Am J Cancer Res 2025;15(5):2208-2221
www.ajcr.us /ISSN:2156-6976/ajcr0163475

Original Article

Higher hospital frailty risk score is predictive of 90-day readmission after minimally invasive colorectal cancer surgery: a national readmission database analysis

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Received January 21, 2025; Accepted April 28, 2025; Epub May 15, 2025; Published May 30, 2025

Abstract: Minimally invasive procedures are common in colorectal cancer (CRC) surgeries, but the impact of frailty on postoperative outcomes is unclear. This study aimed to assess how frailty status affects postoperative outcomes after minimally invasive CRC surgery. This study examined the impact of frailty on postoperative outcomes following minimally invasive colorectal cancer (CRC) surgery. Using data from the 2016-2020 U.S. National Readmission Database, the study included patients aged ≥ 60 years who underwent first-time minimally invasive (laparoscopic or robotic) CRC resection during hospitalization. Patients were categorized into low, intermediate, and high frailty risk groups based on the Hospital Frailty Risk Score (HFRS). Outcomes assessed included 90-day readmissions, in-hospital mortality, and complications. The analysis of 6,417 patients revealed that intermediate frailty was associated with higher in-hospital mortality (OR = 2.01), and high frailty had an even greater risk (OR = 3.83). Frailty also showed a dose-response relationship with complications, with the odds of complications being significantly higher in both intermediate (OR = 4.59) and high frailty groups (OR = 37.12). Only the high frailty group had an elevated risk of 90-day readmission (OR = 1.27). Certain subgroups, such as patients aged < 80, without diabetes or chronic kidney disease, with rectal tumors, and those undergoing robotic surgery, were particularly affected by frailty in terms of in-hospital mortality. The study highlights that higher frailty, as measured by the HFRS, is a strong predictor of adverse postoperative outcomes and early readmission in older patients undergoing minimally invasive CRC surgery, with especially notable effects in certain subgroups, possibly due to the greater surgical complexity or physiological burden in these groups.

Keywords: Hospital frailty risk score (HFRS), colorectal cancer (CRC), minimally invasive surgery, National Readmission Database (NRD), readmission

Introduction

Colorectal cancer (CRC) ranks as the third most common malignancy worldwide, accounting for approximately 1.9 million new cases and 930,000 deaths in 2020 [1, 2]. In the United States, the 5-year survival rate is approximately 64%, depending on stage at diagnosis [3]. Forecasts suggest a significant increase in incidence, which is projected to rise to approximately 3.2 million new cases, while fatalities are projected to reach 1.6 million by 2040. Predominantly, this epidemiology affects high Human Development Index (HDI) countries [4, 5]. The primary goal in CRC treatment is the complete surgical removal of the tumor and metastases, which is critical for improving patient survival and quality of life.

Advances in surgical techniques, particularly the shift from open resections towards minimally invasive surgeries such as robotic and laparoscopic methods, have marked a significant evolution in CRC management [6, 7].

https://doi.org/10.62347/GQFR4339

These techniques are favored, due to their documented benefits, which include reduced recovery times and lower post-operative discomfort, factors that contribute to their superior outcomes compared with traditional open surgeries [8, 9]. Minimally invasive CRC surgery not only improves short-term outcomes but also achieves long-term oncologic results comparable to those of open surgeries [10, 11].

The above factors notwithstanding, the role of patient frailty as a preoperative risk factor remains a critical area of investigation. Frailty is a well-established predictor of adverse surgical outcomes, particularly among the elderly population undergoing major procedures [12-14]. It has been associated with increased postoperative complications, prolonged length of stay, and higher rates of early readmission [15]. However, the specific impact of frailty on the outcomes, especially readmission rates, of minimally invasive CRC surgery has not been thoroughly examined. This gap in knowledge underscores the need for further research to evaluate how frailty influences readmission rates and overall recovery in these patients. The aim of such work is to enhance preoperative risk assessment and optimize postoperative care strategies.

Methods

Data source and study design

We conducted a retrospective analysis of the United States (US) Nationwide Readmissions Database (NRD). The NRD is a publicly available all-payer database developed by the Agency for Healthcare Research and Quality (AHRQ) for the Healthcare Cost and Utilization Project (HCUP). It is derived from the HCUP State Inpatient Databases. The NRD provides an accurate representation of total US hospitalizations and readmissions visits regardless of insurance provider. The NRD includes verified patient linkage numbers; thus, it allows for the tracking of individuals across hospitals within a given year, while adhering strictly to privacy guidelines. The NRD encompasses a full calendar year of data with diagnoses and procedures reported using the International Classification of Disease, Tenth Revision, Clinical Modification (ICD-10-CM), and procedure codes (ICD-10-PCS) coding system beginning in data year 2016. An overview of the NRD can be found at: https://hcup-us.ahrq.gov/nrdoverview.jsp.

Study population

The study population comprised adults aged ≥ 60 years admitted with principal or secondary diagnostic codes for primary CRC, identified by ICD-10-CM codes (C18-19 for colon and C20 for rectal cancers). Only patients undergoing first minimally invasive primary tumor resections (i.e., laparoscopic or robotic surgery) during the index hospitalization (from January 1 to September 30 of each year from 2016 to 2020), identified by the ICD-10-PCS, were included. Following the index admission, patients were considered 'at-risk' for hospitalization and contributed to the follow-up period until December 31 of the admission year, or until death. Patients with missing demographic information, outcomes of interest, or with metastatic cancer were excluded. A full list of diagnosis and procedure codes is available in Table S1, provided in the online appendix.

Ethics statement

This study complies with the terms of the NRD data-use agreement. Data were obtained through the Online HCUP Central Distributor and were secondary and anonymized, with no direct patient participation. No further informed consent is needed accordingly.

Ascertainment of the HFRS

The HFRS was initially developed and validated by Gilbert *et al.* 2018 [16]. This score assigns weights to various components based on ICD codes. This method covers conditions, such as heart failure, chronic pulmonary disease, and volume depletion. Designed for screening frailty in over 1.04 million hospitalized elderly patients aged 75 and above, the HFRS helps identify those at increased risk for mortality, readmission, and prolonged hospital stays. Utilizing ICD-10 codes, this cost-effective score integrates into hospital information systems and is comparable in performance to other frailty and risk assessment tools. Each ICD code is assigned a specific point value that reflects its impact on overall frailty risk. These points are summed to calculate a cumulative score for each patient, with higher scores indicating a greater likelihood of frailty. In this

study, frail conditions are categorized into two risk levels: low risk (less than 5 points), moderate to high risk (5-15 points) and high risk (above 15 points). This classification has been applied in various published studies utilizing HFRS [17, 18].

Outcome measures

The outcomes measured included in-hospital mortality, and postoperative complications including intestinal adhesions with obstruction, ileus complications, other digestive system complications, acute myocardial infarction (AMI), cerebral vascular accidents (CVA), venous thromboembolism (VTE), sepsis, respiratory failure, mechanical ventilation, acute kidney injury (AKI), shock, and bleeding, as well as 90-day readmission rate. Following the index admission (from January 1 to September 30), patients were monitored to determine their risk of readmission in each calendar year.

Covariates

Covariates included age, sex, insurance status, major comorbidities (hypertension, diabetes mellitus [DM], obesity, chronic pulmonary disease, chronic kidney disease [CKD], severe liver disease, rheumatic disease, heart failure, and coronary artery disease [CAD]), whether or not receiving diverting ileostomy, type of surgery (robotic or laparoscopic), tumor location (colon, rectum, or both), whether or not admitted at the weekend, admission status (emergent, elective), hospital bed numbers, and hospital location/teaching status.

