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Patient complexity by surgical specialty does not correlate with work relative value units

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A R T I C L E I N F O

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A B S T R A C T

Background: Understanding the differences in how patient complexity varies across surgical specialties can inform policy decisions about appropriate resource allocation and reimbursement. This study evaluated variation in patient complexity across surgical specialties and the correlation between complexity and work relative value units.
Study design: The 2017 American College of Surgeons National Surgical Quality Improvement Program was queried for cases involving otolaryngology and general, neurologic, vascular, cardiac, thoracic, urologic, orthopedic, and plastic surgery. A total of 10 domains of patient complexity were measured: American Society of Anesthesiologists class ≥4, number of major comorbidities, emergency operation, major complications, concurrent procedures, additional procedures, length of stay, non-home discharge, readmission, and mortality. Specialties were ranked by their complexity domains and the domains summed to create an overall complexity score. Patient complexity then was evaluated for correlation with work relative value units.
Results: Overall, 936,496 cases were identified. Cardiac surgery had the greatest total complexity score and was most complex across 4 domains: American Society of Anesthesiologists class ≥4 (78.5%), 30-day mortality (3.4%), major complications (56.9%), and mean length of stay (9.8 days). Vascular surgery had the second greatest complexity score and ranked the greatest on the domains of major comorbidities (2.7 comorbidities) and 30-day readmissions (10.1%). The work relative value units did not correlate with overall complexity score (Spearman's $\rho = 0.07$; $P < .01$). Although vascular surgery had the second most complex patients, it ranked fifth greatest in median work relative value units. Similarly, general surgery was the fifth most complex but had the second-least median work relative value units.
Conclusion: Substantial differences exist between patient complexity across specialties, which do not correlate with work relative value units. Physician effort is determined largely by patient complexity, which is not captured appropriately by the current work relative value units.

Introduction

Efficient health care delivery depends on matching resources with need. Patient complexity is a difficult-to-define conceptual framework, but complexity inherently implies increased resource utilization and effort to provide adequate care. Patient complexity has been defined as a dynamic state in which personal, social, and clinical aspects of the patient's experience operate as complicating factors.[1] Recent assessment of patient complexity across medical specialties suggests wide variation, which has ramifications for health care policy, education, and attributed resources.[2] Although major differences between medical specialties and surgical specialties exist, assessment of patient complexity stratified by surgical specialty has yet to be performed. This assessment is particularly important, because surgical care alone accounts for more than half of all Medicare spending and represents 20% of the total health care expenditure of the United States.[3] Therefore, defining relative patient complexity as it applies to surgical specialties is imperative to

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guide resource allocation of the health care system and to ensure appropriate reimbursement by payers, including the Centers for Medicare and Medicaid Services. Complex patients require greater resources through increased complications, readmissions, physician time, ancillary support, greater length of stay, and need for postdischarge rehabilitation and nursing care.

Relative value units (RVUs) were created by the Centers for Medicare and Medicaid Services to provide a rank on a common scale of the resources used to provide each service. The RVU is the basis for the Medicare Physician Fee Schedule that is used to determine payments nationally. RVUs include the physician's work, the expense to the physician's practice, professional liability, and an adjustment for geographic variation.[4] The physician's work is captured by the work RVU (wRVU). The wRVU encompasses the time, technical skill and effort, mental effort and judgment, and stress to provide each service.[4] Because patient complexity increases each component of the wRVU, it would follow that patient complexity should correlate closely with wRVUs. The RVU determination is assessed via the Relative Value Scale Update Committee (RUC), formulated by a group of physicians convened by the American Medical Association. The RUC often has been criticized, and recent evidence suggests that the RUC estimates on time spent performing various operations are innacurate.[5] RUC updates to RVUs are a zero-sum game and are based largely on expert opinion rather than on evidence, creating the potential for misappropriation of resources.[4]

Many health care systems have moved toward RVU-based compensation models aimed at incentivizing productivity. Understanding the interplay between patient complexity and RVUs helps determine whether there may be unintended consequences to these commonly used, RVU-based compensation models. Reimbursement fundamentally drives care delivery, and there is a potential to disincentivize care for complex patients who are not recognized adequately with wRVUs.[6] Furthermore, specialties with complex patients may be wholly undervalued by wRVU, which could lead to decreased resources and worse care for the very patients who need it the most. Understanding patient complexity across surgical specialties is thus fundamental to providing equitable and efficient health care. This study aimed to define surgical patient complexity across multiple domains to help benchmark specialties and determine whether wRVU correlates with patient complexity. We hypothesized that patient complexity would vary between specialties and would correlate positively with wRVUs.

Methods

This retrospective cohort analysis is presented according to the reporting guidelines of the Strengthening the Reporting of Observational Studies in Epidemiology initiative.[7] This study did not contain any protected health information because of the deidentified nature of the data, which is not considered human research and therefore, was considered exempt by the institutional review board of the University of California, San Francisco.

