Exploring Trajectories of Health Care Utilization Before and After Surgery

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BACKGROUND: Long-term trajectories of health care utilization in the context of surgery have not been well characterized. The objective of this study was to examine health care utilization trajectories among surgical patients and identify factors associated with high utilization that could possibly be mitigated after surgical admissions.

STUDY DESIGN: Hospital medical and surgical admissions within 2 years of an index inpatient surgery in the Veterans Health Administration (October 1, 2007 to September 30, 2014) were identified. Group-based trajectory analysis identified 5 distinct trajectories of inpatient admissions around surgery. Characteristics of trajectories of utilization were compared across groups using bivariate statistics and multivariate logistic regression.

RESULTS: Of 280,681 surgery inpatients, most underwent orthopaedic (29.2%), general (28.4%), or peripheral vascular procedures (12.2%). Five trajectories of health care utilization were identified, with 5.2% of patients among consistently high inpatient users accounting for 34.0% of inpatient days. Male (95.4% vs 93.5%, $p < 0.01$), African-American (21.6% vs 17.3%, $p < 0.01$), or unmarried patients (61.6% vs 52.5%, $p < 0.01$) were more likely to be high health care users as compared with other trajectories. High users also had a higher comorbidity burden and a strikingly higher burden of mental health diagnoses (depression: 30.3% vs 16.3%; bipolar disorder: 5.3% vs 2.1%, $p < 0.01$), social/behavioral risk factors (smoker: 41.1% vs 33.6%, $p < 0.01$; alcohol use disorder: 28.9% vs 12.9%, $p < 0.01$), and chronic pain (6.4% vs 2.8%, $p < 0.01$).

CONCLUSIONS: Mental health, social/behavioral, and pain-related factors are independently associated with high pre- and postoperative health care utilization in surgical patients. Connecting patients to social workers and mental health care coordinators around the time of surgery may mitigate the risk of postoperative readmissions related to these factors. (J Am Coll Surg 2019; 228:116–128. © 2018 by the American College of Surgeons. Published by Elsevier Inc. All rights reserved.)

Pre-admission health care utilization has been shown to be one of the most important predictors of post-discharge 30-day readmission for both medical and surgical patients.[1,2] In surgical patients, studies of post-discharge readmissions find that surgical complications and patient factors are the primary drivers of readmission;

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Abbreviations and Acronyms

ASA = American Society of Anesthesiologists
ERAS = Enhanced Recovery after Surgery
OR = odds ratio
VACDW = Veterans Administration Corporate Data Warehouse
VASQIP = Veterans Administration Quality Improvement Program
VHA = Veterans Health Administration

however, there remains a large amount of unexplained variation. Taken together, these findings suggest that health care utilization patterns are likely drivers of both surgery-related and unrelated readmissions in surgical patients. Hospital stays are growing increasingly expensive, often exceeding $4,000 per day for surgical patients,[3,4] and health care providers are increasingly looking for opportunities to reduce inpatient costs and unnecessary readmissions, further stressing the importance of identifying modifiable factors associated with excess utilization. When modifiable factors associated with increased health care utilization have been identified,[2-4] they are typically specific to a medical population, and the results have informed successful interventions to reduce both avoidable inpatient utilization and costs.[5-7] However, parallel research on inpatient health care utilization in surgical populations does not yet exist.

Predictors of high inpatient utilization in medical populations include multiple comorbidities and mental health diagnoses such as depression or anxiety, but surgical patients likely have additional risk factors for high utilization.[2-4] One additional factor that could contribute to different health care utilization patterns among surgical patients is the indication for surgery itself.[1,8,9] Some operations are undertaken to fix problems that were causing high health care utilization[8] (ie knee arthroplasty in the context of pain[10]), while other indications for surgery may identify problems that could result in necessary and unavoidable increased health care utilization (ie cancer surgery).[9] Surgical populations also drastically differ from inpatient medical populations in other ways that may affect health care utilization patterns. Not only are surgical patients healthier than the average medical inpatient,[11] but they also report higher inpatient pain and experience post-discharge pain related to surgical recovery.[12,13] To date, the majority of research on surgical outcomes, including post-discharge health care utilization, has focused on a short timeframe, typically not exceeding 30 to 90 days after discharge. With few examples extending beyond this period of time, there is little information on the long-term effect of surgery on subsequent health care utilization.[14,15]

By examining longitudinal patterns of inpatient admissions in the 2 years before through the 2 years after surgery, this study represents the next logical step in better understanding predictors of health care utilization in surgical populations. This study is novel in that it extends beyond the traditional approach of patient centered analyses to population analyses. We hypothesized that there are unique trajectories of health care utilization around surgery that could inform policy on management of populations that undergo surgery. The objective of this study was to identify and characterize these trajectories of health care utilization around surgery and to identify modifiable factors for patients exhibiting trajectories of high utilization after surgery that are unexplained by surgical complications.

METHODS

This is a cohort study using administrative data collected and maintained by the Veterans Health Administration (VHA). The study protocol has been reviewed and approved by the Veterans Administration (VA) Central Institutional Review Board, with a waiver of informed consent.

Study population

The study population includes patients undergoing noncardiac inpatient surgery assessed by the VA Surgical Quality Improvement Program (VASQIP), from October 1, 2007 through September 30, 2014. Surgical procedures occurring within the VHA were retrospectively identified from VASQIP. To ensure that the index operations were inpatient procedures, they were limited to those with a hospital length of stay of 48 hours or longer. Additionally, only patients discharged alive from the surgery hospitalization were included in the analysis to ensure a population at risk for post-discharge health care utilization. In the event that a patient had multiple procedures during the study timeframe, only the first surgical procedure was included in the analysis.