Statistical analysis

National estimates were calculated by utilizing the discharge-level weight (DISCWT) to project discharges at community hospitals in the US, excluding rehabilitation and LTAC facilities. For standard error (SE) calculations, stratification (NRD_STRATUM) and hospital clusters (HOSP_NRD) were considered. DISCWT, NIS_STRATUM, and HOSP_NRD were used for all analyses. In SAS, the SURVEY procedure was used to analyze sample survey data. Descriptive statistics for patients with a primary or secondary discharge diagnosis of malignant colorectal cancer who underwent robotic or laparoscopic surgery for the primary tumor at index admission were presented as either the number (n) and weighted percentages (%), or mean and SE, categorized by HFRS. Categorical data were analyzed using the PROC SURVEYFREQ statement, while continuous data were assessed using the PROC SURVEYREG statement. The SURVEYFREQ procedure includes the Rao-Scott chi-square test to evaluate the significance of weighted proportions. The SURVEYREG procedure fits linear models to survey data and provides significance tests for the model effects.

Patients identified as having a higher risk of frailty were matched to those who had intermediate and low frailty risks using the propensity score matching (PSM) technique at a 1:4 ratio, with matching performed using the nearest neighbor matching (NNM), respectively. In NNM, each treated unit is matched with one or more control units whose propensity scores are closest. This method increases statistical power by utilizing more information from the control group. The propensity score was calculated based on the multivariable model adjusting for variables significantly different between the HFRS-defined frailty risk groups, including age (in years), insurance status/primary payer, hypertension, diabetes, obesity, chronic pulmonary disease, CKD, severe liver disease, rheumatic disease, surgery type, tumor location, weekend admission, admission type, and hospital location/teaching status.

Logistic regressions were then conducted using the PROC SURVEYLOGISTIC statement to assess the associations between the frailty risk groups (low, intermediate, and high) and the outcomes of interest. The results were reported as odds ratios (OR) with 95% confidence intervals (CI). All *p*-values were two-sided, with p-values < 0.05 considered statistically significant. Statistical analyses were performed using SAS software version 9.4 (SAS Institute Inc., Cary, NC, USA).

Results

Patient selection

The selection process for the study population is illustrated in **Figure 1**. The selection process for the study population is illustrated in **Figure 1**. A total of 96,109 patients who underwent the first resection between January 1, 2016, and September 30, 2020, in the calendar year for primary tumor were identified. Patients who

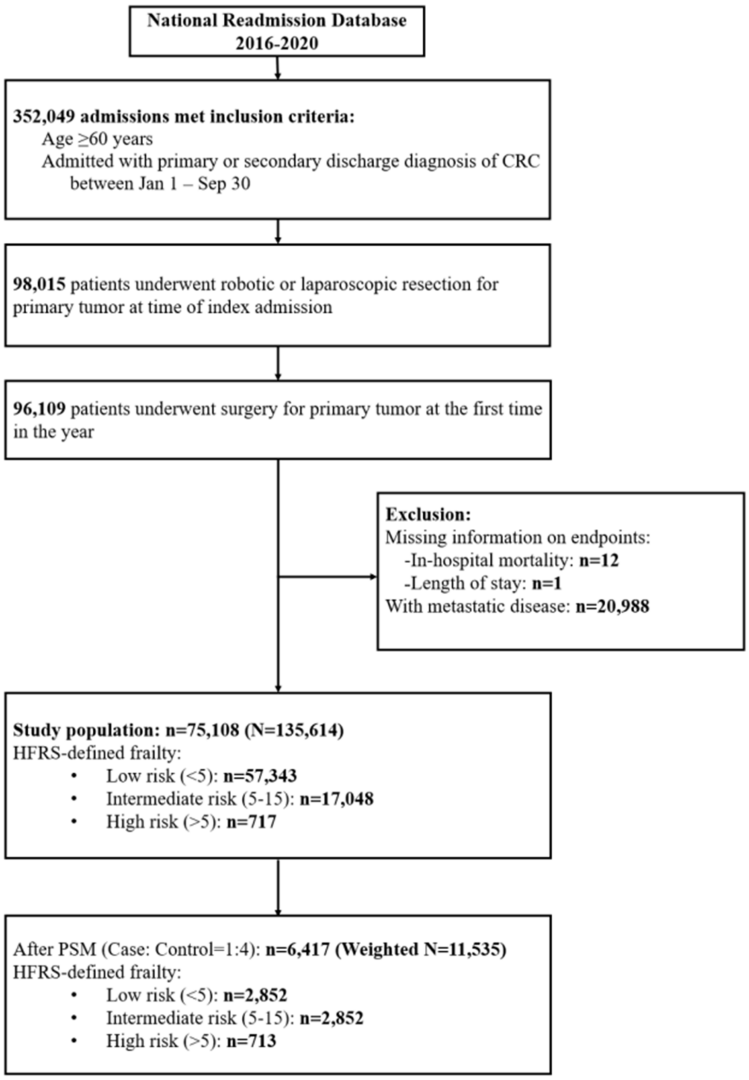

Figure 1. Flow diagram of patient selection process. Out of 98,015 admissions identified in the NRD database aged ≥ 60 years, with a primary or secondary discharge diagnosis of primary CRC, and undergoing robotic or laparoscopic surgery for primary tumors between January 1, 2016, and September 30, 2020, a total of 96,109 patients were identified. Patients who had missing information on in-hospital mortality and length of stay (n = 13) or had metastatic cancer (20,988) were excluded. Finally, 75,108 patients were included in the study, with 23% having an intermediate risk and 1% having a high risk of HFRS. After PSM, 6,435 remained for subsequent analyses, consisting of 715 cases with a high risk of frailty and 2,860 cases respectively for low-risk and intermediate-risk patients. This sample represents a total of 11,560 hospitalizations in the US.

had missing information on in-hospital mortality and length of stay (n = 13) or had metastatic diseases (20,988) were excluded. Finally, 75,108 patients were included as the primary cohort, with 23% having intermediate frailty risk and 1% having high frailty risk defined by the HFRS.

After PSM, 6,417 remained for subsequent analyses, consisting of 713 patients with a high frailty risk and 2,852 cases respectively for low-risk and intermediate-risk. This sample represents a total of 11,535 hospitalizations in the entire US (**Figure 1**).

Characteristics of the study population

The characteristics of the study population prior to PSM were documented in Table S2. The mean age was 73.6 years, and 51.5% were males. Patients with high frailty risk were the oldest. They had higher proportions of Medicare/Medicaid payers, rheumatic disease, non-robotic surgery, tumor locations in both the colon and rectum, weekend and emergent admissions, and were more likely to live in metropolitan non-teaching areas compared to those with intermediate and low frailty risk groups. As frailty risk advanced, the occurrence of poor outcomes increased, including in-hospital mortality, complications, and 90-day readmission (Table S2).

After PSM, all baseline characteristics among the comparison groups showed no significant difference (**Table 1**).