Data source and cohort

We analyzed retrospectively the Participant User File of the 2017 American College of Surgeons National Surgical Quality Improvement Program (NSQIP). The NSQIP is a clinical database that collects prospective data on adult patients (≥18 years of age) from participating institutions. The database has been used heavily, and details on the sampling strategy, data collection, variables, and outcomes have been reported elsewhere.[8] Our analysis was restricted to patients undergoing a primary procedure with the following surgical specialties as defined within the database: otolaryngology (ENT) and general, neurologic, vascular, cardiac, thoracic, urologic, orthopedic, and plastic surgery. Because the NSQIP only collects data on adult patients, pediatric and congenital surgical patients were not included. The NSQIP does not collect data on transplant or trauma surgery patients. Therefore, these patients also are not included in this study or represented. Major comorbidities were grouped by system using previously described methods.[9,10] Major complications included postoperative venous thromboembolism, renal injury and failure, sepsis, deep tissue infection, failure to wean off of ventilator, reintubation, pneumonia, stroke, cardiac arrest, myocardial infarction, bleeding, and return to the operating room.[11] All variables utilized had <10% of data missing. Missing data were grouped with the referent group to create a conservative estimate for all independent variables.

Domains of complexity

Currently, there are no accepted measures of surgical patient complexity.[12] Surgical patient complexity in this study included assessments across the domains of surgical care, including preoperative factors, intraoperative measures, and postoperative outcomes. A total of 10 domains were evaluated (Fig 1). These domains were chosen to include metrics from all phases of surgical care, including patient characteristics, inpatient utilization, and postoperative outcomes. Preoperative measures included the American Society of Anesthesiologists (ASA) class ≥4, number of major comorbidities by system, and emergency operations. ASA class and the presence of major comorbidities are global indicators of a patient's surgical and anesthetic risks and have been demonstrated to correlate positively with morbidity and mortality.[13] Emergency operations can be more physically and emotionally demanding, more technically complex, and generally have compromised outcomes.[14] Operative measures included undergoing a concurrent procedure with a different specialty, requiring an additional procedure, and length of hospital stay. Requiring a concurrent or additional procedure indicates the requirement of multiple procedures and coordination among other teams or services, both of which can take substantial effort and work from the primary surgeon. Postoperative measures included non-home discharge to a rehabilitation or skilled nursing facility and 30-day rate of readmissions, major complications, and mortality. Non-home discharge demonstrates that the patient requires a high level of care or rehabilitation and also can complicate discharge planning.[15] Readmissions and complications are linked directly to the primary surgeon and hospital and require additional effort, energy, and work. Furthermore, these metrics affect reimbursement and may play more substantial roles in future models of insurance reimbursement.

Ranking and complexity score

To examine how patient complexity differed by surgical specialty, specialties were first ranked from 1 (most complex) to 9 (least complex) by each individual domain of complexity. This was accomplished by first determining the proportion or mean for each domain (depending on whether a categorical or continuous measure) according to specialty. We then ranked the specialties from the greatest proportion or mean to the least. Points were assigned to each rank where the greatest ranked specialty received 9 points and the least ranked specialty received 1 point. This was performed for each domain of complexity. Points were then summed to create an overall complexity score, translating to an overall complexity rank. To examine how overall patient complexity for each specialty compared with general surgery, a ratio was created using the overall complexity score of general surgery as the referent.

Preoperative	Intraoperative	Postoperative
▪ ASA class ≥ 4	▪ Concurrent procedure	▪ Non-home discharge
▪ Major comorbidities	▪ Additional procedure	▪ Readmission
▪ Emergent operation	▪ Length of hospital stay	▪ Major complication
		▪ Mortality

Fig 1. Domains of complexity. Currently there are no accepted measures of patient complexity, and therefore, a broad spectrum of surgical care including preoperative, intraoperative, and postoperative measures were examined.

Work RVUs

The primary wRVU was defined as collected in NSQIP, encompassing only the index operation. Surgical specialties then were ranked by median wRVUs. The correlation between median wRVU and patient complexity was assessed using Spearman's rank correlation test. To examine how overall patient complexity correlated with wRVU, an observed-to-expected ratio for wRVU was created using the overall complexity score for the most complex surgical specialty. A ratio was created comparing each individual specialty with the most complex specialty. This was then multiplied by the median wRVUs for the most complex specialty to create an adjusted wRVU. The adjusted wRVU was then used to create the observed-to-expected ratio, using the median wRVU for each specialty.

Statistical analysis

All statistical analyses were performed using STATA v 15.0 (StataCorp LLC, College Station, TX, USA). Patients first were stratified by their primary operating specialty. Summary statistics were reported using median and interquartile range (IQR) for continuous variables and frequency and percentage for categorical variables. Differences between specialties were calculated using a X^2 test for categorical variables and a Kruskal-Wallis test for continuous variables. Statistical significance was set at 2-sided $P < .05$. A 95% confidence interval (CI) was calculated for each estimated proportion. For each categorical domain of complexity, an unadjusted odds ratio was calculated using general surgery as the referent. A Spearman's rank correlation was used to examine the correlation between primary wRVU and overall complexity score.