Data sources and variable definitions

We used VASQIP data to identify all noncardiac inpatient procedures and then merged these data with the VA Corporate Data Warehouse (CDW) to obtain information on sociodemographics, patient-reported pain, opioid medication history, and hospital stays. The primary outcome for all analyses was health care utilization around the time of surgery, defined by inpatient stays in the VA Health Care System. Health care utilization was

measured as the occurrence of any inpatient admission for each month in the 24 months before through the 24 months after hospitalization for a surgical procedure. Inpatient admissions were obtained from the Inpatient Domain of the VACDW and do not include inpatient admissions to medical facilities outside of the VA Health Care System.

Covariate selection was guided by Hill's Criteria for Causality.[16] To identify potential covariates, we performed a thorough review of the literature and then further refined our list of predictors with other clinically significant and biologically plausible variables not previously assessed. Covariates identified included age, sex, race, marital status (married vs other), BMI, Charlson Comorbidity Index (CCI) from diagnoses in the year before surgery,[17] previous emergency department (ED) visits, and discharge location after surgery, obtained from a query of the CDW Inpatient domain. These variables have been previously defined.[1] Surgical specialty, work relative value unit (RVU), emergency case status, postoperative diagnosis, smoking status, functional status as assessed by a VASQIP nurse at the time of surgery, American Society of Anesthesiologists (ASA) physical status classification at surgery, and nurse-abstracted postoperative complications were obtained from the VASQIP dataset.

International Classification of Diseases, version 9 (ICD9) codes in the CDW Outpatient domain were queried for evidence of clinically important mental health and social-behavioral factors including depression (ICD9: 296.2, 296.3, 296.82, 298.0, 300.4, 301.12, 309.0, 309.1, 309.28, 311.0), anxiety (ICD9: 300.0, 300.2. 309.20. 309.21. 309.24), post-traumatic stress disorder (PTSD) (ICD9: 309.81), bipolar disorder (ICD9: 296.1, 296.4, 296.5-8), psychosis (ICD9: 295.x, 297.1, 297.3, 298.8, 298.9, 301.22), alcohol use disorder (ICD9: 291.x, 303.x, 305.0x), and a history of chronic pain (IDC9: 338.2x, 338.4). All social-behavioral factors with the exception of alcohol use disorder, smoking, and chronic pain were defined as 2 or more separate visits (inpatient or outpatient) with an ICD9 diagnosis in the year preceding admission for surgery. Alcohol use disorder and chronic pain were defined as any instance of an ICD9 diagnosis code in the year preceding admission for surgery, and smoking was defined as a designation of current smoker at the time of surgery by the VASQIP nurse. Given previous experience examining 30-day readmissions,[1,18] aspects of pain perception were also included as potential predictors of health care utilization. The CDW Outpatient Pharmacy domain was used to obtain information on preoperative opioid prescriptions in the 6 months before surgery. Patients with a daily supply of opioids during the 6-month period before surgery and having $\geq$80% adherence were considered persistent opioid users.[19] Other patients with evidence of opioid coverage but less than 80% adherent in the 6 months before surgery were considered limited opioid users.[19] The Vital Signs domain was queried for maximum patient-reported pain during the inpatient stay, as recorded on a visual analogue scale ranking pain from 0 to 10.

Analytic steps

The first stage of this analysis involved the use of trajectory analysis, also known as latent class growth curve modeling. Trajectory analysis is a technique most commonly used in the field of developmental psychology to examine developmental trajectories.[20,21] It was applied in this study to examine changes to inpatient utilization across time around a surgical procedure. The PROC TRAJ procedure for SAS was used to identify latent classes of trajectories, or longitudinal patterns, of a patient's monthly risk of any inpatient admission in the 24 months preceding admission for surgery through the 24 months after hospital discharge post-surgery.[22,23] Several group-based trajectory models were run using PROC TRAJ in SAS v9.2 examining the possibility of between 3 and 10 unique trajectories.[23] In each iteration, patients were assigned to groups according to their highest predicted probability of group membership. The probability of group membership was calculated using a multinomial logit function, and patients contributed utilization only up until death, allowing the model to fit patients to a trajectory that best fit their pre-death utilization. The predicted probabilities of group membership do not account for the decrease in utilization after death. The resulting latent groups represent clusters of patients following similar trajectories across time. Similar to previous studies, we also required all trajectories to include at least 5% of the total number of patients in our population.[24,25] The final number of groups was chosen by comparing the Bayesian Information Criterion for each model and visual inspection of the trajectories plotted as a smoothed nonlinear plot across time. The model with 5 health care utilization trajectories was determined to be the best determination of health care utilization. These 5 trajectories were examined as the independent variable in subsequent analyses.

Univariate and bivariate statistics were used to describe characteristics of this VHA sample as well as differences and similarities across the 5 trajectories of health care utilization. Missingness and normality were assessed for all variables. Chi-square tests were used to test for associations among categorical variables. Given the large sample

size, normality was assumed, and *t*-tests or ANOVAs were used to test for group differences in continuous variables. An alpha of 0.01 was assumed for the threshold of statistical significance. Multivariate logistic regression was performed to identify and rank independent predictors of the highest health care utilization trajectory. Factors were ranked by their contribution to the model defined as the Type 3 chi-square value minus the degrees of freedom.[26] All analyses were completed using SAS version 9.4 except for the trajectory analysis. Trajectory analysis was completed with SAS version 9.2 using PROC TRAJ.[23]

RESULTS

Study sample

We identified a total of 280,681 inpatients undergoing noncardiac surgery in the VHA between October 1, 2007 and September 30, 2014 (Table 1). Consistent with current research on samples of noncardiac procedures, most operations were orthopaedic (29.2%), general (28.4%), or peripheral vascular (12.2%); 30.2% were other types of surgery (Table 1). The majority of patients were male (93.6%), aged 63.4 years old (SD 11.6 years), and identified as white (76.5%) or African American (17.6%) at surgery. At the time of surgery, patients had an average Charlson Comorbidity Index of 2.2 (SD 2.6), with 23.5% of patients having 3 or more Charlson comorbidities and 26.5% of patients having evidence of at least 1 mental illness in the year preceding their surgery. Depression was most common, affecting 17.0% of patients. Smoking (34.0%) was also a common patient characteristic, as was alcohol use disorder, which was identified among 13.8% of patients. Although a diagnosis of chronic pain before surgery was infrequent (3.0%), 35.2% of operations had evidence of opioid use in the 6 months preceding surgery, and 12.9% of self-reported preoperative pain scores were $\geq$8.

