD, Qin H, Mercer SQ, et al. Risk factors for 30-day hospital readmission in patients ≥65 years of age. Proc (Bayl Univ Med Cent). 2008; 21:363–372. [PubMed: 18982076]
30. Mudge AM, Kasper K, Clair A, et al. Recurrent readmissions in medical patients: a prospective study. J Hosp Med. 2011; 6:61–67. [PubMed: 20945294]
31. Mukamel DB, Chou CC, Zimmer JG, et al. The effect of accurate patient screening on the cost-effectiveness of case management programs. Gerontologist. 1997; 37:777–784. [PubMed: 9432994]

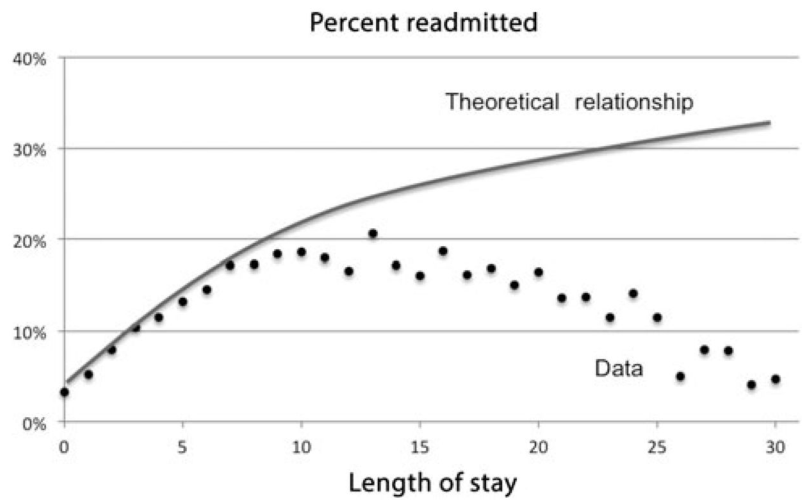

FIGURE 1.

Average readmission rate by length of stay for general, vascular, and thoracic surgery. Data fail to approximate the theoretical relationship at increasing length of stay because of immortal person-time bias.

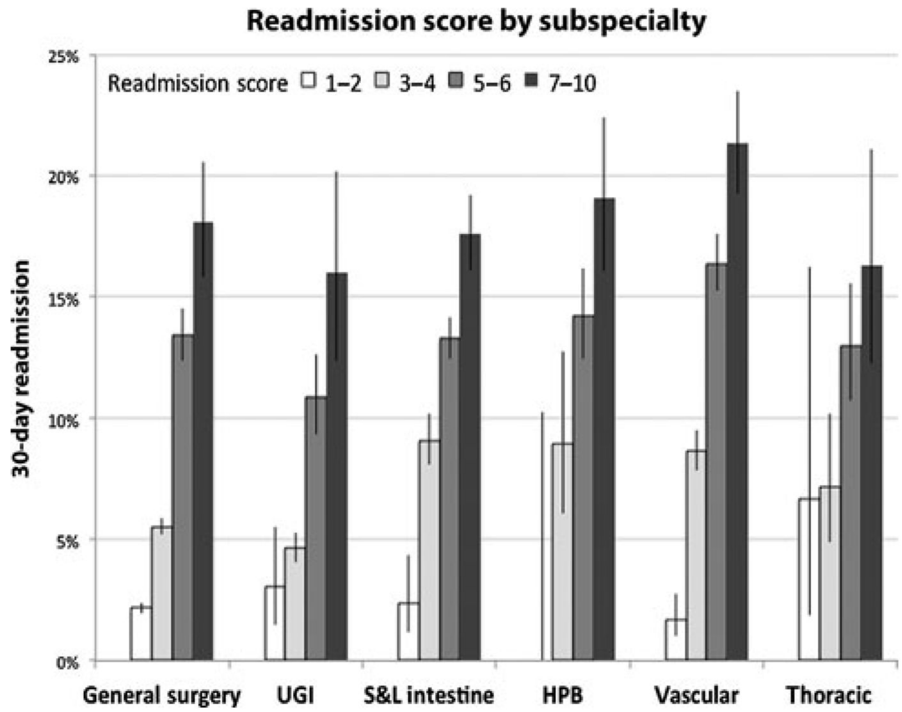

FIGURE 2.