Results

Baseline characteristics

Overall, 936,496 patients were identified. The cohort included 52.7% females, with 79.2% of the white race, and a median age of 59 years (IQR: 46–70) (Table I). After stratification by surgical specialty, vascular surgery patients had the greatest median age (68 years; IQR = 59–76); plastic surgery patients were most frequently female (82.6%), and cardiac surgery patients were most frequently white (83.1%) (Table I). Operative time differed across surgical specialties, with cardiac surgery having the greatest median operative time (225 minutes; IQR = 165–292), and general surgery having the least median operative time (75 minutes; IQR = 44–132).

Domains of complexity by specialty

When domains of patient complexity were considered individually, there were statistically significant differences between surgical specialties (Tables II and III). Vascular and cardiac surgery patients were consistently the most complex across a majority of the domains examined. Cardiac surgery was most complex across 4 individual domains: ASA class ≥4 (78.5% versus least ranked specialty in this category [least] 1.6%), mean length of hospital stay (9.8 days versus [least] 1.5 days), major complications (56.9% versus [least] 5.1%), and mortality (3.4% versus [least] 0.1%). When compared with general surgery patients, cardiac surgery patients had more than 65 times the odds of having an ASA class ≥4, 11 times the odds of having a major complication, and 3 times the odds of 30-day mortality. Vascular surgery patients were ranked greatest for number of major comorbidities (2.73; 95% CI = 2.72–2.74 versus [least] 0.82; 95% CI = 0.81–0.84) and readmissions (10.1%; 95% CI = 9.8–10.3% versus [least] 3.0%; 95% CI = 2.8–3.2%).

Orthopedic surgery patients required the most postoperative rehabilitation services, with the greatest proportion of patients requiring non-home discharge (17.3%; 95% CI = 17.2–17.5% versus [least] 1.5%; 95% CI = 1.3–1.6%). Plastic surgery patients had the greatest proportion of patients requiring a concurrent procedure (14.3%; 95% CI = 13.9–14.7% versus [least] 0.83%; 95% CI = 0.79–0.86%) and an additional procedure (63.6%; 95% CI = 63.0–64.1% versus [least] 22.7%; 95% CI = 22.6–22.9%). General surgery patients had the greatest proportion of patients undergoing an emergency operation (13.5%; 95% CI = 13.4–13.6% versus [least] 1.4%; 95% CI = 1.2–1.5%).

Overall complexity score and rank

The individual rankings for each domain of complexity were then summed to create an overall complexity score, which was utilized to create an overall complexity rank (Fig 2). When specialty type was ranked across all 10 complexity domains, the order from most to least complex was cardiac surgery, vascular surgery, thoracic surgery, neurologic surgery, general surgery, urologic surgery, orthopedic surgery, ENT, and plastic surgery (Table IV).

Several sensitivity analyses examining other potential domains of patient complexity were completed. A sensitivity analysis also including operative time as a domain of complexity did not alter the rank order. A sensitivity analysis ranking specialty by the 5-item modified frailty index yielded a ranking that was very similar to the "Major Comorbidities" ranking (Supplemental Table I).[16] A sensitivity analysis including patient age as a domain of complexity resulted in a single change to the overall ranking, with urology and orthopedic surgery switching ranks so that urology was ranked sixth and orthopedic surgery ranked seventh (Supplemental Table II). The lack of any substantial change in the overall ranking suggests that patient age in and of itself may not be an adequate marker of complexity and that comorbidities and ASA class are better markers of patient physiology and complexity. It was, therefore, not included as a final domain of complexity. Because of variables that are unavailable in the NSQIP, sensitivity analyses