The proportions of adverse in-hospital outcomes according to HFRS-defined frailty status

After PSM, as frailty risk advanced (from low-risk to high-risk), the incidence of poor outcomes significantly increased, including in-hospital mortality (2.4% to 8.6%, P < 0.001), complications (34.1% to 95.0%, P < 0.001), and 90-day readmissions (31.7% to 37.1%, P = 0.027). This significant trend could also be

Table 1. Characteristics of older adults undergoing minimally invasive CRC resection after PSM, compared between HFRS-defined frailty status

Characteristics	Total (n = 6417)	HFRS-defined frailty status			*p*-value
		Low risk (< 5) (n = 2,852)	Intermediate risk (5-15) (n = 2,852)	High risk (> 15) (n = 713)	
Demography					
Age, years	78.6 ± 0.1	78.6 ± 0.2	78.6 ± 0.2	78.6 ± 0.3	0.972
60-64	396 (6.3)	170 (6.3)	178 (6.2)	48 (6.8)	0.197
65-69	748 (11.7)	327 (11.3)	351 (12.7)	70 (9.6)	
70-74	871 (13.5)	405 (13.8)	365 (12.9)	101 (14.6)	
75-79	1,157 (18.3)	490 (17.4)	533 (19.0)	134 (18.8)	
80-84	1,263 (19.8)	593 (21.0)	535 (18.7)	135 (19.3)	
85-89	1,245 (19.3)	546 (19.4)	550 (18.7)	149 (21.2)	
90+	737 (11.1)	321 (10.8)	340 (11.9)	76 (9.6)	
Sex					0.298
Male	3,150 (48.9)	1,379 (48.0)	1,406 (49.2)	365 (51.4)	
Female	3,267 (51.1)	1,473 (52.0)	1,446 (50.8)	348 (48.6)	
Insurance status/Primary payer					0.964
Medicare/Medicaid	6,033 (93.7)	2,687 (93.8)	2,677 (93.5)	669 (94.0)	
Private including HMO	277 (4.5)	117 (4.4)	128 (4.7)	32 (4.4)	
Self-pay/no-charge/other	107 (1.8)	48 (1.8)	47 (1.7)	12 (1.6)	
Diverting ileostomy	123 (2.0)	64 (2.2)	45 (1.7)	14 (2.0)	0.414
Major comorbidities					
Hypertension	5,143 (80.1)	2,291 (80.4)	2,291 (80.4)	561 (78.2)	0.453
DM	2,232 (34.5)	1,028 (36.1)	966 (33.4)	238 (32.2)	0.069
Obesity	664 (10.4)	301 (10.8)	288 (10.0)	75 (10.1)	0.603
Chronic pulmonary disease	1,543 (24.9)	686 (24.7)	684 (25.1)	173 (24.7)	0.960
CKD	2,535 (39.8)	1,124 (39.5)	1,121 (39.9)	290 (40.2)	0.946
Severe liver disease	71 (1.2)	38 (1.4)	25 (1.0)	8 (1.2)	0.379
Rheumatic disease	168 (3.0)	76 (3.0)	71 (2.9)	21 (3.3)	0.930
Heart failure	1,577 (24.5)	695 (24.9)	704 (24.3)	178 (24.1)	0.850
CAD	1,788 (28.3)	842 (29.9)	740 (26.8)	206 (28.1)	0.055
Surgery type					0.182
Laparoscopic	5,801 (90.3)	2,592 (90.9)	2,566 (89.5)	643 (91.0)	
Robotic	616 (9.7)	260 (9.1)	286 (10.5)	70 (9.0)	
Tumor location					0.782
Colon	5,597 (87.2)	2,475 (87.0)	2,506 (87.7)	616 (86.2)	
Rectum	746 (11.6)	347 (12.0)	313 (11.1)	86 (12.3)	
Colon and Rectum	74 (1.1)	30 (1.1)	33 (1.1)	11 (1.4)	
Weekend admission					0.074
No	5,380 (84.0)	2,428 (85.2)	2,362 (83.2)	590 (82.5)	
Yes	1,037 (16.0)	424 (14.8)	490 (16.8)	123 (17.5)	
Admission type					0.628
Elective	1,309 (20.7)	569 (20.2)	590 (20.9)	150 (21.8)	
Emergent	5,102 (79.3)	2,279 (79.8)	2,261 (79.1)	562 (78.2)	
Missing	6	4	1	1	
Hospital bed numbers					0.639
Small	987 (15.9)	450 (16.0)	435 (16.0)	102 (15.4)	
Medium	1,898 (29.5)	858 (29.7)	837 (29.9)	203 (27.0)	
Large	3,532 (54.6)	1,544 (54.3)	1,580 (54.1)	408 (57.6)	

Hospital location/Teaching status					0.832
Metropolitan non-teaching	1,732 (24.7)	752 (24.1)	783 (25.1)	197 (25.7)	
Metropolitan teaching	4,395 (69.8)	1,965 (70.3)	1,945 (69.6)	485 (69.0)	
Non-metropolitan hospital	290 (5.4)	135 (5.7)	124 (5.2)	31 (5.3)	

Abbreviations: PSM, propensity score matching; HFRS, hospital frailty risk score; DM, diabetes mellitus; CAD, coronary artery disease; CKD, chronic kidney disease. Continuous variables are presented as mean ± SE; categorical variables are presented as unweighted counts (weighted percentage).

Table 2. Clinical outcomes of patients with different HFRS-defined frailty status, after PSM

Outcomes	Total (n = 6417)	HFRS-defined frailty status			*p*-value
		Low risk (n = 2,852)	Intermediate risk (n = 2,852)	High risk (n = 713)	
In-hospital mortality	263 (4.1)	62 (2.4)	140 (4.7)	61 (8.6)	**< 0.001**
Complications, any	3,664 (57.0)	978 (34.1)	2,006 (70.3)	680 (95.0)	**< 0.001**
Intestinal adhesions with obstruction	53 (0.8)	23 (0.9)	23 (0.8)	7 (0.8)	0.778
Ileus complications	750 (11.4)	272 (9.3)	382 (13.0)	96 (13.5)	**< 0.001**
Other complications of the digestive system	362 (5.5)	126 (4.5)	182 (5.9)	54 (8.0)	**0.002**
AMI	194 (3.0)	73 (2.7)	92 (2.9)	29 (4.2)	0.150
CVA	446 (7.0)	42 (1.4)	214 (7.7)	190 (26.3)	**< 0.001**
VTE	419 (6.4)	140 (4.8)	206 (6.9)	73 (10.7)	**< 0.001**
Sepsis	779 (11.9)	123 (4.5)	407 (13.6)	249 (34.2)	**< 0.001**
Infection	1,655 (25.4)	309 (10.9)	866 (29.4)	480 (67.2)	**< 0.001**
Respiratory failure	372 (5.8)	77 (2.8)	209 (7.3)	86 (11.9)	**< 0.001**
Mechanical ventilation	428 (6.7)	84 (3.2)	211 (7.1)	133 (19.2)	**< 0.001**
AKI	1,935 (30.0)	414 (14.3)	1,102 (38.4)	419 (59.1)	**< 0.001**
Shock	439 (6.7)	72 (2.7)	252 (8.3)	115 (16.3)	**< 0.001**
Bleeding	111 (1.6)	41 (1.4)	60 (1.9)	10 (1.2)	0.227
90-day readmission[a]	2,057 (33.4)	887 (31.7)	923 (34.2)	247 (37.1)	**0.027**

Abbreviations: PSM, propensity score matching; HFRS, hospital frailty risk score; AKI, acute kidney injury; AMI, acute myocardial infarction; CVA, cerebral vascular accident; VTE, venous thromboembolism. Continuous variables are presented as mean ± SE; categorical variables are presented as unweighted counts (weighted percentage). *P*-values < 0.05 are shown in bold.
[a]Excluding patients who died in hospitals.

seen with individual complications, including ileus complications, other complications of the digestive system, CVA, VTE, sepsis, infection, respiratory failure, mechanical ventilation, AKI, and shock, but not intestinal adhesions with obstruction, AMI, or bleeding (**Table 2**).

