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ACS-NSQIP risk calculator predicts cohort but not individual risk of complication following colorectal resection

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ABSTRACT

Objective: Compare the ACS-NSQIP risk calculator with institutional risk for colorectal surgery.
Methods: Actual and predicted outcomes were compared for both cohort and individuals.
Results: For the cohort, the risk calculator was accurate for 7/8 outcomes; there were more serious complications than predicted (19.4 vs 14.7%, $p < 0.05$). Risk calculator Brier scores and null Brier scores were comparable.
Patients: with better outcomes than predicted were current smokers (OR 4.3 95% CI 1.2–15.4), ASA ≥ 3 (OR 10.4, 95% CI 2.8–39.2), underwent total/subtotal colectomy (OR 3.5, 95% CI 1.1–12.2) or operated by Surgeon 2 (OR 2.9, 95% CI 1.4–11.6). Patients with serious complications who had low predicted risk had low ASA (OR 10.5, 95% CI 1.3–82.6), and underwent operation by Surgeon 2 (OR 11.8, 95% CI 2.5, 55.2).
Limitations: Single center study, sample size may bias subgroup analyses.
Conclusions: The ACS NSQIP calculator did not predict outcome better than sample risk.

Introduction

Complications are common in colorectal surgery, experienced by up to 40% of patients at substantial cost.[1,2] Surgeon intuition does not predict postoperative morbidity,[3] so there is a clear role for clinical calculators. Accurately predicting which patients are at risk for complication is essential both patients and providers as observed versus expected performance will be increasingly used for payment.[4,5] Risk calculators have been shown to improve predictions compared to provider intuition alone.[6–10] Risk calculators have the potential to inform shared-decision making between patients and clinicians by facilitating communication about risk.[11] They can also be used for global benchmarking of surgical quality.[12] Despite these benefits, implementation has been limited due to unwieldiness.[6]

The ACS-NSQIP calculator is a unique tool built using aggregate data from 2.7 million operations to create a "universal" calculator that purports to address some of the logistical shortcomings of older calculators as it is available free online and uses variables that are commonly present in administrative databases.[13] It predicts risk of 15 major outcomes within the thirty days following surgery. In initial validation studies, the ACS-NSQIP calculator outperformed procedure-specific calculators and had a low Brier Score[14,15] (where Brier scores compare a continuous prediction with a binary outcome, so 0 is a perfect model and 1 is a model that is always wrong.) Two small single institution studies of colorectal procedures found that the ACS-NSQIP calculator accurately predicted most adverse outcomes, though each found areas where it fell short.[16,17] Critiques of the risk calculator have included that it underestimates risk for ulcerative colitis patients and following proctectomy,[17,18] and variables that may be important in assessing risk such as preoperative laboratory evaluation are not included.[19] Although imperfect, the ACS-NSQIP calculator has been found to compare favorably to other similar tools[20] which has motivated investigators to propose modifications to improve it.[21]

Our primary goal was to assess the predictive capability of the risk calculator for patients undergoing colorectal resection on both a population level using observed to expected calculations and on an individual using a comparative Brier score. Our hypothesis was

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that the ACS-NSQIP calculator would perform better than simply assigning each patient the overall sample risk of the population. Our secondary goal was to analyze the subsets of patients for whom the calculator performs best and worst in order to generate hypotheses as to which patients has best predictive capability. Investigations into when the ACS-NSQIP calculator has utility and conversely where it falls short will assist in the application of this tool into situations in which it has clinical merit.

Methods

Patients who were admitted to the Division of Colorectal Surgery at this institution following colorectal resection between October 2015 and September 2016 were identified from a prospectively maintained institutional review board-approved outcomes database, Columbia Colorectal Surgical Outcomes Database (CCSOD). Complication data is entered into CCSOD 30 days postoperatively and charts were reanalysed for missed complication at time of enrolment into this study. Analysis was limited to patients who underwent elective or emergent partial or total resection of the colon and/or rectum by one of four surgeons active in the division during the study period. Patients who underwent procedures without resection such as rectopexy were excluded. CCSOD case entry and variable definition is modelled on the ACS-NSQIP definitions, with exceptions noted below. Risk factors available in both databases and specific to the CCSOD (such as surgeon) were both considered.