Table I
Patient demographics and comorbidities by surgical specialty

	Cardiac	Vascular	Thoracic	Neurologic	General	Orthopedic	Urology	Plastics	ENT	*P* value*
Demographics										
Count	4,012	56,981	12,298	54,856	444,203	243,991	61,140	31,124	27,891	<.001
Age† (y)	66 (58–74)	68 (59–76)	65 (46–72)	59 (48–69)	56 (42–67)	63 (52–72)	66 (57–74)	49 (38–59)	49 (31–63)	<.001
White‡	3,334 (83.1%)	45,040 (79.0%)	10,180 (82.8%)	45,553 (83.0%)	339,172 (76.4%)	202,531 (83.0%)	50,273 (82.2%)	23,732 (76.3%)	21,495 (77.1%)	<.001
Female‡	1,186 (29.6%)	22,260 (39.1%)	5,990 (48.7%)	26,075 (47.5%)	252,229 (56.8%)	131,742 (54.0%)	11,940 (19.5%)	25,710 (82.6%)	16,492 (59.1%)	<.001
Operative time† (min)	225 (165–292)	105 (66–167)	125 (73–197)	127 (82–196)	75 (44–132)	79 (54–109)	90 (39–184)	115 (66–189)	81 (36–146)	<.001
Comorbidities‡										
Pulmonary	1,451 (36.2%)	11,114 (19.5%)	3,978 (32.4%)	4,621 (8.4%)	35,287 (7.9%)	17,905 (7.3%)	5,304 (8.7%)	1,008 (3.2%)	1,696 (6.1%)	<.001
Cardiac	3,008 (75.0%)	42,944 (75.4%)	6,405 (52.1%)	27,061 (49.3%)	180,953 (40.7%)	123,962 (50.8%)	33,722 (55.2%)	7,912 (25.4%)	8,796 (31.5%)	<.001
Renal	820 (20.4%)	14,586 (25.6%)	1,715 (14.0%)	5,462 (10.0%)	45,089 (10.2%)	30,157 (12.4%)	10,767 (17.6%)	1,421 (4.6%)	1,609 (5.8%)	<.001
Dialysis	112 (2.8%)	4,282 (7.5%)	120 (1.0%)	239 (0.4%)	6,094 (1.4%)	1,317 (0.5%)	677 (1.1%)	157 (0.5%)	106 (0.4%)	<.001
Morbid obesity	265 (6.6%)	4,203 (7.4%)	670 (5.5%)	5,349 (9.8%)	66,034 (14.9%)	27,689 (11.4%)	3,862 (6.3%)	2,255 (7.3%)	2,807 (10.1%)	<.001
Malnutrition	60 (1.5%)	2,086 (3.7%)	759 (6.2%)	923 (1.7%)	14,277 (3.2%)	4,103 (1.7%)	1,042 (1.7%)	520 (1.7%)	670 (2.4%)	<.001
Diabetes mellitus	1,284 (32.0%)	19,381 (34.0%)	2,058 (16.7%)	9,548 (17.4%)	65,628 (14.8%)	37,223 (15.3%)	11,502 (18.8%)	2,674 (8.6%)	3,077 (11.0%)	<.001
Ascites	5 (0.1%)	111 (0.2%)	23 (0.2%)	21 (0.04%)	1,976 (0.4%)	132 (0.1%)	44 (0.1%)	14 (0.04%)	6 (0.02%)	<.001
Smoking	798 (19.9%)	18,569 (32.6%)	3,369 (27.4%)	11,567 (21.1%)	74,237 (16.7%)	34,358 (14.1%)	9,791 (16.0%)	3,955 (12.7%)	4,967 (17.8%)	<.001
Steroids	123 (3.1%)	2,686 (4.7%)	671 (5.5%)	3,232 (5.9%)	18,040 (4.1%)	8,362 (3.4%)	1,648 (2.7%)	697 (2.2%)	646 (2.3%)	<.001
Bleeding disorder	405 (10.1%)	12,665 (22.2%)	442 (3.6%)	1,231 (2.2%)	14,509 (3.3%)	8,331 (3.4%)	1,557 (2.6%)	454 (1.5%)	348 (1.3%)	<.001
Anemia	997 (24.9%)	18,397 (32.3%)	2,668 (21.7%)	6,463 (11.8%)	81,771 (18.4%)	34,977 (14.3%)	8,393 (13.7%)	3,776 (12.1%)	2,117 (7.6%)	<.001
Disseminated cancer	30 (0.8%)	382 (0.7%)	1,367 (11.1%)	2,420 (4.4%)	13,177 (3.0%)	1,748 (0.7%)	1,685 (2.8%)	244 (0.8%)	475 (1.7%)	<.001
Functionally Dependent	76 (1.9%)	4,087 (7.2%)	240 (1.9%)	1,615 (2.9%)	9,269 (2.1%)	9,083 (3.7%)	1,149 (1.9%)	533 (1.7%)	248 (0.9%)	<.001

* Calculated using a χ^2 test for categorical variables and a Kruskal-Wallis test for continuous variables.
† Reported as median (interquartile range).
‡ Reported as *n* (percent).

including rankings using the Charlson or Elixhauser comorbidity indices were unable to be completed.

Work relative value units

On Spearman's rank test, there was no correlation between overall complexity score and median wRVU (Spearman's ρ=0.07; $P < .01$). Specialties then were ranked by median wRVUs (Table V). Consistent with the overall complexity ranking, cardiac surgery had the greatest median wRVUs (33; IQR: 33.1–43.3), and ENT had the least (11.2; IQR: 4.4–15.6). Although top and bottom median wRVUs were conserved, vascular surgery had the second greatest overall complexity but only ranked fifth in median wRVUs. The discrepancy between patient complexity and wRVUs also was apparent for general surgery, which ranked fifth in overall complexity but was ranked eighth in median wRVUs.

An analysis of the observed-to-expected ratio of wRVUs demonstrated that vascular and general surgery were outliers with observed-to-expected ratios of 0.64 and 0.50, respectively (Table V). Other specialties, including orthopedic surgery, plastic surgery, and ENT, were high outliers with observed-to-expected ratios of 1.15, 1.18, and 1.18, respectively.