Trajectories of utilization

The overall pattern of inpatient health care utilization across time before trajectory analysis was undertaken is plotted in Figure 1A. Before trajectory analysis, health care utilization was relatively symmetric around surgery. There was a slight increase in utilization noted as patients moved toward the surgical procedure, followed by a significant increase in utilization in the 30 to 60 days after surgery, and then a steady small decline in utilization as the patient moved temporally away from surgery.

We identified 5 unique groups of patients with distinctly different health care utilization trajectories around the time of surgery (Fig. 1B). More than one-third of patients had no evidence of any other inpatient admission during the 4 years surrounding surgery (35.2%, Fig. 1B). These patients were more likely to undergo lower complexity orthopaedic, urology, or gynecology procedures and be younger, with fewer comorbidities (Table 1). Another 18.3% of patients had evidence of utilizationhealth care, but only in the months closest to surgery (Fig. 1B). In fact, these patients tended to have no evidence of inpatient admissions in the VA more than 8 months after surgery or more than 12 months before surgery. These patients were more likely to undergo general and peripheral vascular procedures and be older with more comorbidities, reporting relatively low postoperative pain scores (Table 1). The third trajectory consisted of patients with approximately a 10% risk each month of at least 1 inpatient admission in the 24 months preceding surgery, who saw a 50% reduction in risk in the 2 to 24 months after surgery. This pattern was seen in 17.7% of the operations and was more common in orthopaedic procedures among white patients with slightly higher rates of depression and postoperative pain ratings (Table 1).

The last 2 trajectories represent patterns of increased health care utilization after surgery (Table 1). The fourth trajectory (23.6%) included patients with little to no presurgery utilization, who saw an increase after surgery to an approximate 10% risk of at least 1 inpatient admission per month. These patients were more frequently older white patients with less comorbidity, undergoing thoracic procedures. They also were more likely to have a postoperative diagnosis of cancer. The final trajectory (5.2%) represented patients with a 10% to 25% baseline monthly risk of any inpatient admission before surgery, which remained the same after the surgical procedure (Table 1). Interestingly, these patients were more likely to undergo general or vascular operations and be younger male patients with significantly more mental health comorbidity, including depression and bipolar disorder, at the time of surgery. These patients were also more likely to be unmarried, current smokers, or have alcohol use disorder, and they had a significantly higher level of chronic pain before surgery (Table 1).

Although patients in the highest health care utilization trajectory represented only 5.2% of our cohort, this small group accounted for 34.0% of all inpatient days, 19.9% of all emergency department visits, and 8.3% of primary care visits experienced in 24 months before through the 24 months after surgery (Fig. 2). In contrast, patients in the no utilization trajectory, representing 35.2% of all patients, accounted for only 14.0% of emergency department visits over the study period and 27.6% of primary care visits—far less than the 35.2% that would have

Table 1. Patient Demographics, Comorbidity Burden, and Social/Behavioral Characteristics of Health Care Utilization Patterns Around Surgery

Variable	Overall	No utilization/no readmission	Utilization around surgery only	Reduced or no change in post-surgery utilization	Increased post-surgery utilization	Highest utilization	p Value
Overall, n (%)	280,681 (100)	98,817 (35.2)	51,491 (18.3)	49,599 (17.7)	66,227 (23.6)	14,457 (5.2)	
Patient demographic							
Age, y, mean (SD)	63.4 (11.6)	62.0 (11.9)	64.5 (11.8)	64.0 (11.4)	64.1 (11.0)	63.6 (11.3)	<0.001
Sex, n (%)							<0.001
Female	18,107 (6.5)	8,138 (8.2)	2,690 (5.2)	3,011 (6.1)	3,604 (5.4)	664 (4.6)	
Male	262,574 (93.6)	90,679 (91.8)	48,801 (94.8)	46,588 (93.9)	62,623 (94.6)	13,883 (95.4)	
Race, n (%)							<0.001
White	214,830 (76.5)	74,664 (75.6)	39,702 (77.1)	38,348 (77.3)	51,241 (77.4)	10,875 (74.8)	
Black or African American	49,257 (17.6)	17,236 (17.4)	8,620 (16.7)	8,819 (17.8)	11,447 (17.3)	3,135 (21.6)	
Other	5,110 (1.8)	1,914 (1.9)	920 (1.8)	873 (1.8)	1,156 (1.8)	247 (1.7)	
Unknown	11,484 (4.1)	5,003 (5.1)	2,249 (4.4)	1,559 (3.1)	2,383 (3.6)	290 (2.0)	
Body mass index, kg/m^2, mean (SD)	29 (6.4)	29 (6.3)	28 (6.4)	29 (6.5)	29 (6.4)	28 (6.7)	<0.001
Patient comorbidity burden							
Functional health status, n (%)							<0.001
Independent	253,391 (90.3)	92,269 (93.4)	45,896 (89.1)	44,040 (88.8)	59,552 (89.9)	11,634 (80.0)	
Partially/totally dependent	27,290 (9.7)	6,548 (6.6)	5,595 (10.9)	5,559 (11.2)	6,675 (10.1)	2,913 (20.0)	
Charlson Comorbidity Index, mean (SD)	2.2 (2.6)	1.8 (2.0)	2.6 (2.7)	2.8 (2.7)	2.0 (2.5)	3.5 (3.4)	<0.001
ASA Classification, n (%)							<0.001
1–2	54,916 (19.6)	29,024 (29.4)	7,963 (15.5)	6,247 (12.6)	10,890 (16.5)	792 (5.5)	
3	192,557 (68.6)	64,276 (65.1)	35,629 (69.2)	35,868 (72.3)	47,356 (71.5)	9,428 (64.9)	
4–5	33,136 (11.8)	5,495 (5.6)	7,881 (15.3)	7,475 (15.1)	7,971 (12.0)	4,314 (29.7)	
Postoperative cancer diagnosis, n (%)	69,208 (24.7)	25,320 (25.6)	14,992 (29.1)	8,910 (18.0)	17,618 (26.6)	2,368 (16.3)	<0.001
Surgery characteristic							
Emergent surgery, n (%)	20,377 (7.3)	6,210 (6.3)	4,071 (7.9)	3,694 (7.5)	4,868 (7.4)	1,534 (10.6)	<0.001
Work relative value unit, n (%)	20.1 (7.9)	20.4 (7.1)	20.2 (8.8)	19.3 (7.7)	20.6 (8.1)	17.6 (8.8)	<0.001
Other health care utilization							
No. of previous ED visits in 6 mo, mean (SD)	0.7 (1.5)	0.3 (0.8)	1.1 (1.7)	0.7 (1.4)	0.7 (1.4)	2.4 (3.2)	<0.001
Discharged to other than community, n (%)	27,290 (9.7)	6,548 (6.6)	5,595 (10.9)	5,559 (11.2)	6,675 (10.1)	2,913 (20.0)	<0.001
Inpatient readmission within 30 d, n (%)	26,412 (9.4)	0 (0.0)	12,129 (23.6)	3,633 (7.3)	6,801 (10.3)	3,849 (26.5)	<0.001
Days to first, mean (SD)	11.5 (8.3)	0.0 (0.0)	11.3 (8.3)	11.3 (8.3)	11.4 (8.3)	12.5 (8.5)	<0.001
ED visit within 30 d, n (%)	42,126 (15.0)	8,431 (8.5)	11,320 (22.0)	7,428 (15.0)	10,993 (16.6)	3,954 (27.2)	<0.001

