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Prehabilitation for older patients with colorectal cancer: patient selection, targets and effectiveness

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Validation of the ACS NSQIP surgical risk calculator in older patients with colorectal cancer undergoing elective surgery

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ABSTRACT

Background

For clinical decision making it is important to identify patients at risk for adverse outcomes after colorectal cancer (CRC) surgery, especially in the older population. Because the American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) surgical risk calculator is potentially useful in clinical practice, we performed an external validation in a Dutch multicenter cohort of patients ≥ 70 years undergoing elective non-metastatic CRC surgery.

Methods

We compared the ACS NSQIP calculator mean predicted risk to the overall observed rate of anastomotic leakage, return to operation room, pneumonia, discharge not to home, and readmission in our cohort using a one-sample Z-test. Calibration plots and receiver operating characteristic (ROC) curves were used to determine the calculator's performance.

Results

Six hundred eighty-two patients were included. Median age was 76.2 years. The ACS NSQIP calculator accurately predicted the overall readmission rate (predicted: 8.6% vs. observed: 7.8%, $p=0.456$), overestimated the rate of discharge not to home (predicted: 11.2% vs. observed: 7.0% $p=0.005$) and underestimated the observed rate of all other outcomes. The calibration plots showed poor calibration for all outcomes. The ROC-curve showed an area under the curve (AUC) of 0.75 (95% confidence interval [CI] 0.67-0.83) for pneumonia and 0.70 (0.62-0.78) for discharge not to home. The AUC for all other outcomes was poor.

Conclusions

The ACS NSQIP surgical risk calculator had a poor individual risk prediction (calibration) for all outcomes and only a fair discriminative ability (discrimination) to predict pneumonia and discharge not to home. The calculator might be considered to identify patients at high risk of pneumonia and discharge not to home to initiate additional preoperative interventions.

INTRODUCTION

Primary treatment for patients with non-metastatic colorectal cancer (CRC) is surgical resection [1]. Surgery is a major stressor, especially for the older population. Populations of older patients are often highly heterogeneous and consist of a large proportion of patients with frailty (a clinical syndrome characterized by a decreased physiological capacity contributing to an increased risk of adverse health outcomes). The older population is at increased risk of mortality [2-4], postoperative complications [5-8] and readmissions after CRC surgery [9, 10]. As a consequence, older patients may experience a persistent functional decline up to one year after surgery that can lead to loss of independence [11, 12]. Therefore, it is important to identify patients who are at the highest risk of adverse outcomes, enabling better shared decision making and to consider additional preoperative care, like prehabilitation [13-15].

Easy-to-use models to predict outcome after surgery in the older CRC population are scarce and the majority of these prediction models have moderate to high bias or lack external validation [16]. However, the American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) surgical risk calculator (<http://riskcalculator.facs.org>) may potentially be used in daily practice [16], as this online surgical risk calculator originated from a large ACS NSQIP dataset that consisted of 1,414,006 patients (mean age 61.8 years) who received surgery (of all surgical specialties) between 2009-2012 in 393 hospitals in the United States of America (USA) [17] [18]. It predicts the risk for fifteen different surgical outcomes based on 21 variables: 20 preoperative variables and the surgical procedure. The ACS NSQIP surgical risk calculator has not been validated yet in older patients receiving elective CRC surgery.

Therefore, we externally validated the ACS NSQIP surgical risk calculator in a cohort of older patients (≥ 70 years) who underwent elective CRC surgery in the Netherlands.

METHODS

Study population and design

The study population consisted of all consecutive patients ≥ 70 years who received CRC surgery between January 2014 and December 2017 in three Dutch hospitals; Diaconessenhuis in Utrecht, Reinier de Graaf Hospital in Delft and Westfriesgasthuis in Hoorn. Patients were identified through a nationwide obligatory prospective data collection: the Dutch ColoRectal Audit (DCRA) [19]. The DCRA contains patients' demographics, tumor and treatment characteristics, and postoperative outcomes of all consecutive CRC patients who underwent surgery in the Netherlands. Each participating hospital is required to provide prospectively collected data. Patients were excluded in cases of metastatic disease, non-elective surgery

or local excision as surgical procedure. The study was approved by the institutional review boards of the participating hospitals.