Associations between HFRS-defined frailty and clinical outcomes

The impacts of frailty on outcomes are illustrated in **Figure 2**. For in-hospital mortality, compared to the low frailty risk group, the intermediate frailty risk group exhibited a significantly higher risk (OR = 2.01, 95% CI: 1.46-2.78), while the high frailty risk group demonstrated an even greater risk (OR = 3.83, 95% CI: 2.54-5.76).

For complication, a dose-response relationship was observed, with the intermediate frailty risk group showing significantly increased odds (OR = 4.59, 95% CI: 4.03-5.23), and the high frailty risk group demonstrating an even greater risk (OR = 37.12, 95% CI: 25.14-54.83).

For 90-day readmission, the intermediate frailty risk group did not exhibit a significantly increased risk, whereas the high frailty risk group showed a significantly elevated risk (OR = 1.27, 95% CI: 1.05-1.54).

Among specific complications, the most pronounced risk increase was observed in CVA, with the intermediate frailty risk group having an OR of 5.70 (95% CI: 4.02-8.07) and the high frailty risk group demonstrating a strikingly ele-

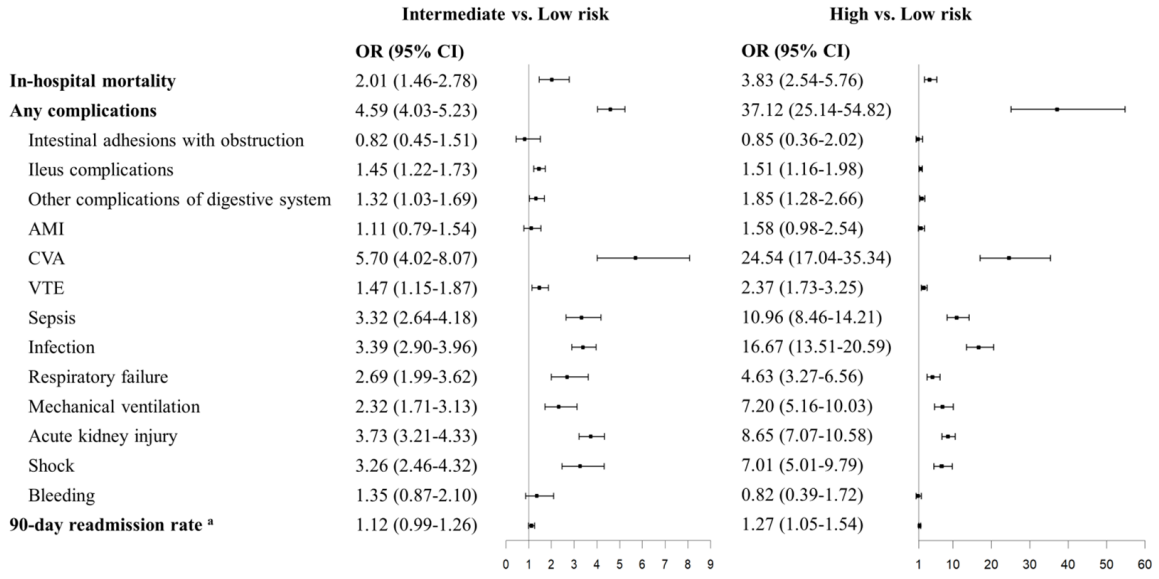

Figure 2. Associations between the HFRS-defined frailty risk and clinical outcomes.

vated OR of 24.54 (95% CI: 17.04-35.34) (**Figure 2**).

The most common reasons for 90-day readmission

Table 3 shows the most common principal diagnoses of the patients' 90-day readmissions. For those with low- and intermediate-risk frailty, the most common diagnosis was CRC. However, in patients with a high risk of hospital frailty, septicemia was the most frequently diagnosed condition.

The Diagnosis Category Clinical Classification Software Refined (DXCCSR) (a tool developed by the AHRQ to group diagnosis codes from the ICD codes) mapping to ICD-10-CM is listed separately in Table S3.

Associations between HFRS-defined frailty status and outcomes, stratified by age, DM, CKD, tumor location, and surgery type

Stratified analyses by age, DM, CKD, tumor location, and surgery type are shown in **Table 4**. For in-hospital mortality, HFRS-defined frailty demonstrated a dose-dependent impact. Moreover, the impact of frailty on in-hospital mortality was notably stronger in specific subgroups, including patients aged < 80 years, without DM or CKD, those with rectal tumors, and those undergoing robotic surgery.

The effects of HFRS-defined frailty on complications and readmissions were generally consistent with the findings from the main analysis (**Table 4**).

Discussion

This study demonstrated a clear dose-response relationship between higher HFRS-defined frailty risk and worse clinical outcomes in patients undergoing minimally invasive CRC surgery. Patients in the intermediate frailty risk group exhibited a twofold increase in in-hospital mortality risk, while those in the high frailty risk group faced an almost fourfold increase. Similarly, for postoperative complications, a strong dose-dependent trend was observed, with the intermediate frailty risk group showing a fourfold increase in risk, and the high frailty risk group demonstrating an extraordinary 37-fold increase. Although the intermediate frailty risk group did not show a significant increase in 90-day readmission risk, patients in the high frailty risk group had a 1.3-fold increased risk of readmission. Among specific complications, the most pronounced risk increase was observed for CVA, followed by sepsis and infections, highlighting the vulnerability of frail patients to critical systemic complications. This dose-response trend underscores the need for tailored perioperative strategies and enhanced postoperative monitoring for patients with elevated frailty risk [19-21].

Table 3. The most common principal diagnosis of 90-day readmission, by HFRS-defined frailty status (after PSM)

DXCCSR	Principal diagnosis	Low risk (n = 887)		Intermediate risk (n = 923)		High risk (n = 247)	
		Rank	n (%)	Rank	n (%)	Rank	n (%)
INJ034	Complication of genitourinary device, implant or graft, initial encounter					4	11 (4.45%)
NEO015	CRC	1	314 (35.4%)	1	216 (23.4%)	2	35 (14.17%)
INF002	Septicemia	2	58 (6.54%)	2	90 (9.75%)	1	52 (21.05%)
DIG024	Postprocedural or postoperative digestive system complication	3	43 (4.85%)			3	13 (5.26%)
DIG012	Intestinal obstruction and ileus	4	38 (4.28%)				
INJ037	Complications of other surgical or medical care, injury, initial encounter	5	38 (4.28%)	3	59 (6.39%)		
CIR019	Heart failure			4	51 (5.53%)		
GEN002	AKI			5	50 (5.42%)	5	10 (4.05%)

Abbreviations: DXCCSR, Diagnosis Category Clinical Classification Software Refined; PSM, propensity score matching; HFRS, hospital frailty risk score; AKI, acute kidney injury.