Thirty-day readmission by readmission score and subspecialty for the LOS 10 days or fewer. Readmission score = LOS/2 + ASA class, rounded up. Confidence intervals of 95% are plotted.

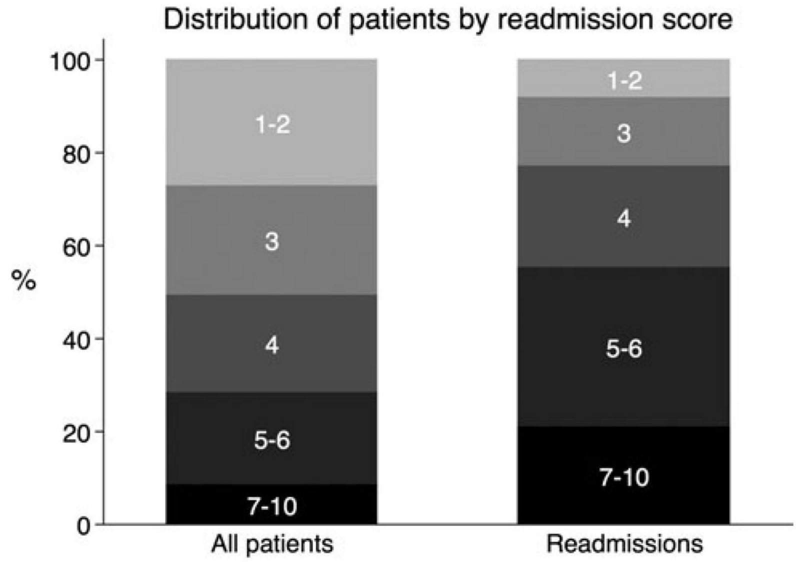

FIGURE 3.

Distribution of readmission score among all and readmitted patients for the LOS 10 days or fewer. Readmission score = LOS/2 + ASA class, rounded up. S&L intestine indicates small and large intestine.