ACS NSQIP variables

The ACS NSQIP surgical risk calculator consists of 21 variables. The variables age, sex, emergency case, American Society of Anesthesiologists (ASA) class, disseminated cancer, diabetes, history of severe chronic obstructive pulmonary disease (COPD), dialysis, height and weight (for body mass index [BMI] calculation), and type of surgical procedure were collected from the DCRA. The variables functional status, steroid use for chronic condition, ascites within 30 days prior to surgery, hypertension requiring medication, congestive heart failure within 30 days prior to surgery, dyspnea, current smoker within one year, and acute renal failure were collected from the medical records. We did not collect information about systemic sepsis within 48 hours prior to surgery and ventilator dependency, as these symptoms do not occur in case of elective surgery. Discharge not to home (discharge to nursing home or geriatric rehabilitation center) was collected from the medical record.

The risk factors were entered for each patient in the ACS NSQIP online Surgical Risk Calculator (<http://riskcalculator.facs.org>), by two researchers (ES and RdJ). The surgical procedures were remodeled into a Current Procedural Terminology (CPT) code used in the calculator (Appendix Table 1). In the ACS NSQIP Surgical Risk Calculator, age is a categorical variable, divided into ‘under 65 years’, ‘65-74 years’, ‘75-84 years’, and ‘85 years and older’. Our cohort consisted of patients ≥ 70 years, so patients aged 70-74 were categorized as ‘65-74 years’ in the online calculator. In the ACS NSQIP Surgical Risk Calculator functional status was classified as ‘independent’, ‘partially dependent’, and ‘totally dependent’. The definition of each category was provided, but without specific cutoff points for objective evaluation. To determine functional status in our cohort, we used the Katz Activities of Daily Living (ADL) scale [20]. We used five items to evaluate the daily activities; bathing, dressing, toileting, transferring, and feeding. When a patient needed supervision or personal assistance during the activity, one point was given. In case of a Katz-ADL score of 0, patients were categorized as ‘independent’, a Katz-ADL of 1-3, patients were categorized as ‘partially dependent’, and a Katz-ADL of 4-5, as ‘totally dependent’. We did not use the item ‘incontinence’ of the Katz-ADL scale (modified Katz-1 [21]) as ‘incontinence’ may inaccurately define patients as ‘dependent’. Incontinence has a high prevalence in the older population, and many older patients who experience incontinence are still able to take care of themselves. The modified Katz-1 is a validated tool [21-24] and had more agreement with the given definition of functional dependency of the ACS NSQIP calculator than the original Katz-ADL. When the Katz ADL was not scored and no deficits were registered in the medical record, functional status was entered in the calculator as ‘independent’. All other variables in our dataset fulfilled the provided definitions in the ACS NSQIP Surgical Risk Calculator. Information about race/ethnicity was not collected as this information was not required for the ACS NSQIP calculator. We did not use the Surgeon Adjustment of Risks. The preoperative data was not entered by the surgeon, meaning that we

were not able to determine whether the surgeon decided that the risk should be higher than the estimated risk.

Outcomes

The ACS NSQIP Surgical Risk Calculator calculates the risk for fifteen outcomes in the first 30 days after surgery: serious complication, any complication, pneumonia, cardiac complication, surgical site infection, urinary tract infection, venous thromboembolism, renal failure, colectomy ileus, colectomy anastomotic leak, readmission, return to operation room (OR), death, discharge to nursing or rehab facility, and sepsis. The following outcomes in the first 30 days after surgery were available in DCRA database: any complications, pneumonia, anastomotic leakage, readmission, return to the OR, and 30-day mortality. We were unable to validate for 30-day mortality, because of the low rate of deaths in the first 30 days after surgery in our cohort (eight events) and for 'any complications' because of the non-agreement of the definition of any complication in the DCRA and the more extensive definition of any complication in the ACS NSQIP Surgical Risk Calculator. Due to the fact that the risk for anastomotic leakage was not predicted by the ACS NSQIP calculator in case of a proctectomy (no anastomosis is created), we needed to exclude the patients undergoing a proctectomy for the validation of anastomotic leakage. To validate for discharge not to home, patients from Reinier de Graaf Hospital were excluded, because this hospital initiated a program in 2014 that enabled all patients to recover in a rehabilitation center after discharge. In addition, we excluded patients who already lived in a nursing home prior to surgery. Finally, we externally validated the ACS NSQIP online surgical risk calculator for anastomotic leakage, return to OR, pneumonia, discharge not to home, and readmission.