Patient data were entered into the online ACS-NSQIP calculator by trained personnel blinded to patient outcome. The database contains all of the variables required for the ACS-NSQIP calculator with concordant definitions for all variables except two: diabetes (binary in the database and "no, oral antihyperglycemics, insulin dependent" in the calculator) and smoking status ("current, former, and never in the database" and binary "smoking in the past 1 year" in the calculator). Therefore, for diabetics and former smokers direct chart review was completed to determine their correct ACS-NSQIP calculator classification. The calculator risk scores for eight outcomes (serious complication, any complication, surgical site infection, venous thromboembolism, readmission, reoperation, length of stay and death) were recorded for each patient. Actual outcomes as recorded in the database were merged to match the ACS-NSQIP format (i.e. pulmonary embolism, deep vein thrombosis and mesenteric vein thrombosis were merged together under "venous thromboembolism"). Predicted outcomes were compared to the actual outcomes recorded in the institutional database. Length of stay was excluded from the Brier score analysis as it is not a binary outcome. For each of the seven binary outcomes considered, the Brier score was calculated, where a Brier score of 0 represents perfect prediction. A second "null" Brier score was calculated using the population risk as the "prediction" and this null Brier score was compared to calculator Brier score using the methodology described by Redelmeier.[22] Receiver operating characteristic (ROC) curves were generated for serious and any complications, and the area under the ROC was used as an adjunctive measure of the predictive strength of the calculator. Subgroup analysis was performed in the groups with most divergent predictions and results i.e. the 20% of patients with serious complication who had the lowest predicted risk of serious complication, and the 10% of patients with no serious complication who had the highest predicted risk of serious complication.

Results are displayed as mean ± SD for parametric data and as median (interquartile range [IQR]) for nonparametric data. Mann-Whitney, Student's t-test, Fisher exact test, ANOVA and chi-square tests were used to assess the significance of differences between groups as appropriate. A P value less than 0.05 was considered statistically significant. All analyses were conducted using SPSS. This study was approved by the Columbia University Medical Center Institutional Review Board.

Results

Of 288 colorectal resections, 78% were laparoscopic and cancer was the most common indication for surgery (52.4%) (Table 1). The four surgeons represented in the sample differed with respect to

Table 1
Patient characteristics.

Patient Demographics N = 288	N(%) or median (IQR)
Age (years)	60 (50–69.8)
Sex (male)	149 (51.7)
Race	24 (8.3)
Black	159 (55.2)
White	6 (2.0)
Asian/Pacific Islander	99 (34.4)
Other/Missing	
Hispanic	57 (19.8)
BMI	11 (3.8)
Underweight	111 (38.5)
Normal weight	91 (31.6)
Overweight	65 (22.6)
Obese	
ASA	4 (1.4)
1	144 (50.0)
2	119 (41.3)
3	14 (4.5)
4	
Diagnosis	151 (52.4)
Cancer	33 (11.5)
IBD	4 (1.4)
Pelvic floor	57 (19.8)
Diverticular other	42 (14.6)
Procedure	95 (33)
Right colectomy	59 (20.5)
Left colectomy	26 (9)
Other partial colectomy	66 (22.9)
Low anterior resection	9 (3.1)
Abdominoperineal resection	13 (4.5)
Total/subtotal colectomy	20 (6.9)
J-pouch	
Surgeon 1	64 (22.2)
Surgeon 2	92 (31.9)
Surgeon 3	87 (30.2)
Surgeon 4	44 (15.3)
Current Smoker	24 (8.3)
Ever smoker	94 (32.6)
Alcohol use	34 (11.8)
Hypertension	123 (42.7)
Recent inpatient for CHF	7 (2.4)
MI in previous 6 months	9 (3.1)
History of PCI	20 (6.9)
History of cardiac surgery	12 (4.2)
COPD	18 (6.3)
Dyspnea	8 (2.8)
History of Stroke	3 (1.0)
History of TIA	6 (2.1)
Dialysis	4 (1.4)
Hypercoagulability	18 (6.3)
Diabetes	65 (22.6)
Weight loss	13 (4.5)
Chronic Steroid Use	28 (9.7)
Disseminated Cancer	13 (4.5)
History of organ transplant	11 (3.8)

BMI: body mass index; ASA: American Society of Anesthesiology class; IBD: inflammatory bowel disease; CHF: congestive heart failure; MI: myocardial infarction; PCI: history of percutaneous coronary intervention; COPD: chronic obstructive pulmonary disease; TIA: transient ischemic attack. Weight loss: weight loss >10% in previous 6 months.

operative indication, case-mix and operative approach (Table 2). The ACS-NSQIP calculator accurately predicted cohort rates for seven of the eight outcomes considered: any complication, surgical site infection, venous thromboembolism, readmission, reoperation, and death. Serious complications were under predicted (Table 3).

The Brier scores for the ACS-NSQIP calculator (0.144 serious, 0.1535 any) were not statistically significant from the null Brier score (0.1570 serious, 0.1675 any) for any of the outcomes except death (Table 3). For death, the null Brier score performed better (0.0076 vs 0.0139, p = <0.001). Moderate predictive ability of the calculator was confirmed by AUCs of 0.685 and 0.680 for serious and any complication respectively.