(Continued)

Table 1. Continued

Variable	Overall	No utilization/no readmission	Utilization around surgery only	Reduced or no change in post-surgery utilization	Increased post-surgery utilization	Highest utilization	p Value
Days to first, mean (SD)	10.3 (8.3)	10.2 (8.3)	10.0 (8.1)	10.6 (8.5)	10.4 (8.4)	10.7 (8.5)	<0.001
Primary care visit within 180 d, n (%)	221,398 (78.9)	77,135 (78.1)	40,197 (78.1)	39,523 (79.7)	53,491 (80.8)	11,052 (76.0)	<0.001
Medicine clinic visit within 180 d, n (%)	175,766 (62.6)	54,932 (55.6)	34,859 (67.7)	32,523 (65.6)	43,125 (65.1)	10,327 (71.0)	<0.001
Mental health clinic visit within 180 d, n (%)	74,943 (26.7)	21,884 (22.2)	14,092 (27.4)	15,108 (30.5)	18,341 (27.7)	5,518 (37.9)	<0.001
Mental health factor, n (%)							
Depression diagnosis	47,611 (17.0)	13,167 (13.4)	8,020 (15.6)	11,015 (22.3)	11,010 (16.7)	4,399 (30.3)	<0.001
Anxiety diagnosis	15,949 (5.7)	4,669 (4.8)	2,723 (5.3)	3,490 (7.1)	3,660 (5.6)	1,407 (9.7)	<0.001
PTSD diagnosis	29,418 (10.5)	9,110 (9.3)	4,613 (9.0)	6,638 (13.4)	6,865 (10.4)	2,192 (15.1)	<0.001
Bipolar disorder diagnosis	6,337 (2.3)	1,459 (1.5)	972 (1.9)	1,713 (3.5)	1,420 (2.2)	773 (5.3)	<0.001
Psychosis diagnosis	5,867 (2.1)	1,116 (1.1)	1,095 (2.1)	1,535 (3.1)	1,271 (1.9)	850 (5.9)	<0.001
Social factor, n (%)							
Married	131,872 (47.0)	49,721 (50.4)	23,622 (45.9)	22,131 (44.6)	30,814 (46.6)	5,584 (38.4)	
Current smoker	95,362 (34.0)	30,134 (30.5)	18,284 (35.5)	17,193 (34.7)	23,770 (35.9)	5,981 (41.1)	<0.001
Alcohol use disorder	38,462 (13.8)	9,305 (9.5)	6,847 (13.3)	9,173 (18.5)	8,937 (13.5)	4,200 (28.9)	<0.001
Pain perception							
History of chronic pain, n (%)	8,385 (3.0)	2,075 (2.1)	1,635 (3.2)	1,825 (3.7)	1,924 (2.9)	926 (6.4)	<0.001
Preoperative opioid use, n (%)							<0.001
No evidence	184,579 (65.8)	67,058 (67.9)	33,059 (64.2)	29,944 (60.4)	45,793 (69.2)	8,725 (60.0)	
Limited usage	44,842 (16.0)	14,610 (14.8)	9,386 (18.2)	8,250 (16.6)	10,117 (15.3)	2,479 (17.0)	
Persistent usage	63,922 (19.2)	18,041 (17.7)	11,853 (18.8)	17,281 (23.9)	11,699 (16.0)	5,048 (23.2)	
Highest postoperative pain, mean (SD)	7.4 (2.6)	7.3 (2.5)	7.4 (2.6)	7.6 (2.6)	7.5 (2.6)	7.9 (2.6)	<0.001
Closest preoperative pain reported, mean (SD)	3.3 (3.1)	3.3 (3.0)	3.2 (3.1)	3.5 (3.2)	3.3 (3.2)	3.7 (3.3)	<0.001
Postoperative complication							
Pre-discharge, n (%)	16,444 (5.9)	3,900 (4.0)	3,773 (7.3)	3,098 (6.3)	4,351 (6.6)	1,322 (9.1)	<0.001
14-d post-discharge, n (%)	11,140 (4.0)	1,617 (1.6)	3,765 (7.3)	1,778 (3.6)	2,926 (4.4)	1,054 (7.3)	<0.001
30-d post-discharge mortality, n (%)	2,322 (0.8)	578 (0.6)	402 (0.8)	468 (0.9)	591 (0.9)	283 (2.0)	<0.001

ASA, American Society of Anesthesiologists; ED, emergency department; PTSD, post-traumatic stress disorder.