Discussion

This study evaluated surgical patient complexity across 9 surgical specialties using 10 domains for patient complexity. The overall complexity score demonstrated that cardiac surgery had the greatest complexity across patient domains captured in NSQIP. The complexity score was conserved largely across domains, with little variation in specialty rank. Across specialties, there was wide variation in patient complexity as assessed using the current scoring system. This variation becomes concerning, because wRVUs did not correlate with overall complexity, grossly undervaluing general and vascular surgery. General surgery, on average, was undervalued by 50%, and vascular surgery was undervalued by 36%. This analysis suggests these specialties might require further adjustment of their assigned wRVUs and increased recognition regarding the incurred health care burden for these specialties.

The conceptual framework regarding patient complexity is one fraught with difficulty. Although the specific components and weight of these individual domains are debatable, this study found that various domains of complexity were largely conserved. Compensation models using RVUs have been rolled out across the country despite major criticisms about how RVUs incentivize volume over value, all of which contributes to physician burnout.[17] There have been calls for major changes to RVUs as well, because they do not incorporate time spent with challenging patients, education, and any effort that is not specifically captured in the RVU.[17,18] Incentivization through RVUs can change practice, as has been observed with the placement of inferior vena cava filters with a drastic decrease in placement after bundled payments decreased the inferior vena cava filter RVU.[19] Calls to change practice based on RVU/minute also have been made in hip arthroplasty, where redo arthroplasty had considerably decreased RVUs/minute compared with the primary procedure, and the authors[20] suggest that because this finding could encourage orthopedic surgeons to avoid complex redo procedures. This type of incentivization can be bad for patients if not monitored closely and evaluated.

Discrepancies between RUC estimated operative times and measured operative times across surgical specialties has identified that current RVU allocation may not be appropriate. Chan et al[5] assessed operative time estimates in NSQIP compared with RUC estimates and found that vascular surgery was undervalued in the amount of US$30 million in missed revenue. There was also an

Table II
Preoperative and intraoperative domains of complexity by surgical specialty

	ASA class ≥ 4			Number of major comorbidities		Emergent surgery			Concurrent procedure			Additional Procedure			Mean Length of Hospital Stay (days)	
	Proportion (95% CI)	Unadjusted OR (95% CI)*	*P* value	Mean (95% CI)	*P* value	Proportion (95% CI)	Unadjusted OR (95% CI)*	*P* value	Proportion (95% CI)	Unadjusted OR (95% CI)*	*P* value	Proportion (95% CI)	Unadjusted OR (95% CI)*	*P* value	Mean (95% CI)	P Value
Cardiac	78.5% (77.2–79.8)	65.1 (60.3–70.3)	<.001	2.35 (2.31–2.40)	<.001	9.2% (8.3–10.1)	0.65 (0.58–0.72)	<.001	1.9% (1.5–2.4)	0.37 (0.29–0.46)	<.001	60.7% (59.2–62.3)	3.20 (3.00–3.41)	<.001	9.8 (9.5–10.1)	<.001
Vascular	27.0% (26.7–27.4)	6.62 (6.47–6.77)	<.001	2.73 (2.72–2.74)	<.001	8.2% (8.0–8.4)	0.57 (0.55–0.59)	<.001	1.5% (1.4–1.6)	0.28 (0.26–0.30)	<.001	37.6% (37.2–38.0)	1.25 (1.23–1.27)	<.001	5.0 (4.9–5.1)	<.001
Thoracic	11.7% (11.2–12.3)	2.37 (2.24–2.51)	<.001	1.99 (1.97–2.02)	<.001	2.4% (2.2–2.7)	0.16 (0.14–0.18)	<.001	2.7% (2.5–3.0)	0.533 (0.48–0.60)	<.001	63.1% (62.2–64.0)	3.54 (3.41–3.67)	<.001	6.1 (5.9–6.2)	<.001
Neurologic	6.8% (6.6–7.0)	1.30 (1.25–1.35)	<.001	1.45 (1.44–1.46)	<.001	4.7% (4.5–4.9)	0.32 (0.30–0.33)	<.001	2.6% (2.4–2.7)	0.50 (0.47–0.53)	<.001	61.8% (61.4–62.3)	3.36 (3.29–3.42)	<.001	4.0 (3.9–4.1)	<.001
General	5.3% (5.2–5.4)	Referent		1.410 (1.406–1.414)	<.001	13.5% (13.4–13.6)	Referent		5.0% (4.9–5.1)	Referent		32.6% (32.4–32.7)	Referent		3.29 (3.27–3.31)	<.001
Orthopedic	4.0% (3.9–4.1)	0.75 (0.73–0.76)	<.001	1.391 (1.386–1.396)	<.001	4.8% (4.7–4.9)	0.323 (0.316–0.329)	<.001	0.83% (0.79–0.86)	0.16 (0.15–0.17)	<.001	22.7% (22.6–22.9)	0.61 (0.60–0.62)	<.001	2.44 (2.42–2.45)	<.001
Urology	4.4% (4.2–4.5)	0.81 (0.78–0.85)	<.001	1.49 (1.48–1.50)	<.001	1.8% (1.6–1.9)	0.114 (0.107–0.121)	<.001	2.6% (2.5–2.8)	0.51 (0.49–0.54)	<.001	30.7% (30.4–31.1)	0.92 (0.90–0.94)	<.001	2.21 (2.18–2.24)	<.001
Plastics	1.6% (1.4–1.7)	0.29 (0.26–0.31)	<.001	0.82 (0.81–0.84)	<.001	1.4% (1.2–1.5)	0.09 (0.08–0.10)	<.001	14.3% (13.9–14.7)	3.17 (3.06–3.28)	<.001	63.6% (63.0–64.1)	3.61 (3.53–3.70)	<.001	1.54 (1.48–1.59)	<.001
ENT	2.4% (2.2–2.6)	0.44 (0.40–0.47)	<.001	0.99 (0.97–1.00)	<.001	1.4% (1.3–1.6)	0.09 (0.08–0.10)	<.001	3.4% (3.1–3.6)	0.66 (0.62–0.70)	<.001	30.6% (30.1–31.2)	0.91 (0.89–0.94)	<.001	1.50 (1.46–1.55)	<.001