Statistical analysis

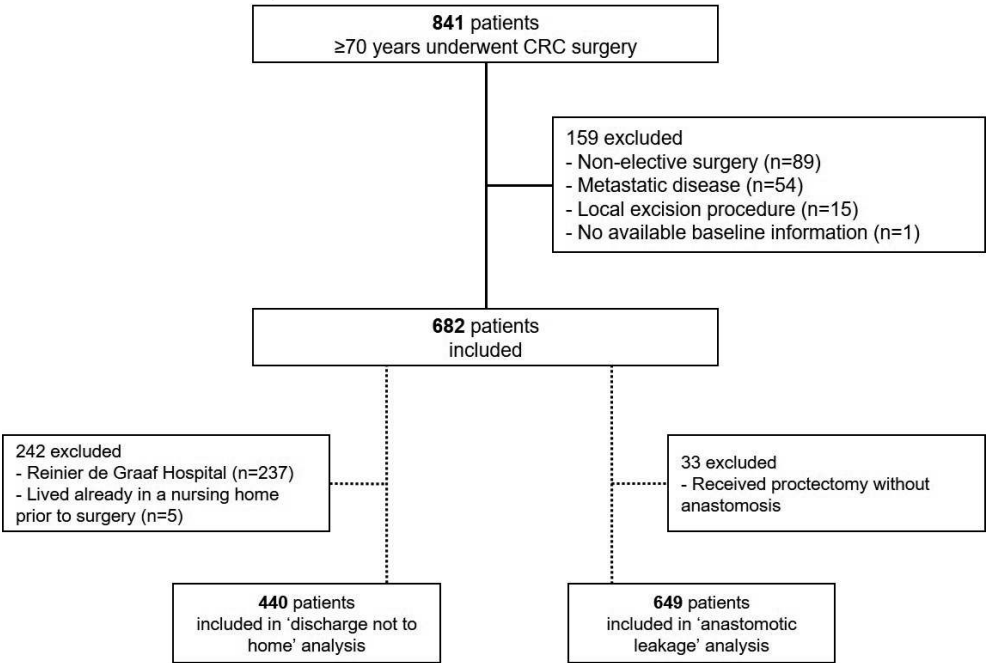
We expressed continuous baseline variables as mean (normally distributed) with standard deviation (SD) and median (non-normally distributed) with interquartile range (IQR). Categorical variables are shown as numbers with percentages. First, for each outcome, we calculated the mean predicted risk - based on the ACS NSQIP calculator - in the study cohort and compared this to the observed rate in the study cohort by using a one-sample Z-test. The mean predicted risk was used as fixed value. Second, for each outcome, we divided the study cohort in six groups based on the predicted risk, resulting in approximately 100 patients per group. The first group consisted of the lowest predicted risk sextile and the sixth group of the highest predicted risk sextile. Then, to assess calibration, we graphically plotted the observed outcome in the six predicted risk groups against the line $y=x$ that expresses the ideal relation between the predicted and observed outcome. Third, to assess discrimination, we used receiver-operator characteristics (ROC) curves and the corresponding area under the curve (AUC) per outcome. The AUC can be interpreted as: $0.5 \leq \text{AUC} < 0.7$ is poor, $0.7 \leq \text{AUC} < 0.8$ is good, $0.8 \leq \text{AUC} < 0.9$ is excellent and $\text{AUC} \geq 0.9$ is outstanding. A p-value ≤ 0.05 was considered statistically significant and we used SPSS version 25.0, Inc., Chicago, IL.

