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Hulst, H.C.V.; Dekker, J.W.T.; Bastiaannet, E.; Bol, J.M. van der; Bos, F. van den; Hamaker, M.E.; ... ; Souwer, E.T.D.

Journal of Geriatric Oncology 13 (2022) 788–795

Contents lists available at ScienceDirect

Journal of Geriatric Oncology

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Heleen C. van der Hulst [a,*], Jan Willem T. Dekker [a], Esther Bastiaannet [b,c], Jessica M. van der Bol [d], Frederiek van den Bos [e], Marije E. Hamaker [f], Anandi Schiphorst [g], Dirk J.A. Sonneveld [h], Johan S. Schuijtemaker [i], Robin J. de Jong [b], Johanna E.A. Portielje [b], Esteban T.D. Souwer [b]

[a] Department of Surgery, Reinier de Graaf Hospital, Delft, the Netherlands
[b] Department of Medical Oncology, Leiden University Medical Center, Leiden, the Netherlands
[c] Department of Surgery, Leiden University Medical Center, Leiden, the Netherlands
[d] Department of Geriatric Medicine, Reinier de Graaf Hospital, Delft, the Netherlands
[e] Department of Geriatric Medicine, Leiden University Medical Center, Leiden, the Netherlands
[f] Department of Geriatric Medicine, Diakonessenhuis, Utrecht, the Netherlands
[g] Department of Surgery, Diakonessenhuis, Utrecht, the Netherlands
[h] Department of Surgery, Dijklander Ziekenhuis, Hoorn, the Netherlands
[i] Department of Geriatric Medicine, Dijklander Ziekenhuis, Hoorn, the Netherlands

ARTICLE INFO

Article history:
Received 8 January 2022
Received in revised form 16 March 2022
Accepted 6 April 2022
Available online 22 April 2022

Keywords:
Colorectal cancer
Surgery
Elderly
External validation
Postoperative outcome

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.

1. 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

* Corresponding author at: Department of Surgery, Reinier De Graaf Gasthuis, PO Box 5011, 2600 GA Delft, the Netherlands.
E-mail address: h.vanderhulst@rdgg.nl (H.C. van der Hulst).

https://doi.org/10.1016/j.jgo.2022.04.004
1879-4068/

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 and 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.

2. Methods

2.1. 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; Diakonessenhuis 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.

2.2. 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 h 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.

2.3. 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.

2.4. 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 ≤ AUC <0.7 is poor, 0.7 ≤ AUC <0.8 is good, 0.8 ≤ AUC <0.9 is excellent and AUC ≥0.9 is outstanding. A *p*-value ≤0.05 was considered statistically significant and we used SPSS version 25.0, Inc., Chicago, IL.

3. Results

3.1. 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 (Fig. 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.

3.2. 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.

3.3. 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%, $p = 0.005$).

3.4. Calibration

In Fig. 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 (Fig. 2D). The calibration plot for readmission showed an alternating under- and overestimation of the observed readmission risk. (Fig. 2E).