ASA, American Society of Anesthesiology; *CI*, confidence interval; *OR*, odds ratio.
* Reported with general surgery as referent.

Table III
Postoperative domains of complexity by surgical specialty

	Non-home discharge			30-day major complication			30-day readmission			30-day mortality		
	Proportion (95% CI)	Unadjusted OR (95% CI)*	*P* value	Proportion (95% CI)	Unadjusted OR (95% CI)*	*P* value	Proportion (95% CI)	Unadjusted OR (95% CI)*	*P* value	Proportion (95% CI)	Unadjusted OR (95% CI)*	*P* value
Cardiac	14.8% (13.7–15.9)	3.86 (3.53–4.22)	<.001	56.9% (55.3–58.4)	11.2 (10.5–12.0)	<.001	8.7% (7.8–9.6)	1.61 (1.44–1.80)	<.001	3.4% (2.9–4.0)	3.10 (2.61–3.69)	<.001
Vascular	15.7% (15.4–16.0)	4.15 (4.04–4.26)	<.001	21.8% (21.5–22.2)	2.38 (2.33–2.43)	<.001	10.1% (9.8–10.3)	1.89 (1.83–1.95)	<.001	2.6% (2.5–2.8)	2.38 (2.25–2.53)	<.001
Thoracic	6.6% (6.1–7.0)	1.56 (1.45–1.68)	<.001	17.4% (16.7–18.0)	1.79 (1.71–1.88)	<.001	7.7% (7.2–8.1%)	1.40 (1.31–1.50)	<.001	2.0% (1.7–2.2)	1.76 (1.54–2.00)	<.001
Neurologic	15.2% (14.9–15.5)	3.99 (3.88–4.10)	<.001	10.9% (10.6–11.2)	1.04 (1.01–1.07)	.005	5.8% (5.6–6.0)	1.04 (1.00–1.08)	.047	1.2% (1.1–1.3)	1.05 (0.96–1.14)	0.268
General	4.3% (4.2–4.4)	Referent		10.5% (10.4–10.6)	Referent		5.6% (5.5–5.7)	Referent		1.12% (1.09–1.15)	Referent	
Orthopedic	17.3% (17.2–17.5)	4.68 (4.59–4.76)	<.001	8.3% (8.2–8.4)	0.77 (0.75–0.78)	<.001	3.47% (3.40–3.54)	0.61 (0.59–0.62)	<.001	0.71% (0.67–0.74)	0.63 (0.59–0.66)	<.001
Urology	2.4% (2.3–2.5)	0.54 (0.51–0.57)	<.001	9.2% (9.0–9.5)	0.86 (0.84–0.89)	<.001	6.1% (5.9–6.3)	1.10 (1.06–1.14)	<.001	0.47% (0.42–0.53)	0.42 (0.37–0.47)	<.001
Plastics	2.1% (2.0–2.3)	0.49 (0.45–0.53)	<.001	6.0% (5.8–6.3%)	0.55 (0.52–0.57)	<.001	3.2% (3.0–3.4)	0.56 (0.52–0.60)	<.001	0.11% (0.08–0.016)	0.10 (0.07–0.14)	<.001
ENT	1.5% (1.3–1.6)	0.33 (0.30–0.37)	<.001	5.1% (4.9–5.4)	0.46 (0.44–0.49)	<.001	3.0% (2.8–3.2)	0.52 (0.49–0.56)	<.001	0.20% (0.15–0.26)	0.18 (0.14–0.23)	<.001

CI, confidence interval; *OR*, odds ratio.
* Reported with general surgery as referent.