TABLE 1

Risk Factors by Surgical Subspecialty*

Risk Factor	Overall (n= 162,159), % (n/total)	General Surgery (n = 89,758), % (n/ total)	Upper GI (n = 16,134),% (n/total)	S&L Intestine (n = 25,191), % (n/total)	HPB (n = 4,721), % (n/total)	Vascular (n = 22980), % (n/total)	Thoracic (n = 3375), % (n/total)
Male	42.8 (69,297/161,813)	40.4 (36,149/89,557)	25.6 (4,123/16,096)	46.1 (11,590/25,139)	46.2 (2,179/4,715)	59.1 (13,550/22,940)	50.7 (1,706/3,366)
Race							
Non-Hispanic white	70.5 (114,275/162,159)	68.1 (61,116/89,758)	68.9 (11,117/16,134)	74.4 (18,735/25,191)	72.5 (3,422/4,721)	75.6 (17,375/22,980)	74.4 (2,510/3,375)
Black	10.3 (16,776/162,159)	10.3 (9,238/89,758)	13.8 (2,229/16,134)	9.2 (2,320/25,191)	9.4 (443/4,721)	10.1 (2,318/22,980)	6.8 (228/3,375)
Hispanic	7.5 (12,096/162,159)	8.9 (7946/89758)	8.3 (1,347/16,134)	5.4 (1,348/25,191)	5.1 (242/4,721)	4.4 (1,013/22,980)	5.9 (200/3,375)
Asian	2.7 (4,378/162,159)	3.2 (2,835/89,758)	1.2 (193/16,134)	2.6 (657/25,191)	4.3 (204/4,721)	1.7 (395/22,980)	2.8 (94/3,375)
Other/unknown	11.7 (19,012/162,159)	12.8 (11458/89758)	8.9 (1,441/16,134)	11.1 (2,788/25,191)	13.0 (614/4,721)	9.9 (2,274/22,980)	12.9 (437/3,375)
ASA class							
1	9.3 (15,038/161,481)	14.7 (13,199/89,487)	1.1 (172/16,102)	3.7 (933/25,164)	1.8 (86/4,712)	2.6 (594/22,645)	1.6 (54/3,371)
2	44.8 (72,306/161,481)	54.5 (48,791/89,487)	38.0 (6,118/16,102)	47.8 (12,027/25,164)	32.4 (1,525/4,712)	13.4 (3,027/22,645)	24.3 (818/3,371)
3	40.5 (65,432/161,481)	28.3 (25338/89487)	58.0 (9,334/16,102)	43.7 (10,992/25,164)	61.9 (2,915/4,712)	65.0 (14,719/22,645)	63.3 (2,134/3,371)
4	5.3 (8,635/161,481)	2.4 (2,146/89,487)	2.9 (474/16,102)	4.7 (1,195/25,164)	3.9 (185/4,712)	18.9 (4,270/22,645)	10.8 (365/3,371)
5	0.0 (70/161,481)	0.0 (13/89,487)	0.0 (4/16,102)	0.1 (17/25,164)	0.0 (1/4,712)	0.2 (35/22,645)	0.0 (0/3,371)
BMI ≥30	41.3 (67,046/162,159)	40.4 (36236/89758)	81.6 (13,162/16,134)	30.8 (7,754/25,191)	29.8 (1,407/4,721)	32.5 (7,473/22,980)	30.0 (1,014/3,375)
Diabetes	15.8 (25,675/162,159)	11.5 (10,295/89,758)	22.3 (3,595/16,134)	13.6 (3,429/25,191)	20.1 (948/4,721)	30.0 (6,900/22,980)	15.1 (508/3,375)
Current smoker	19.4 (31,414/162,159)	17.4 (15601/89758)	12.2 (1,970/16,134)	18.9 (4,763/25,191)	18.9 (893/4,721)	31.5 (7,236/22,980)	28.2 (951/3,375)
COPD	4.7 (7,684/162,159)	2.9 (2,574/89,758)	2.6 (425/16,134)	4.4 (1,108/25,191)	3.6 (172/4,721)	12.1 (2,785/22,980)	18.4 (620/3,375)
CHF	0.6 (963/162,159)	0.4 (315/89,758)	0.2 (35/16,143)	0.6 (144/25,191)	0.2 (10/4,721)	1.8 (418/22,980)	1.2 (41/3,375)
Dialysis	1.7 (2,809/162159)	1.3 (1,124/89,758)	0.3 (46/16,134)	0.7 (171/25,191)	0.3 (15/4,721)	6.2 (1,422/22,980)	0.9 (31/3,375)
Dependent for ADLs	2.8 (4,528/16,1913)	1.6 (1,453/89,638)	1.0 (168/16,125)	3.7 (938/25,153)	1.6 (75/4,716)	7.8 (1,787/22,913)	3.2 (107/3,368)
Steroids	3.0 (4,854/16,2159)	2.1 (1,911/89,758)	1.7 (281/16,134)	6.1 (1,544/25,191)	2.4 (111/4,721)	3.6 (832/22,980)	5.2 (175/3,375)
Albumin <3.5	19.0 (17,785/93,488)	15.6 (7,403/47,489)	8.7 (1,002/11,485)	26.6 (4,526/16,997)	21.1 (880/4,172)	31.2 (3,504/11,214)	22.1 (470/2,131)
Transferred in	4.0 (6,526/162,084)	2.9 (2,578/89,717)	1.7 (272/16,133)	5.5 (1,385/25,176)	4.1 (194/4,721)	8.5 (1,953/22,963)	4.3 (144/3,374)
Nonelective surgery	24.2 (38,860/160,305)	25.9 (23,039/88,893)	9.1 (1,452/15,990)	30.1 (7,463/24,792)	14.1 (654/4,651)	24.5 (5,563/22,696)	21.0 (689/3,283)
Complications†	6.4 (10,447/162,159)	2.1 (1,908/89,758)	4.1 (657/16,134)	12.4 (3,113/25,191)	21.1 (998/4,721)	15.0 (3,447/22,980)	9.6 (324/3,375)
Discharge to facility	4.7 (7,526/161,433)	2.1 (1,876/89,391)	1.6 (264/16,061)	7.4 (1,865/25,049)	4.9 (228/4,685)	13.6 (3,116/22,889)	5.3 (177/3,358)
Continuous risk factors							