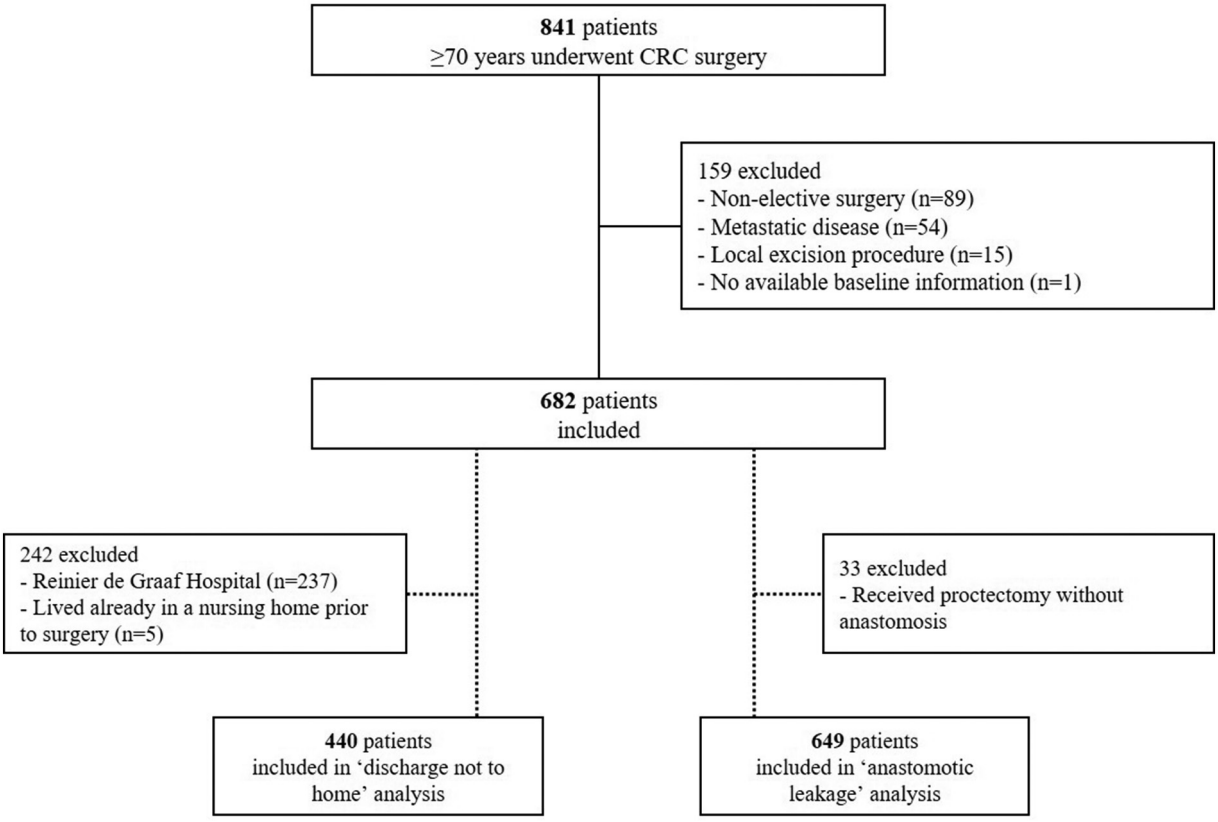

Fig. 1. Flow chart of study population.

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)
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)

3.5. Discrimination

In Fig. 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.

4. 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 ASC 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 ≥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.

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.