Overall Ranking	
1.	Cardiac
2.	Vascular
3.	Thoracic
4.	Neurologic
5.	General
6.	Urology
7.	Orthopedic
8.	ENT
9.	Plastics

	Preoperative			Intraoperative			Postoperative			
	ASA class ≥ 4	Major Comorbidities	Emergent Operation	Concurrent Procedure	Additional Procedure	Length of Hospital Stay	Non-Home Discharge	Readmission	Major Complication	Mortality
1.	Cardiac	Vascular	General	Plastics	Plastics	Cardiac	Orthopedic	Vascular	Cardiac	Cardiac
2.	Vascular	Cardiac	Cardiac	General	Thoracic	Thoracic	Vascular	Cardiac	Vascular	Vascular
3.	Thoracic	Thoracic	Vascular	ENT	Neurologic	Vascular	Neurologic	Thoracic	Thoracic	Thoracic
4.	Neurologic	Urology	Orthopedic	Thoracic	Cardiac	Neurologic	Cardiac	Urology	Neurologic	Neurologic
5.	General	Neurologic	Neurologic	Urology	Vascular	General	Thoracic	Neurologic	General	General
6.	Urology	General	Thoracic	Neurologic	General	Orthopedic	General	General	Urology	Orthopedic
7.	Orthopedic	Orthopedic	Urology	Cardiac	Urology	Urology	Urology	Orthopedic	Orthopedic	Urology
8.	ENT	ENT	ENT	Vascular	ENT	Plastics	Plastics	Plastics	Plastics	ENT
9.	Plastics	Plastics	Plastics	Orthopedic	Orthopedic	ENT	ENT	ENT	ENT	Plastics

Fig 2. Rankings by each domain of complexity and overall ranking. The individual rankings for each domain of complexity were summed to create an overall complexity score, which was utilized to create an overall rank.

underestimate of time required in cardiac surgery, equating to US$130 million of missed revenue. In contrast to the current study, there was no apparent discrepancy for general surgery, which might in part be attributable to the large variation in types of procedures being performed under the umbrella of general surgery and associated variation in operative times. Given the breadth of general surgery, future studies should further examine how patient complexity varies within general surgery or across operations commonly performed by general surgeons and how these correlate with wRVUs. Regardless, it is still concerning that such a broad and varied specialty is so undervalued.

We expected cardiac and vascular surgery most likely to be in the top 2 ranking positions for the majority of complexity domains, including ASA class. ASA classification has been reported to be an important predictor of morbidity and mortality and is a measure of a patient's overall fitness for surgery.[13] In the current study, cardiac and vascular surgery had the greatest proportion of patients with ASA class 4 or greater, which includes patients with severe systemic disease that is a constant threat to life and moribund patients who are not expected to survive without the operation. A total of 79% of cardiac surgery patients had an ASA class 4 or greater, which is 3 times greater than the next greatest group (vascular surgery). This is not surprising, because ASA 4 or greater includes patients with coronary artery disease/stents, ongoing cardiac ischemia, severe valve dysfunction, and a severe decrease in ejection fraction, which are all common indications for cardiac surgery. Vascular surgery had the greatest mean number of comorbidities as grouped by major organ systems, which may be explained by the fact that atherosclerosis is a fundamentally systemic process and is also a common indication for vascular surgery. The number of comorbidities has been associated with poor surgical outcomes, and the top 3 complex specialties by number of comorbidities were the top 3 ranked groups for major complications, readmissions, and mortality.[21]

Although cardiac surgery was the most complex, it appears that cardiac surgeons may be recognized for these efforts, as evidenced by being ranked greatest for median wRVUs. In contrast, general and vascular surgery were largely undervalued by adjusted wRVU and received 50% and 36% fewer RVUs, respectively, than would be expected based on the patient complexity score. This finding is troubling, given that vascular surgery has been found to be undervalued based on operative time (1.5%, equating to US$30 million less in payments) and also represented the oldest patient population in the current study.[5] Vascular surgeons have been reported to spend the most time working on patient-related activities compared with any other medical or surgical specialty.[22] This observation has important implications for the future workforce, because there is already a reported shortage of general and vascular surgeons.[23,24] The relatively low reimbursements despite high work load, complex patients, and time required to care for these patients may impede future recruitment efforts and further exacerbate shortages in general and vascular surgery. Addressing this discrepancy will be important to ensure appropriate vascular surgery coverage going forward and may be an opportunity to improve health care efficiency by devoting more resources to improving care for vascular surgery patients.

General surgery had the greatest proportion of cases that were emergency and a younger patient population, likely reflecting the inclusion of acute care surgery services within general surgery. Although there is a high degree of variation within general surgery,

Table IV
Surgical specialties ranked by overall complexity score

	Overall complexity score *	Ratio of complexity score †
1. Cardiac	75	1.42
2. Vascular	71	1.34
3. Thoracic	66	1.25
4. Neurologic	57	1.08
5. General	53	1.00 (Referent)
6. Orthopedic	40	0.70
7. Urology	37	0.75
8. Plastics	30	0.57
9. ENT	21	0.40

* Specialties were ranked by individual complexity domains and the markers summed to create the overall complexity score.
† Created using the overall complexity score of general surgery as the referent.