RESULTS

Study population

In total, 841 patients ≥ 70 years underwent CRC surgery between January 2014 and December 2017. We excluded 159 patients due to non-elective surgery (n=89), metastatic disease (n=54), local excision as surgical procedure (n=15) and no available baseline information (n=1). Ultimately, 682 patients were included (Figure 1). For the anastomotic leakage and discharge not to home analysis, we included 649 (33 patients excluded due to receiving a proctectomy) and 440 patients (237 patients from Reinier de Graaf Hospital and five patients who already lived in a nursing home prior to surgery were excluded), respectively.

Figure 1. Flow chart of study population



Baseline characteristics

In Table 1, the ACS NSQIP surgical risk calculator variables and additional baseline characteristics of the study cohort are described. Median age at diagnosis was 76.2 years (IQR 73.4-81.3), 386 patients were male (56.6%) and 504 (73.9%) were diagnosed with colon carcinoma. The majority of the patients (n=578, 84.8%) received laparoscopic surgery, 612 (89.7%) patients were functionally independent, and the majority (393 patients; 57.6%) had an ASA score of II. One hundred-seven (15.7%) patients used oral medication for diabetes and 310 (45.5%) used medication for hypertension.

Mean predicted outcome versus observed outcome in all patients

Table 2 shows the mean predicted and observed risk of each outcome in all patients. The ACS NSQIP surgical risk calculator accurately predicted the readmission rate in our cohort (predicted rate of 8.6% vs. observed rate of 7.8%, $p=0.456$), underestimated the observed rate of anastomotic leakage (2.0% vs. 3.7%, $p=0.002$), return to OR (3.5% vs. 8.4%, $p<0.001$) and pneumonia (1.8% vs. 4.4%, $p<0.001$), and overestimated the observed rate of discharge not to home (11.2% vs. 7.0%, $p=0.005$).

Table 1. Baseline characteristics and ACS NSQIP Surgical Risk Calculator variables of all patients

	Total n=682 (%)
Additional baseline characteristics of the study cohort	
Age (median, IQR)	76.2 (73.4-81.3)
Hospital	
Diakonessenhuis Utrecht	243 (35.6)
Reinier de Graaf Hospital Delft	237 (34.8)
Westfriesgasthuis Hoorn	202 (29.6)
Tumor localization	
Colon	504 (73.9)
Rectum	178 (26.1)
AJCC stage	
Stage 1	208 (30.5)
Stage 2	267 (39.1)
Stage 3	207 (30.4)
ACS NSQIP Surgical Risk Calculator variables ^{a b}	
Age category	
70 - 74 years	247 (36.2)
75 - 84 years	371 (54.4)
≥85 years	64 (9.4)
Gender	
Male	386 (56.6)
Female	296 (43.4)
Functional status	
Independent	612 (89.7)
Partial dependent	54 (7.9)
Totally dependent	8 (1.2)
Unknown	8 (1.2)
ASA class	
I	49 (7.2)
II	393 (57.6)
III	226 (33.1)
IV	14 (2.1)

Table 1. Baseline characteristics and ACS NSQIP Surgical Risk Calculator variables of all patients (*continued*)

	Total n=682 (%)
Diabetes	
No	555 (81.4)
Oral	107 (15.7)
Insulin	18 (2.6)
Organ failure	2 (0.3)
Hypertension requiring medication	310 (45.5)
Congestive Heart Failure in 30-day prior to surgery	25 (3.7)
Dyspnea	25 (3.7)
Current smoker	60 (8.8)
(severe) COPD in history	68 (10.0)
BMI (mean, IQR)	26.2 (23.6-28.4)
Surgical procedures	
Laparoscopic	578 (84.8)
Open	104 (15.2)

Abbreviations: *ACS NSQIP* American College of Surgeons National Surgical Quality Improvement Program, *AJCC* American Joint Committee on Cancer, *ASA* American Society of Anesthesiologists, *BMI* body mass index, *COPD* chronic obstructive pulmonary disease, *IQR* Interquartile range

^aThe variables 'urgency' and 'disseminated cancer' are omitted, as all patients (100%) had elective surgery and non-metastatic disease as a consequence of the inclusion criteria.