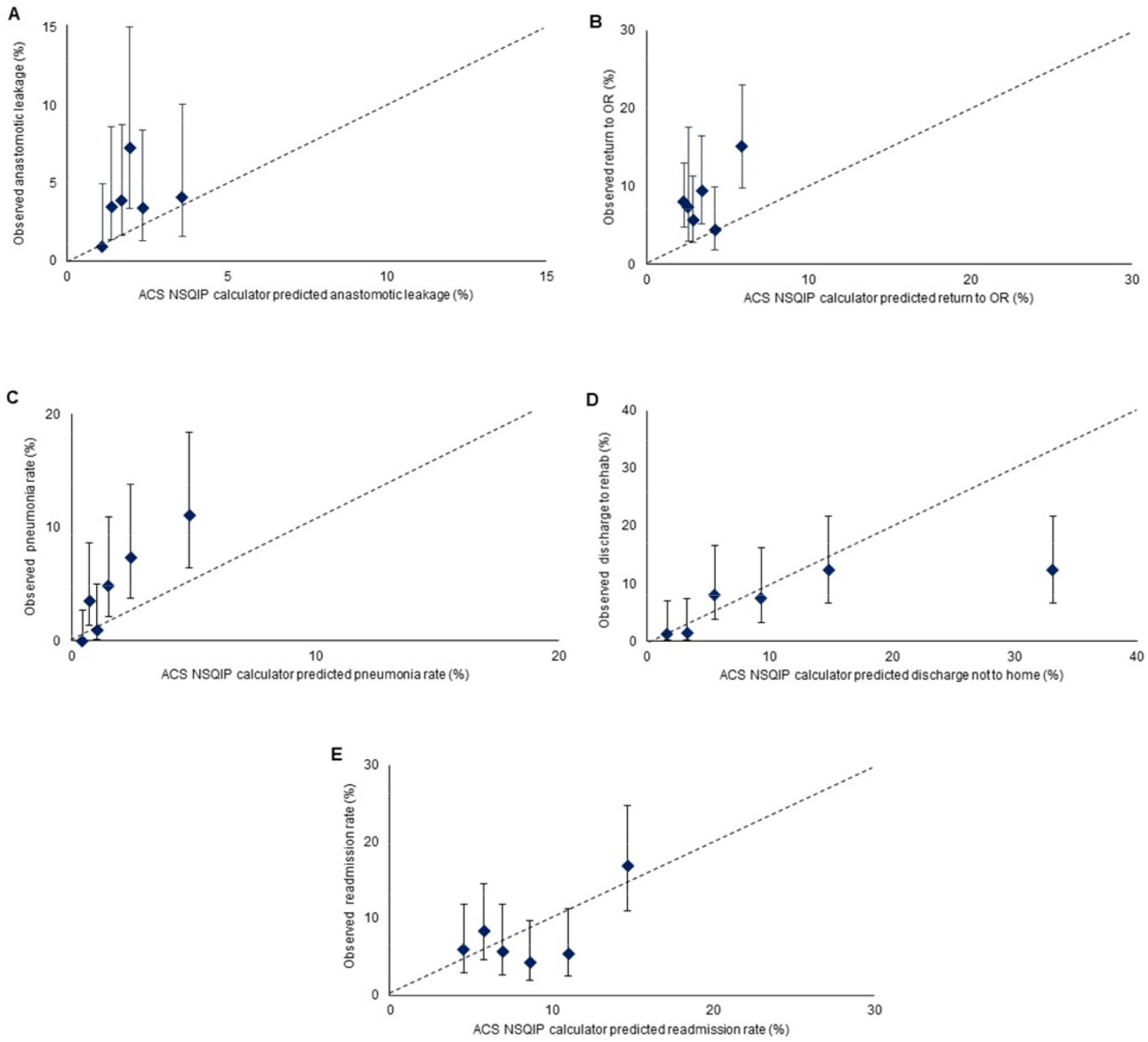

Fig. 2. Calibration plots of observed versus predicted rate of anastomotic leakage (A), return to OR (B), pneumonia (C), discharge not to home (D) and readmission (E) in %.

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.