Patients whose outcomes were better than expected i.e. who had high predicted risk but no complications had a history of smoking (OR 4.3 95% CI 1.2–15.4), ASA ≥ 3 (OR 10.4, 95% CI 2.8–39.2), total/subtotal colectomy (OR 3.5, 95% CI 1.1–12.2) and procedures by Surgeon 2 (OR 2.9, 95% CI 1.4–11.6) on multivariable analysis controlling for elective versus emergent procedure (Table 4).

The 20% of patients with serious complications who had the lowest predicted risk were more likely to have a low ASA (OR 10.5, 95% CI 1.3–82.6), and were more likely to be operated on by Surgeon 2 (OR 11.8, 95% CI 2.5, 55.2) the same surgeon with a largely specialized referral practice who was overrepresented in the other group with mismatched prediction and outcome.

Discussion and conclusion

In this study, the ACS-NSQIP calculator predicted cohort risk of most outcomes, with the notable exception of under predicting serious complication. However, for individual patients, the ACS NSQIP calculator did not perform better than the null calculator in predicting patient risk of major complication following colorectal resection as measured by both a comparative Brier score and receiver operator curves. Most prior studies validating the calculator looked at its predictive capability on a cohort, not individual, level.[17,18] It is difficult to justify using the substantially more complicated calculator if it is not statistically superior to average population risk. Therefore, for lower risk patients we have transitioned to counseling based on departmental complication rates.

The calculator over predicted risk for patients with higher ASA, current smokers, and those undergoing total/subtotal colectomy. It is possible that the calculator may overweigh these variables, or that these variables have become less influential since the calculator derivation; e.g. current smokers smoke less now than they did ten years ago.[23] Some results may be specific to our institution e.g. it is possible that the care at a specialty center may be able to offset some of the increased risk associated with higher ASA. The calculator under predicted risk for a group of low ASA patients undergoing proctectomy as has been found previously,[18] suggesting that there may be disease or patient related factors contributing to increased risk of complication in these patients. This hypothesis is supported by research indicating that the risk factors for readmission differ between colon and rectal resection patients[24] and so a calculator giving a set number of points for a given comorbidity may not be capturing the interaction between that comorbidity and the specific operation. While surgeon could also be a factor influencing these outcomes,[25,26] our finding that the same surgeon was associated with the group of patients where the risk-calculator under predicted and over predicted risk suggests an explanation more complex than simple variation in surgeon quality.

We were surprised to find that the same provider was predominant in both the over prediction and under prediction group, which motivated provider-specific analysis. The calculator performed best for providers with case-mixes that most closely resembled the entire NSQIP sample (primarily right and sigmoid colectomies for cancer and diverticulitis), and worst for the providers whose practices were most heavily subspecialty referral-based (with a large number of IBD patients and ileoanal J-pouches) with intermediate fidelity for the providers in between. Although our sample size limited the complexity of this type of subgroup analysis, the results were both statistically significant and clinically relevant. NSQIP does not report data by provider in the aggregated participant use data files that are used for research, so alternative data sources must be used to investigate the accuracy of the calculator for different providers. If our finding is confirmed in other samples, NSQIP could consider a simple adjunctive tool that would allow providers to enter their own case-mix to generate a measure of similarity/dissimilarity to the overall NSQIP sample and thus give an indication of its likely clinical utility.

There is broad consensus that surgeon intuition alone is insufficient in assessing risk,[27] and that there is a role of high quality risk-assessment models for comparison between centers of meaningful outcomes such as risk-adjusted morbidity.[4,28] Multiple

Table 2
Demographic and casemix differences by surgeon.