Table 4. Associations between HFRS-defined frailty status and outcomes, stratified by age, DM, CKD, tumor location, and surgery type

Subgroups and outcomes	HFRS-defined frailty status (vs. Low risk)			
	Intermediate risk		High risk	
	OR (95% CI)	*P*-value	OR (95% CI)	*P*-value
In-hospital mortality				
Age, years				
< 80	2.27 (1.35-3.82)	0.002	4.58 (2.45-8.58)	**< 0.001**
≥ 80	1.90 (1.24-2.90)	0.003	3.43 (2.01-5.86)	**< 0.001**
DM				
With	1.34 (0.82-2.20)	0.246	2.34 (1.15-4.76)	**0.019**
Without	2.69 (1.75-4.13)	< 0.001	5.28 (3.13-8.89)	**< 0.001**
CKD				
With	1.23 (0.78-1.93)	0.382	2.15 (1.20-3.85)	**0.010**
Without	3.40 (2.09-5.55)	< 0.001	6.79 (3.82-12.09)	**< 0.001**
Tumor location				
Colon	2.02 (1.44-2.84)	< 0.001	3.87 (2.50-6.00)	**< 0.001**
Rectum	2.99 (0.99-9.05)	0.053	4.67 (1.45-15.11)	**0.010**
Surgery type				
Laparoscopic	1.91 (1.36-2.67)	< 0.001	3.72 (2.43-5.68)	**< 0.001**
Robotic	4.81 (1.33-17.33)	0.017	6.68 (1.56-28.72)	**0.011**
Any complications				
Age, years				
< 80	5.36 (4.52-6.35)	< 0.001	50.86 (27.27-94.85)	**< 0.001**
≥ 80	3.95 (3.32-4.72)	< 0.001	28.79 (17.48-47.42)	**< 0.001**
DM				
With	4.88 (3.88-6.15)	< 0.001	46.48 (23.25-92.91)	**< 0.001**
Without	4.49 (3.89-5.20)	< 0.001	34.43 (22.00-53.87)	**< 0.001**
CKD				
With	4.10 (3.29-5.10)	< 0.001	40.45 (21.19-77.18)	**< 0.001**
Without	5.14 (4.41-5.99)	< 0.001	38.76 (24.78-62.15)	**< 0.001**
Tumor location				
Colon	4.37 (3.81-5.00)	< 0.001	33.21 (22.15-49.80)	**< 0.001**
Rectum	8.07 (5.71-11.42)	< 0.001	103.54 (24.07-445.32)	**< 0.001**
Surgery type				
Laparoscopic	4.45 (3.91-5.07)	< 0.001	37.71 (24.57-57.86)	**< 0.001**
Robotic	6.75 (4.69-9.70)	< 0.001	37.52 (16.08-87.55)	**< 0.001**
90-day readmission rate[a]				
Age, years				
< 80	1.26 (1.05-1.50)	0.011	1.60 (1.22-2.10)	**0.001**
≥ 80	0.99 (0.84-1.17)	0.908	1.00 (0.76-1.30)	0.991
DM				
With	1.14 (0.94-1.39)	0.180	1.30 (0.96-1.77)	0.091
Without	1.10 (0.94-1.28)	0.234	1.26 (0.997-1.59)	0.053
CKD				
With	1.18 (0.97-1.42)	0.099	1.18 (0.88-1.59)	0.262
Without	1.07 (0.92-1.25)	0.386	1.33 (1.04-1.70)	**0.024**
Tumor location				
Colon	1.11 (0.98-1.26)	0.106	1.27 (1.04-1.56)	**0.022**
Rectum	1.22 (0.90-1.65)	0.194	1.33 (0.80-2.20)	0.275

Surgery type				
Laparoscopic	1.11 (0.99-1.26)	0.086	1.27 (1.04-1.55)	**0.018**
Robotic	1.23 (0.82-1.83)	0.316	1.27 (0.69-2.34)	0.450

Abbreviations: OR, odds ratio; CI, confidence interval; HFRS, hospital frailty risk score; DM, diabetes mellitus; CKD, chronic kidney disease. *P*-values < 0.05 are shown in bold. [a]Excluding patients who died in hospitals.

Furthermore, our stratified analyses showed the impact of frailty was notably stronger in specific subgroups, including patients aged < 80 years, those without DM or CKD, those with rectal tumors over colon tumors, and those undergoing robotic surgery over laparoscopic surgery. In summary, these findings underscore the importance of frailty assessment in identifying patients who may require more intensive postoperative care and monitoring to mitigate the risk of severe complications.

Over the past several years, minimally invasive CRC surgery has demonstrated that it can improve short-term outcomes, while also having long-term oncologic results comparable to open procedures in settings of colorectal cancer [10, 11]. Such benefits notwithstanding, much less has been elucidated regarding the implications of patient frailty, although frailty status has been a recognized predictor of poor surgical outcomes, particularly among aging patients undergoing a range of non-cardiac procedures [12]. Among the elderly and others undergoing surgical intervention for various conditions, frailty has been associated with higher rates of early hospital readmission [13, 14]. However, there has been a knowledge gap regarding the effects of frailty on readmission rate and other specific outcomes of minimally invasive CRC surgery, including overall recovery.

Nevertheless, some prior reports are directly relevant to the findings of the present study. Looking at colectomy patients of age 80 and up, for instance, one analysis published in 2021 found that high-frailty risk patients (11-point modified frailty index [mFI-11] ≥ 3/11) lacking perioperative management suffered more complications, longer stays, and inferior discharge status compared with low-risk patients [22]. A more recent study found that frailty, as quantified by the Triage Risk Screening Tool, the Charlson Index, or the "Timed-Up-and-Go", independently predicted an increased risk of not achieving a textbook outcome in settings of minimally invasive CRC surgery [23]. Additionally, a 2023 systematic review and meta-analysis furthermore associated frailty with inferior oncological and long-term survival outcomes in CRC resection patients [24], while another analysis found that the 5-mFI score can predict postoperative short- and long-term outcomes and risk factors for mortality unrelated to CRC [25].

While frailty can worsen outcomes in a surgical setting, including in cases of minimally invasive surgery, the present study suggests that, as frailty risk increases, the risks of poor perioperative outcomes, such as in-hospital mortality, complications, and 90-day readmissions, also rise. Adding to the complicated picture, the present study results suggest that frailty, quantified by HFRS, strongly correlates with the occurrence of complications such as CVA, infection, sepsis, and AKI. In connection with these complications, one study published in 2016 suggested that frailty predicted the development of AKI and other adverse outcomes in hospitalized elderly individuals [26], while a more recent analysis found frailty to be associated with a 78% higher risk of infection-related hospitalization [20]. Meanwhile, in the realm of stroke, another recent study found frailty to be a rising stroke risk factor that is associated independently with poor outcomes [19].

When examining the potential mechanisms, the strong association between frailty and these complications can be attributed to the systemic physiological decline and impaired resilience characteristic of frail individuals. In the case of CVA, frailty is often accompanied by chronic inflammation, endothelial dysfunction, and an elevated risk of thrombosis [27], all of which predispose patients to cerebrovascular events. Similarly, frailty is strongly linked to sepsis and infections due to impaired immune function, known as "inflamm-aging", where chronic low-grade inflammation weakens the immune response [21]. This heightened vulnerability to infections is compounded by poor

wound healing, increased exposure to invasive procedures, and the higher likelihood of hospital-acquired infections in frail patients. Once infections develop, frail individuals are less able to mount an effective immune response, increasing their risk of sepsis and subsequent poor outcomes.