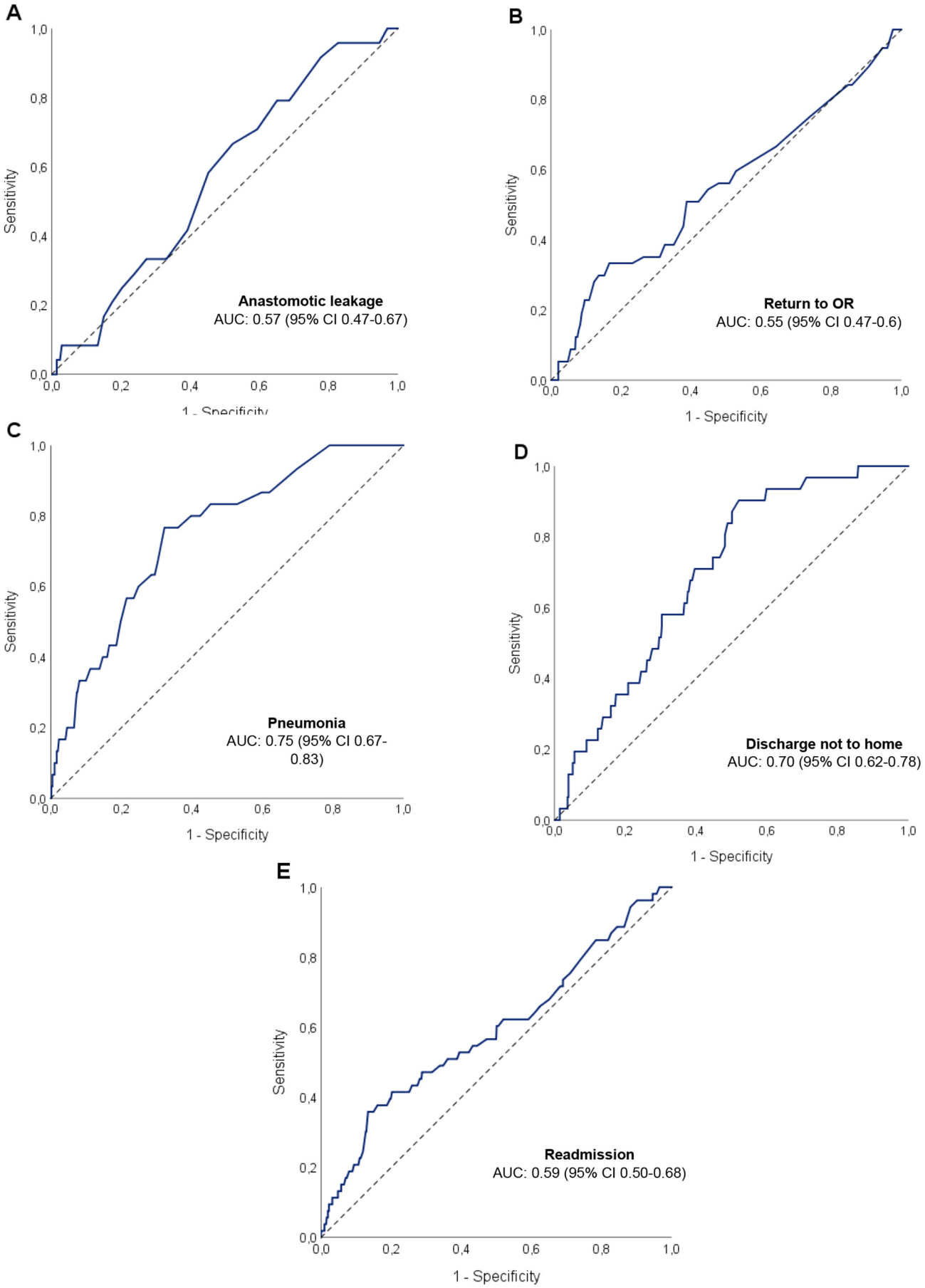

Fig. 3. Receiver operating characteristic (ROC) curves of anastomotic leakage (A), return to OR (B), pneumonia (C), discharge not to home (D) and readmission (E) and the corresponding area under the curve (AUC).

5. 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.