Risk Factor	Overall (n= 162,159), % (n/total)	General Surgery (n = 89,758), % (n/total)	Upper GI (n = 16,134),% (n/total)	S&L Intestine (n = 25,191), % (n/total)	HPB (n = 4,721), % (n/total)	Vascular (n = 22980), % (n/total)	Thoracic (n = 3375), % (n/total)
Age, yr, median (IQR)	56 (43, 68)	53 (40, 65)	48 (38, 58)	60 (48, 71)	61 (51, 69)	68 (59, 77)	64 (53, 71)
LOS, median (IQR)	1 (0, 4)	1 (0, 1)	2 (1, 3)	5 (3, 7)	6 (4, 7)	2 (1, 4)	4 (2, 6)

* $P < 0.001$ for all risk factors for differences across subspecialties.

† Before discharge.

ADLs indicate activities of daily living; ASA, American Society of Anesthesiologists; BMI, body mass index; CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease; GI, gastrointestinal; HPB, hepatopancreatobiliary; IQR, interquartile range; LOS, length of stay; S&L, small and large.

TABLE 2

Unadjusted Readmission Risk, Risk Ratio, and Population Attributable Risk by Risk Factor*

	Readmission Risk, % (n/Total)			
Risk Factor	**Risk Factor Present**	**Risk Factor Absent**	**RR (95% CI)**	**PAR, %**
Overall readmission risk	7.8 (12,651/162,159)			
Surgical subspecialty				35.6
General surgery	5.0 (4,511/89,758)		1 (reference)	
Upper GI	6.9 (1,120/16,134)		1.38 (1.30, 1.47)	
S&L intestine	12.6 (3,173/25,191)		2.51 (2.40, 2.62)	
HPB	15.8 (746/4,721)		3.14 (2.93, 3.38)	
Vascular	11.9 (2,725/22,980)		2.36 (2.26, 2.47)	
Thoracic	11.1 (376/3,375)		2.22 (2.01, 2.45)	
Race				2.2
White	8.0 (9,112/114,275)		1 (reference)	
Black	9.3 (1,556/16,776)		1.16 (1.11, 1.22)	
Hispanic	6.3 (758/12,096)		0.79 (0.73, 0.84)	
Asian	6.9 (302/4,378)		0.87 (0.77, 0.97)	
ASA class				66.1
1	2.6 (398/15,038)		1 (reference)	
2	5.3 (3,866/72,306)		2.02 (1.82, 2.24)	
3	10.4 (6,793/65,432)		3.92 (3.55, 4.33)	
4	17.6 (1,523/8,635)		6.66 (5.99, 7.42)	
5	14.3 (10/70)		5.40 (3.02, 9.66)	
Male	8.2 (5,700/69,297)	7.5 (6,927/92,516)	1.10 (1.06, 1.14)	4.1
BMI ≥30	7.5 (5,025/67,046)	8.0 (7,626/95,113)	0.93 (0.90, 0.97)	n/a[†]
Diabetes	11.5 (2,944/25,675)	7.1 (9,707/136,484)	1.61 (1.55, 1.68)	8.8
Current smoker	9.4 (2,964/31,414)	7.4 (9,687/130,745)	1.27 (1.22, 1.32)	5.0
COPD	14.2 (1,093/7,684)	7.5 (11,558/154,475)	1.90 (1.79, 2.01)	4.1
CHF	23.3 (224/963)	7.7 (12,427/161,196)	3.02 (2.69, 3.39)	1.2
Dialysis	20.8 (585/2,809)	7.6 (12,066/159,350)	2.75 (2.55, 2.96)	2.9
Dependent for ADLs	20.0 (904/4,528)	7.4 (11,672/157,385)	2.69 (2.53, 2.86)	4.5
Albumin <3.5[‡]	15.8 (2,812/17,785)	6.8 (9,839/144,374)	2.07 (1.99, 2.16)	12.6
Steroids	16.9 (818/4,854)	7.5 (1,1833/157,305)	2.24 (2.10, 2.39)	3.6
Transferred in	15.2 (992/6,526)	7.5 (11,645/155,558)	2.03 (1.91, 2.16)	4.0
Nonelective surgery	10.3 (3,998/38,860)	7.0 (8,471/121,445)	1.47 (1.42, 1.53)	10.3
Any inpatient complication	18.8 (1,962/10,447)	7.0 (10,689/151,712)	2.67 (2.55, 2.79)	9.7
Discharge to facility	20.2 (1,522/7,526)	7.2 (11,052/153,907)	2.82 (2.68, 2.96)	7.8
Continuous Risk Factors	Median, 95% (n)			
Age	56, 82 (162,159)		1.43 (1.39, 1.46)	18.2
LOS	1, 8 (162,159)		3.50 (3.38, 3.62)	47.9