^bThe variables 'ascites', 'steroid use', 'dialysis' and 'acute renal failure' are left out in Table 1 (prevalence <1%)

Table 2. Mean predicted and observed risk per outcome

All patients (n=682)				
	Predicted risk in % (mean)	n of events	Observed risk in % (95% CI)	p-value
Anastomotic leakage*	2.0	24	3.7 (2.2-5.2)	0.002
Return to OR	3.5	57	8.4 (6.3-10.5)	<0.001
Pneumonia	1.8	30	4.4 (2.9-5.9)	<0.001
Readmission	8.6	53	7.8 (5.8-9.8)	0.456
Discharge not to home**	11.2	31	7.0 (4.6-9.4)	0.005

Abbreviations; *CI* confidence interval, *OR* operation room

*Patients receiving proctectomy (n=33) were excluded

**Patients from Reinier de Graaf Hospital (n=237) and patients who already lived in a nursing home prior to surgery (n=5) were excluded.

Calibration

In Figure 2 (A-E) the calibration plots per outcome are shown. The calibration plot of anastomotic leakage (A), return to OR (B), pneumonia (C), discharge not to home (D), and readmission (E) show that the observed and predicted outcomes are graphically different from the line that indicates the ideal relation between observed and predicted outcome (line $y=x$). For anastomotic leakage, return to OR and pneumonia, the ACS NSQIP surgical risk calculator underestimated the risk in our cohort. For discharge not to home, the calculator graphically overestimated the risk in the highest predicted risk group (Figure 2D). The calibration plot for readmission showed an alternating under- and overestimation of the observed readmission risk (Figure 2E).

Discrimination

In Figure 3 (A-E), the ROC-curves per outcome are shown. The AUC for anastomotic leakage (A), return to OR (B), and readmission (E) were poor, corresponding to an AUC of 0.57 (95% CI 0.47-0.67), 0.55 (95% CI 0.47-0.64), and 0.59 (95% CI 0.50-0.68), respectively. The discriminative ability of the ACS NSQIP calculator for pneumonia (C) and discharge not to home (D) were fair, with an AUC of 0.75 (95% CI 0.67-0.83) and 0.70 (95% CI 0.62-0.78), respectively.

Figure 2. Calibration plots of observed versus predicted rate of anastomotic leakage (A), return to OR (B), pneumonia (C), discharge not to home (D) and readmission (E) in %.