Author contributions

Study concepts: Heleen. C. van der Hulst, Jan Willem T. Dekker, Esther Bastiaannet, Jessica M. van der Bol, Frederiek van den Bos, Johanna E.A. Portielje, Esteban T.D. Souwer.
Study design: Heleen. C. van der Hulst, Jan Willem T. Dekker, Esther Bastiaannet,
Jessica M. van der Bol, Johanna E.A. Portielje, Esteban T.D. Souwer.
Data acquisition: Jan Willem T. Dekker, Jessica M. van der Bol, Marije E. Hamaker, Anandi Schiphorst, Dirk J.A. Sonneveld, Johan S. Schuijtemaker, Robin J de Jong, Esteban T.D. Souwer.
Quality control of data and algorithms: Heleen C. van der Hulst, Robin J de Jong, E.T.D. Souwer.
Data analysis and interpretation: Heleen C. van der Hulst, Esther Bastiaannet, Esteban T.D. Souwer.
Statistical analysis: H.C. van der Hulst, Esther Bastiaannet.
Manuscript preparation: H.C. van der Hulst.
Manuscript editing: H.C. van der Hulst, Jan Willem T. Dekker, Jessica M. van der Bol Esther Bastiaannet, Johanna E.A. Portielje, E.T.D. Souwer,
Manuscript review: Heleen. C. van der Hulst, Jan Willem T. Dekker, Esther Bastiaannet, Jessica M. van der Bol, Frederiek van den Bos, Marije E. Hamaker, Anandi Schiphorst, Dirk J.A. Sonneveld, Johan S. Schuijtemaker, Robin J de Jong, Johanna E.A. Portielje, Esteban T.D. Souwer.

Declaration of Competing Interest

None.

Acknowledgements

None.