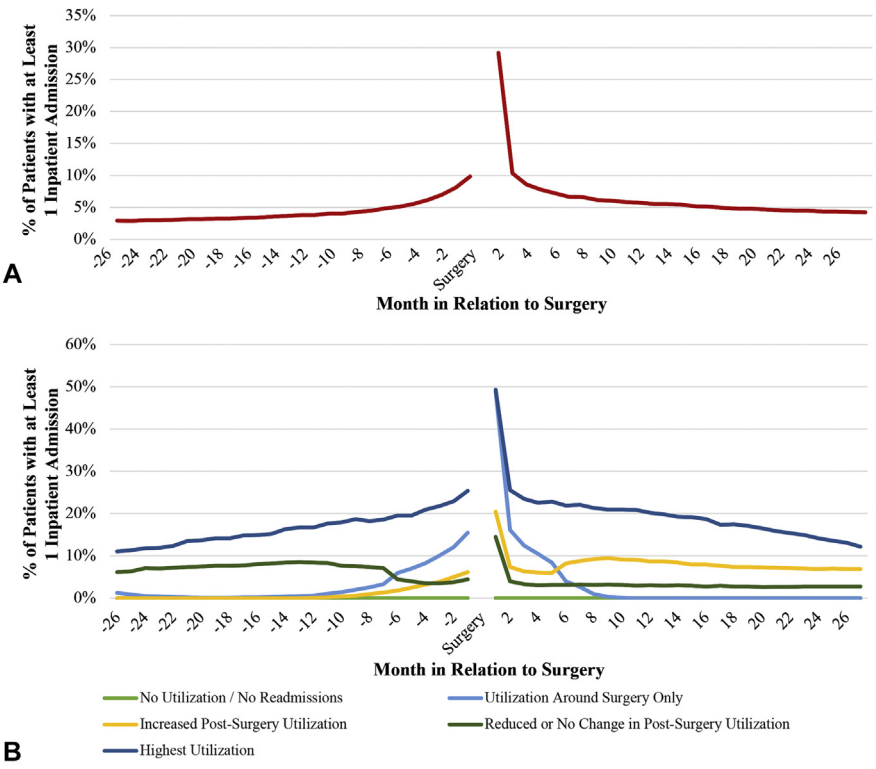

Figure 1. Trajectories of health care utilization in the 24 months before admission for surgery through the 24 months after discharge from surgery. (A) Overall and (B) by Healthcare Utilization Trajectory Group.

been expected. Patients seeing an increase in utilization after surgery also experienced a slightly higher proportion of inpatient days (23.9%), emergency department visits (24.1%), and primary care visits (22.5%) than would have been expected for the group (17.7%, Fig. 2), but not at the magnitude of increase seen for the high health care utilization trajectory.

Variation in trajectories of health care utilization by surgical specialty and procedure indication

Table 2 provides further detail on the differences in health care utilization trajectories by surgical specialty and the top 3 postoperative diagnoses for each specialty represented in our analysis. Health care utilization not only varied across the broad categories of surgical specialties, but also within specialty by the indication for the surgical procedure. Within orthopaedics, the most frequent postoperative diagnosis was osteoarthritis (60.8%). Patients with this diagnosis were 20% less likely to experience high utilization as compared with other orthopaedic procedure indications (1.4% vs 7.4%, $p < 0.01$). In contrast, patients undergoing orthopaedic surgery for the next most frequent postoperative diagnosis, fractures of neck of femur, were 1.8 times more likely to be categorized as high users, both before and after surgery (9.2% vs 3.2%, $p < 0.01$). Similar variation also existed within the general surgery specialty, in which patients with a diagnosis of malignant neoplasm were more likely to be categorized into the trajectory of increased post-surgery use as compared with other general surgical procedures (30.2% vs 20.9%, $p < 0.01$). In contrast, patients with a diagnosis of benign neoplasm, the third most common general surgery indication, were more likely to be categorized into the trajectory of no utilization

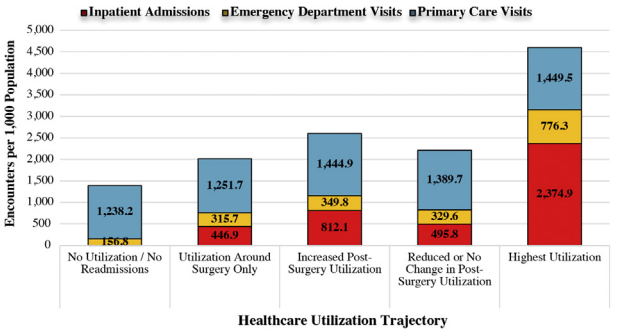

Figure 2. Annual incidence of inpatient visits, emergency department visits, and primary care across the 4-year study period by health care trajectory.