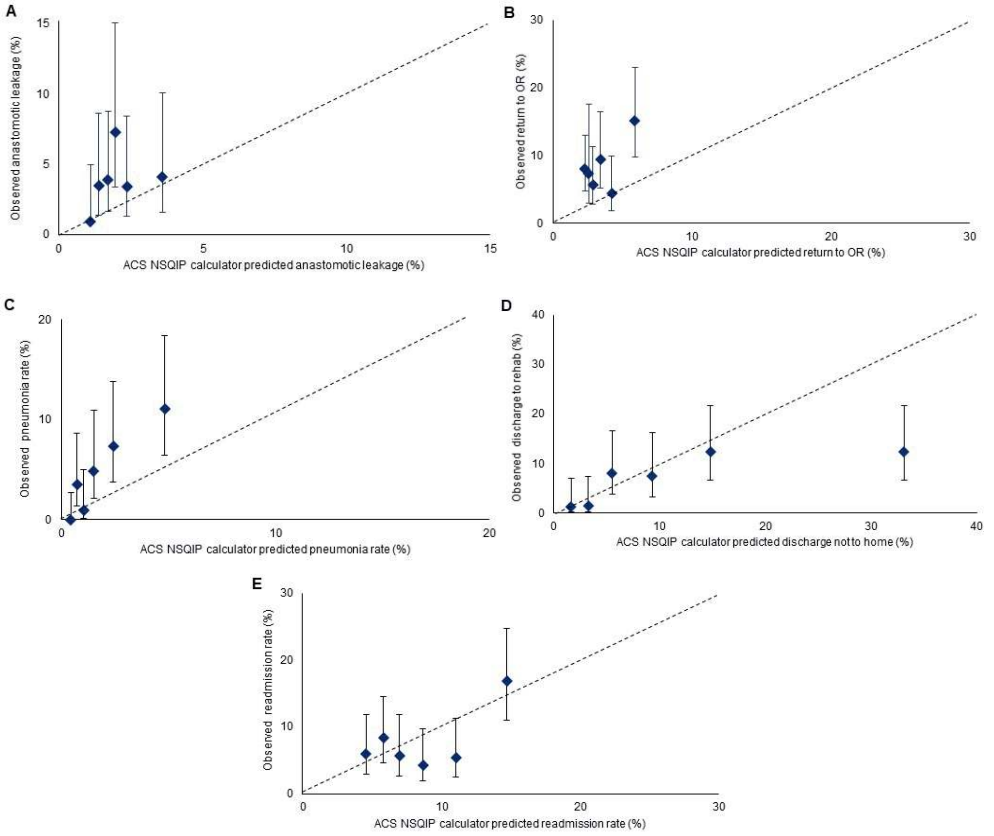
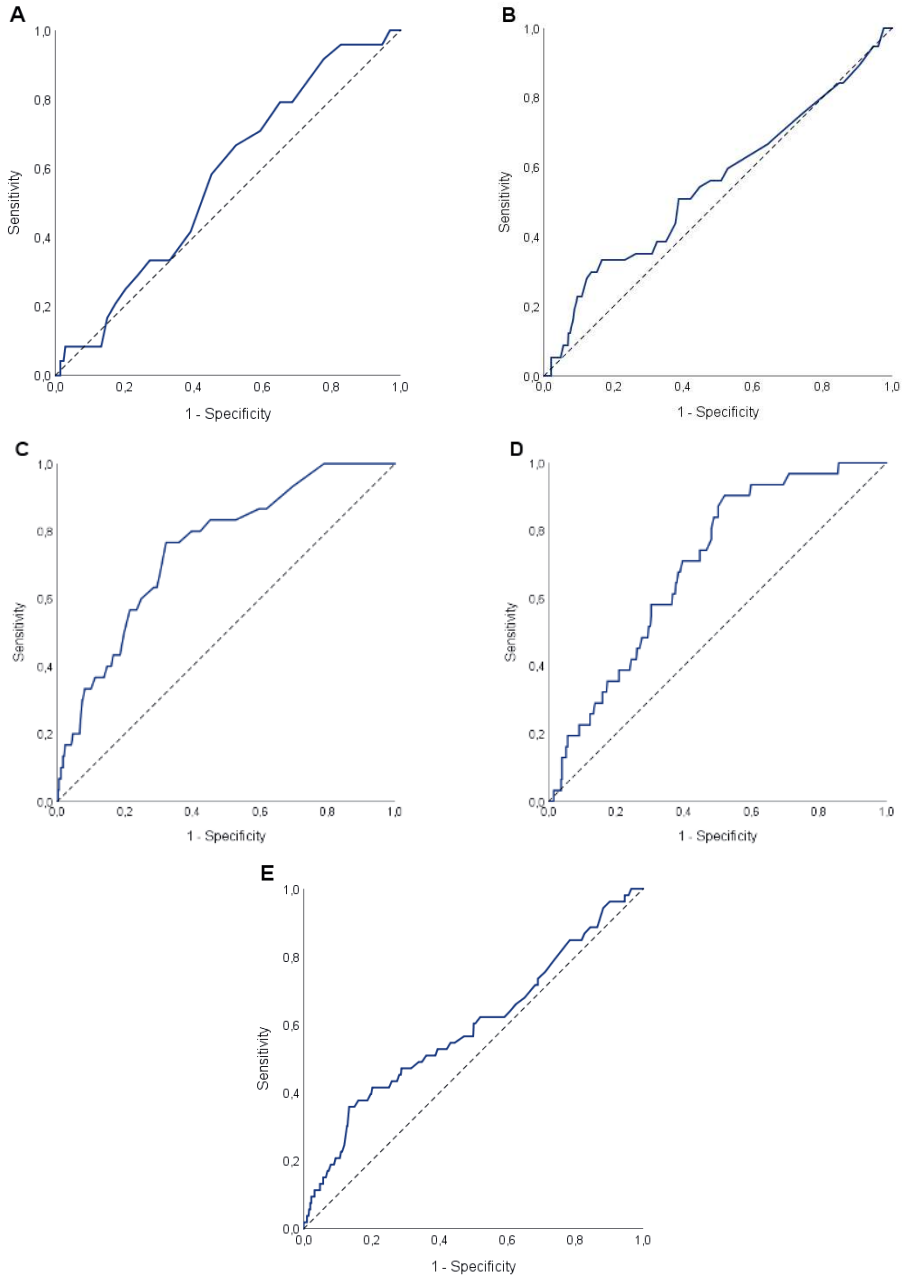