References

[1] Landelijke werkgroep Gastro Intestinale tumoren. Landelijke richtlijn colorectaal carcinoom versie 3.0; 2014; 33–45.
[2] Dekker JW, et al. Importance of the first postoperative year in the prognosis of elderly colorectal cancer patients. Ann Surg Oncol. 2011;18(6):1533–9.
[3] Bos A, et al. Postoperative mortality in elderly patients with colorectal cancer: the impact of age, time-trends and competing risks of dying. Eur J Surg Oncol. 2019;45(9):1575–83.
[4] Ommundsen N, et al. Frailty is an independent predictor of survival in older patients with colorectal cancer. Oncologist. 2014;19(12):1268–75.
[5] Kristjansson SR, et al. Comprehensive geriatric assessment can predict complications in elderly patients after elective surgery for colorectal cancer: a prospective observational cohort study. Crit Rev Oncol Hematol. 2010;76(3):208–17.
[6] Fagard K, et al. Postoperative complications in individuals aged 70 and over undergoing elective surgery for colorectal cancer. Colorectal Dis. 2017;19(9):O329–38.
[7] Pak H, et al. Surgical complications in colorectal cancer patients. Ann Med Surg (Lond). 2020;55:13–8.
[8] Sieber FE, Barnett SR. Preventing postoperative complications in the elderly. Anesthesiol Clin. 2011;29(1):83–97.
[9] Ommundsen N, et al. Post-discharge complications in frail older patients after surgery for colorectal cancer. Eur J Surg Oncol. 2018;44(10):1542–7.
[10] Greenblatt DY, et al. Readmission after colectomy for cancer predicts one-year mortality. Ann Surg. 2010;251(4):659–69.
[11] Hamaker ME, et al. Long-term changes in physical capacity after colorectal cancer treatment. J Geriatr Oncol. 2015;6(2):153–64.
[12] Ronning B, et al. Frailty indicators and functional status in older patients after colorectal cancer surgery. J Geriatr Oncol. 2014;5(1):26–32.
[13] Bruns ER, et al. The effects of physical prehabilitation in elderly patients undergoing colorectal surgery: a systematic review. Colorectal Dis. 2016;18(8):O267–77.
[14] Barberan-Garcia A, et al. Personalised Prehabilitation in high-risk patients undergoing elective major abdominal surgery: a randomized blinded controlled trial. Ann Surg. 2018;267(1):50–6.
[15] Berkel AEM, et al. Effects of community-based exercise Prehabilitation for patients scheduled for colorectal surgery with high risk for postoperative complications: results of a randomized clinical trial. Ann Surg. 2022;275(2):299–306.
[16] American College of Surgeons. ACS NSQIP Surgical risk calculator. Available from. https://riskcalculator.facs.org/RiskCalculator/index.jsp; 2020.
[17] Cohen ME, et al. Development of an American College of Surgeons National Surgery Quality Improvement Program: morbidity and mortality risk calculator for colorectal surgery. J Am Coll Surg. 2009;208(6):1009–16.
[18] Bilimoria KY, et al. Development and evaluation of the universal ACS NSQIP surgical risk calculator: a decision aid and informed consent tool for patients and surgeons. J Am Coll Surg. 2013.;217(5) (833–42 e1–3).
[19] Van Leersum NJ, et al. The Dutch surgical colorectal audit. Eur J Surg Oncol. 2013;39(10):1063–70.
[20] Katz S, et al. Studies of illness in the aged. The index of Adl: a standardized measure of biological and psychosocial function. JAMA. 1963;185:914–9.
[21] Liebzeit D, King B, Bratzke L. Measurement of function in older adults transitioning from hospital to home: an integrative review. Geriatr Nurs. 2018;39(3):336–43.
[22] Mahoney JE, Sager MA, Jalaluddin M. Use of an ambulation assistive device predicts functional decline associated with hospitalization. J Gerontol A Biol Sci Med Sci. 1999;54(2):M83–8.
[23] Ciesla JR, et al. Reliability of Katz's activities of daily living scale when used in telephone interviews. Eval Health Prof. 1993;16(2):190–203.
[24] Sager MA, et al. Measurement of activities of daily living in hospitalized elderly: a comparison of self-report and performance-based methods. J Am Geriatr Soc. 1992;40(5):457–62.
[25] Yap MKC, et al. Validation of the American College of Surgeons risk calculator for preoperative risk stratification. Heart Asia. 2018;10(2):e010993.
[26] Long AM, et al. Evaluation of the performance of ACS NSQIP surgical risk calculator in emergency general surgery patients. Am Surg. 2020;86(2):83–9.
[27] Alzahrani SM, Ko CS, Yoo MW. Validation of the ACS NSQIP surgical risk calculator for patients with early gastric Cancer treated with laparoscopic gastrectomy. J Gastric Cancer. 2020;20(3):267–76.
[28] Shaker S, et al. The American College of Surgeon's surgical risk calculator's ability to predict disposition in older gynecologic oncology patients undergoing laparotomy. J Geriatr Oncol. 2019;10(4):618–22.
[29] Wang X, et al. Predictive validity of the ACS-NSQIP surgical risk calculator in geriatric patients undergoing lumbar surgery. Medicine (Baltimore). 2017;96(43):e8416.
[30] Donadon M, et al. Assessment of the American College of Surgeons surgical risk calculator of outcomes after hepatectomy for liver tumors: results from a cohort of 950 patients. Int J Surg. 2020;84:102–8.
[31] Lubitz AL, et al. American College of Surgeons NSQIP risk calculator accuracy for emergent and elective colorectal operations. J Am Coll Surg. 2017;225(5):601–11.
[32] Adegboyega TO, et al. Applying the National Surgical Quality Improvement Program risk calculator to patients undergoing colorectal surgery: theory vs reality. Am J Surg. 2017;213(1):30–5.
[33] Cologne KG, et al. Use of the American College of Surgeons NSQIP surgical risk calculator for laparoscopic colectomy: how good is it and how can we improve it? J Am Coll Surg. 2015;220(3):281–6.
[34] Hyde LZ, et al. ACS-NSQIP risk calculator predicts cohort but not individual risk of complication following colorectal resection. Am J Surg. 2019;218(1):131–5.
[35] Handforth C, et al. The prevalence and outcomes of frailty in older cancer patients: a systematic review. Ann Oncol. 2015;26(6):1091–101.
[36] Souwer ET, et al. Physical performance has a strong association with poor surgical outcome in older patients with colorectal cancer. Eur J Surg Oncol. 2020;46(3):462–9.
[37] Aaldriks AA, et al. Frailty and malnutrition predictive of mortality risk in older patients with advanced colorectal cancer receiving chemotherapy. J Geriatr Oncol. 2013;4(3):218–26.
[38] Fried LP, et al. Untangling the concepts of disability, frailty, and comorbidity: implications for improved targeting and care. J Gerontol A Biol Sci Med Sci. 2004;59(3):255–63.
[39] Berian JR, et al. Optimizing surgical quality datasets to Care for Older Adults: lessons from the American College of Surgeons NSQIP geriatric surgery pilot. J Am Coll Surg. 2017;225(6):702–712 e1.
[40] Souwer ETD, et al. The prognostic value of a geriatric risk score for older patients with colorectal Cancer. Ann Surg Oncol. 2019;26(1):71–8.
[41] Hornor MA, et al. Enhancing the American College of Surgeons NSQIP surgical risk calculator to predict geriatric outcomes. J Am Coll Surg. 2020;230(1):88–100 e1.
[42] Munoz M, et al. Perioperative anemia management in colorectal cancer patients: a pragmatic approach. World J Gastroenterol. 2014;20(8):1972–85.