Table 2. Surgical Specialty and Top Postoperative Diagnoses per Specialty by Health Utilization Trajectory

Variable	Overall	No utilization/no readmission	Utilization around surgery only	Reduced or no change in post-surgery utilization	Increased post-surgery utilization	Highest utilization
Overall, n (%)	280,681 (100)	98,817 (35.2)	51,491 (18.3)	49,599 (17.7)	66,227 (23.6)	14,457 (5.2)
Orthopaedic	82,041 (29.2)	33,298 (40.6)	10,296 (12.5)	15,670 (19.1)	19,675 (24.0)	3,102 (3.8)
Osteoarthritis; localized	39,564 (48.2)	18,534 (46.9)	3,848 (9.7)	6,672 (16.9)	9,964 (25.2)	546 (1.4)
Osteoarthritis; generalized and unspecified	10,299 (12.6)	4,673 (45.4)	978 (9.5)	1,892 (18.4)	2,589 (25.1)	167 (1.6)
Fracture of neck of femur (hip)	8,563 (10.4)	2,187 (25.5)	1,616 (18.9)	2,106 (24.6)	1,882 (22.0)	772 (9.0)
General	79,592 (28.4)	25,148 (31.6)	16,912 (21.2)	14,368 (18.1)	18,478 (23.2)	4,686 (5.9)
Neoplasm	19,489 (24.5)	5,721 (29.4)	4,823 (24.8)	2,332 (12.0)	5,893 (30.2)	720 (3.7)
Biliary tract disease	14,186 (17.8)	4,780 (33.7)	3,300 (23.3)	2,586 (18.2)	2,732 (19.3)	788 (5.6)
Benign neoplasm	5,374 (6.8)	2,494 (46.4)	927 (17.3)	747 (13.9)	1,089 (20.3)	117 (2.2)
Peripheral vascular	34,121 (12.2)	7,745 (22.7)	8,024 (23.5)	6,265 (18.4)	8,836 (25.9)	3,251 (9.5)
Abdominal aortic aneurysm; without rupture	6,557 (19.2)	2,387 (36.4)	1,405 (21.4)	967 (14.8)	1,603 (24.5)	195 (3.0)
Occlusion or stenosis of precerebral artery	6,473 (19.0)	2,012 (31.1)	1,468 (22.7)	1,186 (18.3)	1,541 (23.8)	266 (4.1)
Atherosclerosis of artery of extremity	6,336 (18.6)	1,121 (17.7)	1,523 (24.0)	1,233 (19.5)	1,869 (29.5)	590 (9.3)
Urology	33,794 (12.0)	13,907 (41.2)	6,225 (18.4)	4,870 (14.4)	7,389 (21.9)	1,403 (4.2)
Neoplasm	22,633 (67.0)	10,188 (45.0)	3,979 (17.6)	2,747 (12.1)	5,054 (22.3)	665 (2.9)
Hyperplasia of prostate	4,557 (13.5)	1,777 (39.0)	894 (19.6)	810 (17.8)	904 (19.8)	172 (3.8)
Other and unspecified disease of kidney and ureter*	1,112 (3.3)	409 (36.8)	233 (21.0)	199 (17.9)	220 (19.8)	51 (4.6)
Neurosurgery	22,235 (7.9)	8,900 (40.0)	3,612 (16.2)	4,024 (18.1)	4,919 (22.1)	780 (3.5)
Spinal stenosis; lumbar region	4,720 (21.2)	2,163 (45.8)	495 (10.5)	918 (19.5)	1,042 (22.1)	102 (2.2)
Intervertebral disc disorder	4,201 (18.9)	1,973 (47.0)	470 (11.2)	768 (18.3)	869 (20.7)	121 (2.9)
Spondylosis and allied disorder	3,138 (14.1)	1,364 (43.5)	405 (12.9)	581 (18.5)	694 (22.1)	94 (3.0)
Thoracic surgery	16,345 (5.8)	4,467 (27.3)	4,126 (25.2)	2,534 (15.5)	4,362 (26.7)	856 (5.2)
Neoplasm	9,772 (59.8)	2,643 (27.1)	2,466 (25.2)	1,416 (14.5)	2,841 (29.1)	406 (4.2)
Other and unspecified lower respiratory disease†	1,225 (7.5)	376 (30.7)	262 (21.4)	214 (17.5)	323 (26.4)	50 (4.1)
Pleurisy; pleural effusion	821 (5.0)	168 (20.5)	232 (28.3)	154 (18.8)	185 (22.5)	82 (10.0)
Otolaryngology	8,347 (3.0)	2,685 (32.2)	1,848 (22.1)	1,393 (16.7)	2,007 (24.0)	414 (5.0)
Neoplasm	4,983 (59.7)	1,243 (24.9)	1,321 (26.5)	785 (15.8)	1,377 (27.6)	257 (5.2)
Benign neoplasm	848 (10.2)	432 (50.9)	114 (13.4)	145 (17.1)	141 (16.6)	16 (1.9)
Other thyroid disorder‡	686 (8.2)	345 (50.3)	87 (12.7)	112 (16.3)	121 (17.6)	21 (3.1)

(Continued)

Table 2. Continued

Variable	Overall	No utilization/no readmission	Utilization around surgery only	Reduced or no change in post-surgery utilization	Increased post-surgery utilization	Highest utilization
Gynecology	4,155 (1.5)	2,649 (63.8)	434 (10.4)	468 (11.3)	550 (13.2)	54 (1.3)
Benign neoplasm	1,830 (44.0)	1,253 (68.5)	167 (9.1)	181 (9.9)	207 (11.3)	22 (1.2)
Menstrual disorder	831 (20.0)	499 (60.1)	107 (12.9)	108 (13.0)	110 (13.2)	7 (0.8)
Endometriosis	275 (6.6)	164 (59.6)	28 (10.2)	30 (10.9)	48 (17.5)	5 (1.8)

*Other and unspecified diseases of kidney and ureters were mainly coded as acute renal disease/insufficiency (International Classification of Disease [ICD], version 9 code 593.9, 56.2%), ureteric obstruction (ICD 9 code 593.4, 12.3%), cyst of kidney (ICD 9 code 593.2, 10.8%) or stricture/kinking of ureter (ICD 9 code 593.3, 10.4%).
†Other and unspecified lower respiratory disease were mainly brocholithiasis/calcification of lung/pulmolithiasis/other nonclassified lung diseases (ICD 9 code 518.89, 47.7%) or chest swelling/mass/lump (ICD 9 code 786.6, 29.9%).
‡Other thyroid disorders were mainly nontoxic nodular goiter (ICD 9 codes 241.0, 241.1, or 241.9, 77.1%).

as compared with other general surgery procedures (46.4% vs 30.5%, $p < 0.01$).