The present study further demonstrated a link between higher frailty and 90-day readmissions in particular. Addressing the readmission rate issue, some previous studies in older individuals undergoing surgery for CRC have elucidated associations between increased frailty and higher readmission rates [28, 29]. One such analysis applied the mFI-11 scale, which revealed a correlation between frailty and readmissions after colorectal resection [30]. The reasons for 90-day readmission were not the same across different frailty risk groups. As one example, our analyses showed that, in the high-frailty risk group, the most common reason for readmission was septicemia, distinct from the low/intermediate-frailty risk patients.

Finally, the present study includes stratified analysis. HFRS-defined frailty is shown to be a stronger predictor of in-hospital mortality among patients with rectal cancer than colon cancer; this suggests that rectal cancer surgery is more significantly impacted by frailty. One potential reason for this difference is that rectal cancer surgeries are often more complex and involve higher risks of complications compared to colon cancer surgeries. The anatomical location of the rectum, closer to critical structures in the pelvis, can make surgical procedures more challenging and prone to complications. Additionally, rectal cancer surgeries often require more extensive dissection and may involve higher rates of postoperative morbidity, making frail patients particularly vulnerable.

Additionally, frailty is associated more strongly with in-hospital mortality in patients without diabetes or CKD. This may be because diabetes and CKD are already significant risk factors that contribute to adverse outcomes independently. As a result, the impact of frailty might be masked or overshadowed by these conditions, making it less apparent in patients who have diabetes or CKD.

The stronger impact of frailty in patients undergoing robotic surgery compared to laparoscopic surgery could be attributed to the distinct characteristics of these surgical approaches. Robotic surgery, while minimally invasive, often involves longer operative times and greater technical complexity compared to laparoscopic procedures [31]. These factors can increase the physiological stress on frail patients, who already have reduced physiological reserves.

Although not evaluated in the present study, it is worth mentioning the approaches to addressing frailty. Prehabilitation, particularly, may potentially mitigate the impact of frailty on CRC surgical outcomes. Being a novel approach, aiming to improve the physical and psychological capacity of patients, prehabilitation has been proposed as a means of reducing postoperative morbidity and improving treatment outcomes. In terms of applying such an approach to CRC surgery settings in particular, three recently published studies are noteworthy, two of which found that prehabilitation reduced both postoperative complications and the average length of hospital stay in frail cancer patients [32, 33]. The other study, a comprehensive review, was unable to demonstrate the same benefits, due to its use of a fairly heterogeneous group of small studies, but the authors did note some positive effects of prehabilitation on physical, nutritional, or psychological status [34]. Building on this concept, given the significant impact of frailty on outcomes identified in our study, it is worth considering whether specific ‘actionable’ frailty components, such as underlying weight loss conditions, could be effectively addressed through prehabilitation strategies. For instance, preoperative nutritional interventions, including consultations with dietitians to support weight maintenance or gain, may assist in optimizing postoperative outcomes.

In summary, this study highlights the importance of incorporating frailty assessment using the HFRS in preoperative evaluations for minimally invasive colorectal cancer surgery. Despite the known lower complication rates associated with minimally invasive procedures compared to open surgery, frailty remains a critical factor to consider. Identifying high-risk patients enables the implementation of tailored periop-

erative care and intensive postoperative monitoring, which may help mitigate unfavorable outcomes and reduce early readmissions.

Strength and limitation

Along with underscoring the importance of frailty assessment in identifying patients who may require more intensive postoperative care and monitoring, the findings of the present study demonstrate the value of utilizing a large, nationally representative database. Doing so allows for robust statistical analysis and enhances the generalizability of the findings. Additionally, the use of a validated tool, HFRS, based on administrative codes, allowed for the assessment of frailty risk in all patients undergoing CRC surgeries in the study population. The comprehensive inclusion of various covariates to adjust for potential confounders further strengthens the reliability of the analyses. Furthermore, we analyzed different patient subgroups to determine which characteristics are more impacted by frailty.

Nevertheless, this study has several limitations. Its retrospective design may introduce inherent biases, including selection and information bias. Additionally, although essential, the database used did not record critical tumor characteristics, such as stage and anatomic location, or related treatments, such as neoadjuvant chemotherapy or long-course chemoradiotherapy, which could not be included in the analysis. Furthermore, treatment strategies for distal and mid-proximal rectal cancer differ significantly, ranging from radiation and chemotherapy to various surgical approaches, from standard procedures to more complex and lengthy surgeries. These variations, which could not be accounted for in this study, may influence outcomes, highlighting the need for subgroup analyses within the rectal cancer cohort when more nuanced clinical details become available in the future. Another limitation is that the HFRS, used to assess frailty, was originally validated in patients over 75 years of age, whereas this study included patients aged 60 and above. While further validation in the 60-75 age group is necessary, our findings demonstrate that the HFRS remains a robust predictor of patient outcomes across this broader age range. Additionally, the reliance on administrative data for frailty assessment means that accuracy depends on the completeness and precision of the documented ICD codes. Intraoperative parameters, such as the duration of operation, intraoperative blood loss, anesthetic-related factors, and medications prescribed before and during admission, were not considered, due to lack of data. Long-term oncological outcomes also were not assessed, as the NRD allows only for follow-up within the year of index admissions. Despite these limitations, the study provides valuable insights into the impact of frailty on surgical outcomes in patients with CRC.

Conclusion

In conclusion, this study underscores the critical role of the HFRS in predicting adverse outcomes among patients undergoing minimally invasive colorectal cancer surgery. High frailty scores are strongly associated with increased risks of in-hospital mortality, postoperative complications, and 90-day readmissions, particularly among certain patient subgroups. The findings highlight the necessity of integrating frailty assessment into preoperative planning to tailor more effective care strategies for at-risk patients. Ultimately, acknowledging and addressing frailty may improve patient management significantly and enhance the overall success of surgical interventions in CRC.

Acknowledgements

We gratefully acknowledge the EDAHP109027 research project for its support.

Disclosure of conflict of interest

None.

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Table S1. ICD codes used to define the diagnoses and procedures

	ICD-10 Code
Colon cancer	CM: C18-19
Rectal cancer	CM: C20
Laparoscopic resection	PCS: 0DTE, 0DTF, 0DTG, 0DTH, 0DTJ, 0DTK, 0DTL, 0DTM, 0DTN, 0DTP (connect 4ZZ, 8ZZ, FZZ); 0DBE, 0DBF, 0DBG, 0DBH, 0DBJ, 0DBK, 0DBL, 0DBM, 0DBN, 0DBP (connect 3ZZ, 4ZZ, 8ZZ)
Robotic resection	PCS: 8E0W0CZ, 8E0W3CZ, 8E0W4CZ, 8E0W7CZ, 8E0W8CZ, 8E0WX-CZ
Metastatic cancer	CM: C77.x-C79.x
Intestinal adhesions with obstruction	CM: K56.5
Ileus complications	CM: K56.7
Other complications of digestive system	CM: K91.8
AMI	CM: I21
CVA	CM: I60, I61, I63, I69
VTE	CM: I26.0, I26.9, I80.0-I80.3, I80.8, I80.9, I81, I82, 008.2, 022.3, 087.1, 088.2
Sepsis	CM: R78.81, A41, R65.2, A42.7, A22.7, B37.7, A26.7, A28.2, A54.86, A32.7, A39.2, A20.7, A21.7, A48.3, A24.1
Infection	CM: L00-L08, A00-B99, T81.43, T81.49, 086.03, Z16
Respiratory failure	CM: J95.2-J95.8, J96.00, J96.90, J80, J81.0
Mechanical ventilation	CM: Z99.12 PCS: 5A1935Z, 5A1945Z, 5A1955Z
AKI	CM: N17
Shock	CM: R57, T81.1, T88.2, R65.21, A48.3
Bleeding	CM: E36.0, G97.32, H59.11x, I97.41x, I97.12, J95.61, J95.62, K91.61, K91.62, L76.01, D78.21, D78.22, E89.81x, G97.3x, G97.5x, H59.11x, H59.12x, H59.31x, H59.32x, H95.2x, H95.4x, I97.6x, J95.83x, K91.6x, K91.84x, L76.0x, L76.2x, M96.81x, M96.83x, N99.6x, N99.82x
Diverting ileostomy	PCS: 0D1B4Z4
Hypertension	CM: I10-I16, I1A
DM	CM: E10-E13
Obesity	CM: E66
Chronic pulmonary disease	CM: I27.8, I27.9, J40 -J47, J4A, J68.4, J70.1, J70.3
CKD	CM: I12.0, I13.1, N03.2-N03.7, N05.2-N05.7, N18, N19, N25.0, Z49.0-Z49.2, Z94.0, Z99.2
Severe liver disease	CM: I85.0, I86.4, K70.4, K71.1, K72.1, K72.9, K76.5, K76.6, K76.7
Rheumatic disease	CM: M05.x, M06.x, M31.5, M32.x-M34.x, M35.1, M35.3, M36.0
Heart failure	CM: I50
CAD	CM: I20, I21, I25