* For categorical variables, RR and PAR are indexed to the reference group. For continuous variables, RR represents risk for the 95th percentile compared with the median, and PAR was calculated by dichotomizing at the median

† Obesity was slightly protective.

‡ Albumin was not obtained in 68,671 patients; these were included in the group with albumin 3.5 or more because of the similar risk profile.

ADLs indicate activities of daily living; ASA, American Society of Anesthesiologists; BMI, body mass index; CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease; GI, gastrointestinal; HPB, hepatopancreatobiliary; LOS, length of stay; PAR, population attributable risk; RR, risk ratio; S&L, small and large.

TABLE 3

Area Under the Receiver Operator Curve for Complex All-Variable Prediction Model and Parsimonious Readmission Score*

	Generation Sample		Validation Sample	
	Complex Model	**Readmission Score**	**Complex Model**	**Readmission Score**
Overall	0.721	0.696	0.724	0.702
General surgery	0.713	0.687	0.719	0.697
Upper GI	0.699	0.659	0.666	0.636
S&L intestine	0.650	0.591	0.640	0.597
HPB	0.657	0.598	0.583	0.591
Vascular	0.696	0.637	0.690	0.653
Thoracic	0.709	0.507	0.579	0.600

*Readmission score = LOS/2 + ASA class, rounded up.

ASA indicates American Society of Anesthesiologists; GI, gastrointestinal; HPB, hepatopancreatobiliary; LOS, length of stay; S&L, small and large.

TABLE 4

Overall Readmission Rate, Sensitivity, and Specificity by Readmission Score in the Validation Sample*

Readmission Score	Readmission, % (n/total)	Sensitivity, %	Specificity, %	PPV, %	NPV, %
1	1.2 (42/3,517)	100	0	8	–
2	2.4 (353/14,694)	99	6	8	99
3	4.7 (750/16,015)	92	28	10	98
4	8.0 (1,144/14,371)	77	52	12	97
5	11.8 (980/8,318)	55	73	15	95
6	14.6 (817/5,603)	37	85	17	94
7	17.2 (655/3,803)	21	92	19	93
8	20.3 (402/1,982)	9	97	21	93
9	22.2 (88/397)	2	100	22	92
10	40.0 (2/5)	0	100	40	92
Total	7.6 (5,233/68,705)				

*Readmission score = LOS/2 + ASA class, rounded up. Using each readmission score as a cutoff for a “positive test” to predict readmission generates a sensitivity and specificity as well as positive and negative predictive values.

LOS indicates length of stay; NPY, negative predictive value; PPV, positive predictive value.

TABLE 5

Proposed Conceptual Model for the Causes of Readmission*

Biologic Factors	Health Care Factors	Social Factors
Disease process	“Quality”	*Discharge setting*
Demographics	Appropriate indication	Socioeconomic status
Comorbidities	Preoperative planning	Informal caregivers
	Surgeon performance	Social support
	Anesthesia	Health beliefs
	Critical care	Health care self-efficacy
	Postoperative care	Health care social norms
	Nursing	
	Infection control	
	Allied health	
	Social work	
	Discharge planning	
	Home health services	
	Outpatient follow-up	
	Care coordination	
	Complications	

*The ACS-NSQIP only addresses italicized factors.