Figure 3. Receiver operating characteristic (ROC) curves of anastomotic leakage (A), return to OR (B), pneumonia (C), discharge not to home (D) and readmission (E) and the corresponding area under the curve (AUC)



A: Anastomotic leakage AUC: 0.57 (95% CI 0.47-0.67), **B: Return to OR** AUC: 0.55 (95% CI 0.47-0.6), **C: Pneumonia** AUC: 0.75 (95% CI 0.67-0.83), **D: Discharge not to home** AUC: 0.70 (95% CI 0.62-0.78), **E: Readmission** AUC: 0.59 (95% CI 0.50-0.68)

DISCUSSION

Our findings show that the ACS NSQIP surgical risk calculator has a poor calibration for all outcomes, a poor discriminative ability to predict anastomotic leakage, return to OR, and readmission, and a fair discriminative ability for pneumonia and discharge not to home in a cohort of CRC patients ≥ 70 years undergoing elective surgery in the Netherlands.

This study emphasizes that calibration and discrimination are both required to determine the validity of a prediction model (a good calibration does not guarantee a good discrimination, and vice versa) and to consider a model's use in clinical practice. A good calibration is important for informing patients about their individual prognosis after surgery (e.g., patients could be informed that 8 out of 100 patients will be readmitted after surgery) and a good discrimination separates the high- from the low-risk patients and will help the care professional to select patients for additional preoperative interventions.

The ACS NSQIP calculator has already been validated in different population cohorts. Some studies found a good overall performance [25, 26], others a poor performance [27-30]. For patients undergoing colorectal procedures, the ACS NSQIP calculator accurately predicted postoperative outcomes (e.g. postoperative complications, return to OR, or discharge to rehabilitation center) [31-34]. However, these study cohorts are not completely comparable to our study population, as we focused specifically on the older population (≥ 70 years) and colorectal cancer as indication for surgery.

The ACS NSQIP calculator particularly underestimated the observed outcome in our cohort and is therefore not useful for individual risk prediction in the older CRC population in the Netherlands. Differences in study population were the main reason for this underestimation. The mean age of patients in our cohort was higher compared to the ACS NSQIP dataset (78 vs. 62 years). Considering that frailty is more common in an older population [35], patients in our cohort had a higher a priori risk of postoperative morbidity than the patients in the ACS NSQIP dataset [4, 5, 36, 37]. As showed in Table 1, the proportion of frail patients in our cohort was low (only 9.1% of patients were partially or totally dependent and only 35.2% had an ASA score of $\geq$ III). However, the ACS NSQIP frailty predictors alone do not completely define 'frailty' [38]. Therefore, adding other frailty markers (e.g. physical performance or nutritional status [36, 37]) could improve the individual risk prediction of the ACS NSQIP surgical risk calculator in our cohort [39, 40]. From 2019 onwards, additional frailty predictors have been included in the online calculator (if age ≥ 65 years) to predict four specific geriatric outcomes (postoperative delirium, functional decline, new mobility aid use, and new/worsening pressure ulcer), but were not used to predict surgical and admission-related outcomes [16, 39, 41].