Abbreviations: ICD, International Classification of Disease; CM, clinical modification; PCS, procedure coding system; AKI, acute kidney injury; AMI, acute myocardial infarction; CVA, cerebrovascular accident; VTE, venous thromboembolism; CAD, coronary artery disease; DM, diabetes mellitus; CKD, chronic kidney disease.

Table S2. Characteristics of the study population before PSM

Characteristic	Total (n = 75,108)	HFRS			*p*-value
		Low risk (n = 57,343)	Intermediate risk (5-15) (n = 17,048)	High risk (n = 717)	
Outcome					
In-hospital mortality	1,196 (1.6)	335 (0.6)	800 (4.5)	61 (8.6)	**<0.001**
Any complications	24,030 (31.9)	11,739 (20.4)	11,607 (67.5)	684 (95.1)	**<0.001**
Intestinal adhesions with obstruction	373 (0.5)	201 (0.4)	165 (0.9)	7 (0.8)	**<0.001**
Ileus complications	7,916 (10.3)	5,099 (8.7)	2,720 (15.6)	97 (13.6)	**<0.001**
Other complications of the digestive system	3,305 (4.3)	1,932 (3.4)	1,318 (7.4)	55 (8.1)	**<0.001**
AMI	1,052 (1.4)	474 (0.9)	549 (3.2)	29 (4.1)	**<0.001**
CVA	1,826 (2.4)	375 (0.7)	1,261 (7.3)	190 (26.2)	**<0.001**
VTE	2,258 (3.0)	1,097 (1.9)	1,088 (6.2)	73 (10.7)	**<0.001**
Sepsis	3,228 (4.2)	768 (1.4)	2,208 (12.3)	252 (34.4)	**<0.001**
Infection	7,869 (10.4)	2,715 (4.8)	4,672 (26.8)	482 (67.0)	**<0.001**
Respiratory failure	2,114 (2.8)	810 (1.5)	1,218 (6.9)	86 (11.9)	**<0.001**
Mechanical ventilation	2,096 (2.8)	608 (1.1)	1,355 (7.6)	133 (19.0)	**<0.001**
AKI	9,467 (12.7)	2,863 (5.1)	6,182 (35.9)	422 (59.2)	**<0.001**
Shock	2,175 (2.9)	611 (1.1)	1,449 (8.1)	115 (16.2)	**<0.001**
Bleeding	950 (1.3)	567 (1.0)	373 (2.1)	10 (1.2)	**<0.001**
90-day readmission rate[a]	17,019 (23.2)	11,472 (20.3)	5,299 (32.8)	248 (37.0)	**<0.001**
Demography					
Age, years	73.6 ± 0.04	72.6 ± 0.04	76.8 ± 0.08	78.70 ± 0.30	**<0.001**
60-64	12,630 (16.9)	10,929 (19.2)	1,653 (9.9)	48 (6.8)	**<0.001**
65-69	15,048 (20.0)	12,681 (22.1)	2,297 (13.7)	70 (9.5)	
70-74	14,353 (19.0)	11,505 (19.9)	2,747 (16.1)	101 (14.5)	
75-79	12,647 (16.9)	9,350 (16.4)	3,163 (18.6)	134 (18.7)	
80-84	10,332 (13.7)	6,980 (12.2)	3,217 (18.7)	135 (19.2)	
85-89	7,030 (9.3)	4,267 (7.4)	2,613 (15.0)	150 (21.2)	
90+	3,068 (4.0)	1,631 (2.8)	1,358 (8.0)	79 (10.1)	
Sex					0.394
Male	38,698 (51.5)	29,473 (51.4)	8,858 (52.1)	367 (51.3)	
Female	36,410 (48.5)	27,870 (48.6)	8,190 (47.9)	350 (48.7)	
Insurance status/Primary payer					**<0.001**
Medicare/Medicaid	60,528 (80.7)	44,732 (78.1)	15,123 (88.6)	673 (94.0)	
Private including HMO	12,741 (16.9)	11,185 (19.3)	1,524 (9.1)	32 (4.4)	
Self-pay/no-charge/other	1,770 (2.5)	1,378 (2.5)	380 (2.3)	12 (1.6)	
Missing	69	48	21	0	
Diverting ileostomy	3,073 (4.1)	2,521 (4.4)	538 (3.2)	14 (2.0)	**<0.001**
Major comorbidities					
Hypertension	51,401 (68.9)	37,387 (65.7)	13,449 (79.0)	565 (78.4)	**<0.001**
DM	21,235 (28.4)	15,089 (26.4)	5,906 (34.8)	240 (32.2)	**<0.001**
Obesity	12,085 (16.4)	9,214 (16.4)	2,796 (16.6)	75 (10.0)	**<0.001**
Chronic pulmonary disease	13,444 (18.2)	9,076 (16.1)	4,191 (25.1)	177 (25.3)	**<0.001**
CKD	11,174 (15.1)	5,343 (9.5)	5,537 (32.6)	294 (40.6)	**<0.001**
Severe liver disease	527 (0.7)	296 (0.5)	223 (1.3)	8 (1.2)	**<0.001**
Rheumatic disease	1,486 (2.0)	1,047 (1.9)	418 (2.4)	21 (3.3)	**<0.001**
Heart failure	8,914 (12.1)	4,711 (8.5)	4,022 (23.7)	181 (24.5)	**<0.001**
CAD	16,183 (22.1)	10867 (19.5)	5,109 (30.5)	207 (28.0)	**<0.001**
Surgery type					**<0.001**
Laparoscopic	57,375 (76.4)	42,373 (73.8)	14,355 (84.3)	647 (91.1)	
Robotic	17,733 (23.6)	14,970 (26.2)	2,693 (15.7)	70 (8.9)	