Predictors of trajectories of health care utilization

Only the final multivariate model predicting the highest utilization trajectory (Group 5) demonstrated a good fit, with an r-square of 19.0%. The results of this model are presented in Table 3. The high utilization trajectory model identified greater ASA classification, greater Charlson Comorbidity Index, and peripheral vascular or general surgical specialty as the top 3 predictors of high utilization both before and after surgery (Table 3). Although only representing 11.8% of patients, patients with an ASA classification > 3 at the time of surgery were more than 6 times as likely to fall into the high user group (odds ratio [OR] 6.43, 95% CI 5.88 to 7.03). Alcohol use disorder, depression, and postoperative pain were the highest ranking potentially modifiable factors predicting the highest utilization categories, ranking fourth, seventh, and eleventh in the final model, respectively. Patients with alcohol use disorder were twice as likely to be high health care users (OR 2.07, 95% CI 1.98 to 2.17), and patients with depression were 74% more likely to be high utilizers (OR 1.74, 95% CI 1.66 to 1.82, Table 3). For every 1-unit increase in a patient's highest reported postoperative pain score, there was a 7% increase in their odds of being in the highest utilization trajectory (OR 1.07, 95% CI 1.06 to 1.08).

As a sensitivity analysis, separate models were constructed for the top indication in each of the top 3 specialties: orthopaedic, general, and peripheral vascular. The most frequent procedure type in our population was an orthopaedic procedure for osteoarthritis, which was experienced by 49,863 patients. The high utilization model limited to this group was similar to the overall model, but with a slightly higher r-square (19.1%). Alcohol use disorder, ASA classification, and depression ranked as the highest contributing predictors of high utilization among orthopaedic operations for osteoarthritis. In contrast, the most frequent indication for general surgery was neoplasms, which were noted in 19,489 patients. The high utilization model limited to this subgroup of patients also demonstrated a good fit (r-square = 14.2%), but had slightly different contributors. Although ASA classification was still the top-ranking contributor, depression, postoperative pain, and functional status were the next highest contributors to high health care among general surgery patients undergoing procedures for neoplasms. Vascular procedures for abdominal aortic aneurysm were the most common peripheral vascular procedures experienced in our cohort. The model limited to this subset of 6,557 patients is still a good fitting model

Table 3. Adjusted Multivariate Model for the Top 15 Highest Ranking Factors* Associated with Consistently High Health Care Utilization

Variable	OR (95% CI)	Chi-square−DF	p Value
ASA Classification			
1−2	Ref	1,934.5	<0.0001
3	2.93 (2.71−3.17)		
4−5	6.43 (5.88−7.03)		
Charlson Comorbidity Index	1.13 (1.13−1.14)	1,442.4	<0.0001
Surgical specialty			
Orthopaedic	Ref	1,034.9	<0.0001
General	1.78 (1.68−1.88)		
Peripheral vascular	2.24 (2.11−2.37)		
Urology	1.79 (1.66−1.94)		
Neurosurgery	0.89 (0.82−0.97)		
Thoracic surgery	1.39 (1.27−1.52)		
Otolaryngology	1.53 (1.36−1.72)		
Gynecology	0.72 (0.54−0.97)		
Alcohol use disorder	2.07 (1.98−2.17)	975.4	<0.0001
Functional status			
Independent	Ref	820.7	<0.0001
Partially/totally dependent	2.07 (1.97−2.17)		
Surgery work relative value unit	0.97 (0.97−0.97)	671.4	
Depression	1.74 (1.66−1.82)	598.0	<0.0001
Discharged to location other than community	1.70 (1.62−1.79)	400.9	<0.0001
Psychosis	2.05 (1.89−2.23)	288.6	<0.0001
Postoperative cancer diagnosis	0.60 (0.57−0.64)	273.5	<0.0001
Highest postoperative pain	1.07 (1.06−1.08)	268.0	<0.0001
Bipolar disorder	1.95 (1.79−2.12)	229.7	<0.0001
Age, y	0.99 (0.98−0.99)	213.4	<0.0001
History of chronic pain	1.71 (1.58−1.85)	174.0	<0.0001
Surgical complication within 14 days after discharge	1.52 (1.42−1.64)	128.7	<0.0001

C = 0.81, R-Square = 0.19.
ASA, American Society of Anesthesiologists; DF, degrees of freedom; OR, odds ratio.

(r-square = 17.5%), but in addition to ASA classification and functional status as the highest-ranking contributors, post-discharge complications rank as the third most important contributor to high utilization among these patients. Patients with a post-discharge complication after a vascular surgery for abdominal aortic aneurysm were 3.5 times more likely to be high utilizers than those without post-discharge complications (OR 3.48, 95% CI 2.10 to 5.75).

DISCUSSION

This study explores long-term trajectories of health care utilization around surgery and identifies unique subpopulations of surgical patients following a distinctive pattern of longitudinal health care utilization. Characterizing cohorts of surgical patients with specific utilization patterns may allow for targeted interventions to anticipate and coordinate care as well as identify targets for reduction in utilization and costs. For the overall cohort, increases in pre-surgery health care utilization were noted as early as 9 months preceding the surgical procedure. There was also a spike in inpatient readmissions in the 1 to 2 months after surgery, likely representing surgery-related complications resulting in readmission. Twenty percent of patients saw an overall reduction in utilization-health care after surgery (17.7%), and nearly one-quarter of patients (23.6%) saw the opposite effect—an increase in utilization after surgery. Lastly, a small cohort of patients (5.2%) with a pattern of high utilization unaffected by the occurrence surgery was also identified.