Table V
Surgical specialties ranked by work relative value units (wRVU)

	Median wRVU (IQR)	Observed/expected ratio of wRVU*
1. Cardiac	33.8 (33.1–43.3)	1.00 (Referent)
2. Thoracic	23.5 (14.5–25.8)	0.79
2. Neurological	23.5 (15.4–27.5)	0.91
4. Orthopedic	20.7 (12.4–20.7)	1.15
5. Vascular	20.5 (10.2–22.5)	0.64
6. Plastics	15.9 (10.4–17.1)	1.18
7. Urology	15.3 (8.0–26.8)	0.92
8. General	11.9 (9.5–20.8)	0.50
9. ENT	11.2 (4.4–15.6)	1.18

IQR, interquartile range; *wRVU*, work relative value units.
* Calculated utilizing the overall complexity score and median wRVU of cardiac surgery.

it remained the most undervalued specialty, because adjusted wRVUs appeared to be half of what they would otherwise be expected based on patient complexity. Study of emergency biliary, hernia, and colorectal operations (likely reflective of acute care surgery) has demonstrated that wRVUs for emergency procedures, although fraught with greater operative times, lengths of stay, and postoperative complications, were not substantially different than their elective case counterparts.[25] This finding suggests that acute care surgeons may not be adequately recognized for their work in challenging clinical scenarios. Poor reimbursement of acute care surgery may disincentivize trainees from becoming acute care surgeons or taking emergency general surgery call, which potentially may contribute to the shortage of acute care surgeons and may worsen access to emergency general surgery in low-education, underserved, and rural communities.[26] This lack of recognition around emergency cases likely explains some of the discrepancies observed in the current study between wRVU and overall complexity score. The discrepancy in wRVU and complexity, however, may be partially offset through shorter operative times. An analysis of 11 common general surgery procedures, ranging from a simple mastectomy to a total thyroidectomy and the Whipple procedure, demonstrated a poor correlation between wRVU and adverse events but a moderate correlation with median operative time ($R^2 = 0.76$).[27] Earlier data, however, still suggest that Medicare reimbursement for common general surgery procedures has decreased steadily since the year 2000.[28] Although likely multifactorial, these results suggest that the discount in wRVU observed in the current study may be partially counterbalanced by decreased overall operative time compared with other specialties, because general surgery had the least operative time of any specialty.

Orthopedic, plastic, and ENT surgery all were overvalued by wRVU when compared with overall complexity score. Plastic surgery may even be erroneously overestimated in terms of patient complexity by inclusion of concurrent and additional procedures in the metrics for patient complexity. If concurrent and additional procedures were removed from the score, plastic surgery would have the least overall complexity score. When RUC estimates were compared with NSQIP benchmarks, plastic surgery was undervalued by 1.8%, and orthopedic surgery had the greatest discrepancy, receiving an additional US$160 million.[5] This overpayment alone represents 1.7% of total Medicare Part B payments, which is consistent with the current study, which overvalued orthopedic surgery wRVUs by 15%. Technical skill is included as a component of wRVU, and some have argued that these specialties are highly technical, which may make up for differences in patient complexity not captured in this analysis. But capturing relative technical skill is difficult and subjective, especially because time spent training is essentially conserved across surgical subspecialties. These results collectively provide further evidence that redistribution of health care resources may be necessary to ensure that certain specialties are not overly favored, which may result in disparities within the workforce followed by inadequate or absent care.

This study has some limitations. Although comorbidity indices have quantitated a patient's risk of morbidity and mortality, there are no validated measures of surgical patient complexity that better reflect the work, energy, and cost that goes into taking care of patients. Clinical experience was utilized to select preoperative, intraoperative, and postoperative variables that would correlate with the level of surgical care required and overall perioperative resource utilization. Our proposed scoring system admittedly has limitations, including the absence of socioeconomic status, frailty, and complex care coordination, none of which were measured in this study but which can increase health care burden. In addition, the NSQIP does not collect data indicating whether an operation is an index or re-do procedure, which may represent additional complexity. Although attempts were made to examine a broad spectrum of surgical care, it is possible that patient complexity was not captured adequately. In addition, the current measures of patient complexity are not independent of each other. Furthermore, all of the measures of complexity are weighted equally, which may not emphasize particularly impactful domains, such as mortality or major complications. Because surgical specialties were examined as defined in NSQIP, general surgery represents a broad field with a high degree of variation and cases. Future studies should further examine how patient complexity varies across general surgery subspecialties and operations within general surgery. Finally, it is important to note that these analyses do not reflect the technical complexity, or the training required to complete the operations.

In conclusion, there were substantial differences between patient complexity across surgical specialties which did not correlate with wRVUs. These results provide evidence that general and vascular surgery may be undervalued based on relative complexity and median wRVU. Efforts should be made to ensure that wRVU determinations are evidence based to align health care resources better with measures of productivity. Future study should continue to evaluate domains of patient complexity and whether hospital reimbursement follows similar trends of physician reimbursement as assessed by wRVU.

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Conflict of interest/Disclosure

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Supplementary materials

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