N(%) or median (IQR)	Surgeon 1	Surgeon 2	Surgeon 3	Surgeon 4	P-value	NSQIP 2016
	N = 64	N = 92	N = 87	N = 44		N = 35908
Procedure					0.003	n/a
Right colectomy	26 (40.6)	29 (31.5)	27 (31.0)	13 (29.5)		
Left colectomy	10 (15.6)	17 (18.5)	23 (26.4)	9 (20.5)		
Other colectomy	2 (3.1)	6 (6.5)	10 (11.5)	7 (15.9)		
LAR	21 (32.8)	18 (19.6)	16 (18.4)	11 (25.0)		
APR	4 (6.3)	2 (2.2)	1 (1.1)	2 (4.5)		
Total/subtotal	1 (1.6)	4 (4.4)	6 (6.8)	2 (4.5)		
J-pouch	0	16 (17.4)	4 (4.6)	0		
Diagnosis					<0.001	
Cancer	36 (56)	41 (45)	49 (56.3)	25 (56.8)		14665 (40.8)
IBD	2 (3)	24 (26)	6 (6.9)	1 (2.3)		2712 (7.5)
diverticular	16 (25)	10 (11)	21 (24.1)	9 (20.5)		7914 (22.0)
other	10 (16)	17 (18.5)	11 (12.6)	9 (20.5)		10617 (29.6)
Minimally invasive	58 (91)	68 (74)	69 (79.3)	29 (65.9)	0.014	23098 (64.3)
Age	64 (51–72)	57 (42–68)	59 (51–71)	64 (58–71)	0.004	62 (52–72)
Drain placement	2 (3.1)	24 (26.4)	13 (15.1)	20 (45.5)	<0.001	n/a
Ebl >300 mL	5 (7.9)	19 (20.7)	11 (12.8)	15 (34.1)	0.003	n/a

No difference in: ASA class, comorbidities, preoperative labs, operative time, length of stay or complications. LAR: low anterior resection; APR: abdominoperineal resection; IBD: inflammatory bowel disease; EBL: estimated blood loss.

Table 3
Predicted rate, actual frequency, AUC and Brier scores by complication type.

30 day outcomes	Predicted (%)	Actual (%)	P-value[a]	AUC (95% CI)	Brier NSQIP	Brier Null	P-value[b]
Serious complication	14.7	19.4	0.05	0.685 (0.598–0.772)	0.144	0.1570	0.93
Any complication	17.4	21.8	0.1	0.680 (0.598–0.761)	0.1535	0.1675	0.99
SSI	8.5	8.1	0.8	0.568 (0.454–0.681)	0.0721	0.0719	0.92
VTE	1.5	1.4	0.9	0.992 (0.982–1.00)[c]	0.0098	0.0105	1.0
Readmission	10.3	10.5	0.9	0.516 (0.393–0.638)[c]	0.0925	0.0923	0.99
OR	4.3	6	0.08	0.635 (0.488–0.781)	0.0651	0.0659	1.0
Death	1.3	1.7	0.6	0.969 (0.932–1.00)[c]	0.0139	0.0076	<0.001

AUC: area under receiver operator characteristic curve; SSI: surgical site infection; VTE: venous thromboembolism; OR: unplanned reoperation.
[a] p-value for ACS-NSQIP prediction versus actual complication rate.
[b] p-value for comparison of NSQIP calculator and null brier scores.
[c] Statistics biased by tie between positive actual state group and negative actual state group.

Table 4
Multivariable analysis for 10% of patients with no serious complication who had the highest predicted risk of serious complication.

	OR (95% CI)	p
Current smoker	4.3 (1.2, 15.4)	0.02
ASA $\geq$ 3	10.4 (2.8, 39.2)	0.001
Total/subtotal colectomy	3.5 (1.1, 12.2)	0.047
Surgeon 2	4.0 (1.4, 11.6)	0.012
Urgent/Emergent	3.0 (0.8, 11.2)	0.11

ASA: Anesthesiologists physical status classification.

studies have demonstrated shortcomings of the ACS-NSQIP calculator in various patient populations.[16,17] However, the ACS-NSQIP calculator has been shown to outperform other models for prediction of mortality in some studies[29] and thoughtful internal analysis of the calculator argues that most of these studies are underpowered to definitively conclude the calculator is not reliable given the high number of outcomes needed to analyze prognostication, a flaw this study shares.[30–32] However, accurate risk prediction remains fraught with difficulty and quality rankings are affected by choice of risk-adjustment tools and inclusion of factors such as patient age and overall hospital case mix.[33,34] The ACS-NSQIP calculator will continue to improve over time as more data is incorporated into to the prediction model, and we anticipate that factors that were over-predictive in our study, such as smoking, will have a lower weighting in future iterations of the calculator.

The ACS NSQIP calculator predicted outcomes for the entire cohort for most outcomes, suggesting it may be used for benchmarking. For an experienced colorectal unit, the calculator may over predict risk for total/subtotal colectomy. The calculator appears to perform better for surgeons whose case-mix resembles that of the NSQIP sample. Serious complication remains difficult to predict, particularly for lower risk patients, and patient risk may be predicted as well by individual center and surgeon characteristics as by nationwide NSQIP risk.

Author contributions

Study design: all authors; Data Acquisition: Hyde, Valizadeh, Data analysis and interpretation: Hyde, Al-Mazrou, Kiran; Manuscript drafting and final approval: all authors.

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Appendix A. Supplementary data

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