This cohort of high users included only 5% of all patients in the study, yet accounted for 34% of the total inpatient days identified in the 4-year observation period around surgery. Patients identified as high utilizers were younger and had significantly higher rates of psychosocial

factors such as mental health disorders, social/behavioral factors, and pain-related issues. Even more interesting was the finding that several social, behavioral, and mental health issues were strong independent predictors of the highest health care utilization trajectory, even after controlling for other known confounders such as comorbidity burden, surgery type, and patient demographics. This suggests that this unique population has high rates of nonsurgery-related utilization health care. These findings have important implications for population health policies; a small shift in the proportion of these patients in an underlying population could have a big impact on overall health care utilization of the population.

Few studies have looked at how social, behavioral, and mental health risk factors might be dealt with preoperatively or at the time of discharge from surgery. In recent years, increasing focus has been placed on surgery as an opportunity for intervention.[27,28] Examples include programs such as variations of "pre-hab,"[29,30] the American College of Surgeons Strong for Surgery program,[31] and the plethora of studies examining variations of Enhanced Recovery After Surgery pathways (ERAS).[32-34] The social, behavioral, and mental health risk factors identified in our study are modifiable through treatment and/or supportive services, and several models of successful interventions exist outside of surgery.[35-37] This research represents a unique population of patients—veterans undergoing surgery within the VHA—who are likely already more connected to health care services than the average population. This likely explains the already high use of primary care and mental health services. Despite the high prevalence of mental health care usage, only 19.7% of patients with a diagnosis of depression and only 13.4% of patients with a diagnosis of alcohol use disorder had a documented mental health visit in the 30 days after surgery, when their risk of inpatient admission was highest. Furthermore, although 75.9% of patients with a diagnosis of depression had evidence of a mental health encounter in the 6 months preceding surgery, only 61.6% had evidence of a mental health encounter in the 6 months after surgery. Similar decreases in post-surgery utilization were seen for the other mental health conditions examined as well. Surgery could potentially provide a sentinel health care moment when currently existing interventions could be modified and included in ongoing ERAS or pre-hab interventions.[38,39]

Currently existing ERAS and pre-hab programs tend to target optimizing a patient for surgery through preoperative counselling, standardized procedures, and comorbidity or mobilization interventions in the perioperative period. The over-riding goal of the programs is improving patient health, with the immediate goal of improving surgical outcomes. Many of these programs have been shown to be effective in improving surgical outcomes, adding to their increasing popularity.[27,28,32-34] Of the modifiable factors examined in this study, smoking cessation and pain medication management are the only factors targeted by some of the currently existing pre-hab and ERAS programs. None of the programs examined or used to date include mental health interventions or detailed social/behavioral assessments. Our results suggest that currently ongoing and future iterations of pre-hab and ERAS programs should include mental health and more social/behavioral components in order to have a greater effect on postoperative utilization. Furthermore, surgery may interrupt ongoing mental health treatments, leading to worsening of other nonsurgery-related conditions,[40] further stressing the importance of including mental health interventions in current pre-hab or ERAS programs.

Limitations

Although these results represent a significant step forward in our understanding of predictors of health care utilization among surgical patients, the results should be considered with the following limitations in mind. First and foremost, this is a retrospective cohort study of administrative data from a veteran population undergoing surgery. Our generalizability to the broader population as a whole is limited by a mainly male population (93.6%), with decreased health evident by the necessity of surgery and greater access to care through the Veteran's Health Administration. The study design, while most efficient for this type of analysis, limits our interpretation of interventions and may be biased by certain provider practices and facility culture. We have attempted to adjust for this in the final model by including facility as an independent variable, but residual confounding likely still remains and could potentially affect our findings. In addition, the use of administrative data has the potential to lead to less exact definitions of data elements. The majority of data elements were obtained from the VASQIP, and VASQIP data elements are nurse-abstracted and therefore are fairly reliable, minimizing this limitation.[41] For other non-VASQIP data elements, extensive efforts were put into cleaning and definitions in order to reduce errors among administrative data elements.

Second, we were unable to identify inpatient admissions outside of the VA Healthcare System and therefore may be underestimating the full extent of perioperative inpatient health care utilization. However, it is likely that non-VA inpatient admissions represent a very small part of overall veteran health care utilization.[42] In

addition, the use of non-VA sources for inpatient admissions is also not likely to be associated with specific covariates included in this study, making it less likely to bias our results significantly, and our study time frame ends before the implementation of the VA CHOICE Act, which would exaggerate this difference by allowing veterans to opt for care outside of the VA more easily. Third, in order to examine post-discharge utilization, it was necessary to exclude patients who died during the surgery hospitalization. This has likely biased our findings to surgical procedures with lower risk of in-hospital complications and in-hospital mortality. Finally, it is important to note that trajectory analysis is a novel technique in surgical outcomes research that uses latent classes and finite mixture modeling to identify longitudinal trajectories. This technique is increasing in popularity, with few concerns regarding reliability of the results, but our findings should be considered with this in mind.

CONCLUSIONS

Subsequent health care utilization in populations undergoing surgery will vary based on the underlying comorbidities, complications, and psychosocial characteristics of the population. We identified depression, alcohol use disorder, and pain as significant modifiable predictors of substantially higher, long-term, pre- and post-discharge utilization among surgical patients that are less related to the quality of surgical care. Each of these characteristics represents an opportunity to intervene, either during preoperative surgical care or during routine postoperative care such as improved discharge planning. Existing successful interventions targeting these factors could easily be incorporated and tested in currently ongoing ERAS and pre-hab programs. Including these interventions in ongoing programs could result not only in improved patient health, well-being, and satisfaction, but also reduced costs to the facility, reduced burden on the health care staff, and improved surgical outcomes.

Author Contributions

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Analysis and interpretation of data: Graham, Wagner, Copeland, Harris, Hawn

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Critical revision: Graham, Wagner, Richman, Morris, Copeland, Harris, Itani, Hawn

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