Furthermore, our study cohort consists of patients diagnosed with colon or rectal cancer, which is in contrast to the ACS NSQIP dataset that included patients with non-malignant diseases as well. Although the calculator adjusts for surgical procedure, the underlying malignant colorectal disease may have resulted in a poorer preoperative condition of our cohort (e.g. anemia, weight loss, or malnutrition [42-44]) and contributed to the underestimation of the observed outcomes.

The calculator's fair discriminative ability for pneumonia and discharge not to home indicates an additional value to tailor preoperative interventions, like prehabilitation. Pneumonia and discharge not to home are common adverse outcomes in the older CRC population. Medical complications – including pulmonary – may occur in 40.5% of the patients [6] and are associated with decreased quality of life, readmissions, and mortality [45-48]. Souwer et al. described a postoperative discharge not to home rate of 18% in 707 CRC patients ≥ 70 years in the Netherlands [40]. Prehabilitation improves pre- and postoperative functional capacity [49], which is associated with home discharge [50, 51] and reduces postoperative complications, including pulmonary complications [14, 15, 49, 52].

In addition to a model's performance, its clinical applicability is important when considering the utility of a prediction model in daily practice. Risk models that use fewer predictors showed similar performance compared to a 21-item model such as the ACS NSQIP calculator, which is time-consuming [53]. Because there is still a lack of an easy-to-use model to predict adverse postoperative outcomes, specifically for the older CRC population, future studies should develop a population-specific prediction model and need to focus on the clinical applicability as well to improve the use in daily practice.

This study had some limitations, mostly due to the retrospective design of this study. We were unable to determine the validity of the ACS NSQIP on other relevant outcomes, e.g., 'any complications', 'serious complications' and 'cardiac complications', because the definitions of these complications in the ACS NSQIP dataset did not match the definitions in the DCRA dataset or on geriatric outcomes (e.g., functional decline), as we were unable to collect these outcomes from the medical record. Furthermore, the ACS NSQIP updated the online risk calculator in December 2020. We have checked the results after the updated calculator for a random sample of patients, and differences in results before and after the update were small, which is consistent with the statement made on the calculator's website (<http://riskcalculator.facs.org>).

The major strength of this study is the validation of the ACS NSQIP surgical risk calculator in a multicenter cohort of patients ≥ 70 years undergoing elective CRC surgery with a respectable sample size and completeness of data. Also, outcome and calculator information were handled separately, reducing bias.

CONCLUSIONS

The ACS NSQIP surgical risk calculator had a poor individual risk prediction (calibration) for all outcomes and only a fair discriminative ability (discrimination) to predict pneumonia and discharge not to home in patients ≥ 70 years undergoing elective CRC surgery in the Netherlands. The calculator might be considered to identify patients at high risk of pneumonia and discharge not to home to initiate additional preoperative interventions, such as prehabilitation. For the older CRC population, an easy-to-use and population-specific prediction model is necessary.

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APPENDIX

Appendix Table 1. The Current Procedural Terminology used in the ACS NSQIP surgical risk calculator

ACS NSQIP procedures	n=682
44204 - Laparoscopic colectomy partial with anastomosis	466
44206 - Laparoscopic colectomy partial with end colostomy (Hartmann procedure)	67
44140 - Colectomy partial with anastomosis	69
44143 - (Hartmann procedure) Colectomy partial with end colostomy and closure of the distal segment	11
44144 - Colectomy partial with resection, with colostomy or ileostomy and creation of mucofistula	15
44210 - Laparoscopy, surgical; colectomy, total, abdominal, without proctectomy, with ileostomy or ileoproctostomy	19
44147 - Colectomy partial abdominal and transanal approach	1
44205 - Laparoscopy, surgical; colectomy, partial with removal of terminal ileum with ileocolostomy	1
45110 - Proctectomy; complete combined abdominoperineal with colostomy	8
45395 - Laparoscopy, surgical; proctectomy, complete, combined abdominoperineal, with colostomy	25