[43] Moghadamyeghaneh Z, et al. Outcome of preoperative weight loss in colorectal surgery. Am J Surg. 2015;210(2):291–7.
[44] Hu WH, et al. Preoperative malnutrition assessments as predictors of postoperative mortality and morbidity in colorectal cancer: an analysis of ACS-NSQIP. Nutr J. 2015; 14:91.
[45] Hamaker ME, et al. Nutritional status and interventions for patients with cancer - a systematic review. J Geriatr Oncol. 2021;12(1):6–21.
[46] Henneman D, et al. Safety of elective colorectal cancer surgery: non-surgical complications and colectomies are targets for quality improvement. J Surg Oncol. 2014;109 (6):567–73.
[47] Kunitake H, et al. Caring for octogenarian and nonagenarian patients with colorectal cancer: what should our standards and expectations be? Dis Colon Rectum. 2010;53 (5):735–43.
[48] Couwenberg AM, et al. The impact of postoperative complications on health-related quality of life in older patients with rectal cancer; a prospective cohort study. J Geriatr Oncol. 2018;9(2):102–9.
[49] Hughes MJ, et al. Prehabilitation before major abdominal surgery: a systematic review and Meta-analysis. World J Surg. 2019;43(7):1661–8.
[50] Everink IH, et al. Factors influencing home discharge after inpatient rehabilitation of older patients: a systematic review. BMC Geriatr. 2016;16:5.
[51] Hung YC, et al. Preoperative functional status is associated with discharge to non-home in geriatric individuals. J Am Geriatr Soc. 2021;69(7):1856–64.
[52] Ge X, et al. Inspiratory muscle training is associated with decreased postoperative pulmonary complications: evidence from randomized trials. J Thorac Cardiovasc Surg. 2018;156(3):1290–1300 e5.
[53] Souwer ETD, et al. Risk prediction models for postoperative outcomes of colorectal cancer surgery in the older population - a systematic review. J Geriatr Oncol. 2020;11(8):1217–28.

Appendix A

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

ACS NSQIP procedures	$n = 682$
44,204 - Laparoscopic colectomy partial with anastomosis	466
44,206 - Laparoscopic colectomy partial with end colostomy (Hartmann procedure)	67
44,140 - Colectomy partial with anastomosis	69
44,143 - (Hartmann procedure) Colectomy partial with end colostomy and closure of the distal segment	11
44,144 - Colectomy partial with resection, with colostomy or ileostomy and creation of mucofistula	15
44,210 - Laparoscopy, surgical; colectomy, total, abdominal, without proctectomy, with ileostomy or ileoproctostomy	19
44,147 – Colectomy partial abdominal and transanal approach	1
44,205 – Laparoscopy, surgical; colectomy, partial with removal of terminal ileum with ileocolostomy	1
45,110 – Proctectomy; complete combined abdominoperineal with colostomy	8
45,395 – Laparoscopy, surgical; proctectomy, complete, combined abdominoperineal, with colostomy	25