Tumor location					**<0.001**
Colon	63,242 (84.1)	48,128 (83.8)	14,497 (84.8)	617 (85.8)	
Rectum	11,289 (15.2)	8,803 (15.5)	2,398 (14.3)	88 (12.6)	
Colon and Rectum	577 (0.8)	412 (0.7)	153 (0.9)	12 (1.6)	
Weekend admission					**<0.001**
No	70,189 (93.5)	54,721 (95.5)	14,876 (87.2)	592 (82.3)	
Yes	4,919 (6.5)	2,622 (4.5)	2,172 (12.8)	125 (17.7)	
Admission type					**<0.001**
Elective	52,781 (70.6)	45,089 (78.9)	7,542 (45.0)	150 (21.6)	
Emergent	22,202 (29.4)	12,161 (21.1)	9,475 (55.0)	566 (78.4)	
Missing	125	93	31	1	
Hospital bed numbers					0.206
Small	11,347 (15.6)	8,672 (15.6)	2,573 (15.7)	102 (15.3)	
Medium	21,812 (28.6)	16,531 (28.4)	5,077 (29.4)	204 (27.0)	
Large	41,949 (55.8)	32,140 (56.0)	9,398 (54.9)	411 (57.8)	
Hospital location/Teaching status					**<0.001**
Metropolitan non-teaching	16,648 (20.5)	12,460 (20.1)	3,991 (21.5)	197 (25.5)	
Metropolitan teaching	54,334 (72.7)	41,743 (73.1)	12,102 (71.5)	489 (69.2)	
Non-metropolitan hospital	4,126 (6.9)	3,140 (6.8)	955 (7.0)	31 (5.2)	

Abbreviations: HFRS, hospital frailty risk score; AMI, acute myocardial infarction; CAD, coronary artery disease; CVA, cerebral vascular accident; VTE, venous thromboembolism. Continuous variables are presented as mean ± SE; categorical variables are presented as unweighted counts (weighted percentage). *P*-values < 0.05 are shown in bold. [a]Excluding patients who died in hospitals.

Table S3. The most common principal diagnoses (DXCCSR mapping to ICD-10-CM) of 90-day readmissions (after PSM)

Rank	DXCCSR	ICD10-CM	Diagnosis description	N (%)
Low risk of frailty				
1	NEO015	C182	Malignant neoplasm of ascending colon	106 (11.95%)
		C180	Malignant neoplasm of cecum	53 (5.98%)
		C184	Malignant neoplasm of transverse colon	41 (4.62%)
		C20	Malignant neoplasm of rectum	23 (2.59%)
		C187	Malignant neoplasm of sigmoid colon	22 (2.48%)
		C189	Malignant neoplasm of colon, unspecified	17 (1.92%)
		C19	Malignant neoplasm of rectosigmoid junction	13 (1.47%)
		C181	Malignant neoplasm of appendix	11 (1.24%)
		C186	Malignant neoplasm of descending colon	11 (1.24%)
		C183	Malignant neoplasm of hepatic flexure	10 (1.13%)
		C185	Malignant neoplasm of splenic flexure	5 (0.56%)
		C188	Malignant neoplasm of overlapping sites of colon	2 (0.23%)
2	INF002	A419	Sepsis, unspecified organism	46 (5.19%)
		A4181	Sepsis due to Enterococcus	4 (0.45%)
		A4151	Sepsis due to Escherichia coli [E. coli]	3 (0.34%)
		A408	Other streptococcal sepsis	1 (0.11%)
		A409	Streptococcal sepsis, unspecified	1 (0.11%)
		A412	Sepsis due to unspecified staphylococcus	1 (0.11%)
		A414	Sepsis due to anaerobes	1 (0.11%)
		A4159	Other Gram-negative sepsis	1 (0.11%)
3	DIG024	K9189	Other postprocedural complications and disorders of digestive system	16 (1.8%)
		K91840	Postprocedural hemorrhage of a digestive system organ or structure following a digestive system procedure	9 (1.01%)
		K913	Postprocedural intestinal obstruction	5 (0.56%)
		K9131	Postprocedural partial intestinal obstruction	3 (0.34%)

		K9130	Postprocedural intestinal obstruction, unspecified as to partial versus complete	1 (0.11%)
		K91870	Postprocedural hematoma of a digestive system organ or structure following a digestive system procedure	1 (0.11%)
		K91872	Postprocedural seroma of a digestive system organ or structure following a digestive system procedure	1 (0.11%)
		K91873	Postprocedural seroma of a digestive system organ or structure following other procedure	1 (0.11%)
		K9402	Colostomy infection	1 (0.11%)
		K9403	Colostomy malfunction	1 (0.11%)
		K9409	Other complications of colostomy	1 (0.11%)
		K9412	Enterostomy infection	1 (0.11%)
		K9419	Other complications of enterostomy	1 (0.11%)
		K9423	Gastrostomy malfunction	1 (0.11%)
4	DIG012	K5660	Unspecified intestinal obstruction	8 (0.9%)
		K56609	Unspecified intestinal obstruction, unspecified as to partial versus complete obstruction	7 (0.79%)
		K567	Ileus, unspecified	6 (0.68%)
		K56600	Partial intestinal obstruction, unspecified as to cause	4 (0.45%)
		K565	Intestinal adhesions [bands] with obstruction (postprocedural) (postinfection)	3 (0.34%)
		K5651	Intestinal adhesions [bands], with partial obstruction	3 (0.34%)
		K5641	Fecal impaction	2 (0.23%)
		K5669	Other intestinal obstruction	2 (0.23%)
		K560	Paralytic ileus	1 (0.11%)
		K562	Volvulus	1 (0.11%)
		K56690	Other partial intestinal obstruction	1 (0.11%)
5	INJ037	T8131XA	Disruption of external operation (surgical) wound, not elsewhere classified, initial encounter	3 (0.34%)
		T8132XA	Disruption of internal operation (surgical) wound, not elsewhere classified, initial encounter	3 (0.34%)
		T8140XA	Infection following a procedure, unspecified, initial encounter	2 (0.23%)
		T8141XA	Infection following a procedure, superficial incisional surgical site, initial encounter	2 (0.23%)
		T8144XA	Sepsis following a procedure, initial encounter	1 (0.11%)
		T81718A	Complication of other artery following a procedure, not elsewhere classified, initial encounter	1 (0.11%)
		T8743	Infection of amputation stump, right lower extremity	1 (0.11%)
		T8754	Necrosis of amputation stump, left lower extremity	1 (0.11%)
Intermediate risk of frailty				
1	NEO015	C182	Malignant neoplasm of ascending colon	53 (5.74%)
		C180	Malignant neoplasm of cecum	32 (3.47%)
		C184	Malignant neoplasm of transverse colon	28 (3.03%)
		C187	Malignant neoplasm of sigmoid colon	24 (2.6%)
		C20	Malignant neoplasm of rectum	19 (2.06%)
		C185	Malignant neoplasm of splenic flexure	14 (1.52%)
		C19	Malignant neoplasm of rectosigmoid junction	14 (1.52%)
		C189	Malignant neoplasm of colon, unspecified	12 (1.3%)
		C186	Malignant neoplasm of descending colon	7 (0.76%)
		C183	Malignant neoplasm of hepatic flexure	6 (0.65%)
		C181	Malignant neoplasm of appendix	5 (0.54%)
		C188	Malignant neoplasm of overlapping sites of colon	1 (0.11%)
		D010	Carcinoma in situ of colon	1 (0.11%)
2	INF002	A419	Sepsis, unspecified organism	58 (6.28%)
		A4151	Sepsis due to Escherichia coli [E. coli]	7 (0.76%)
		A4159	Other Gram-negative sepsis	7 (0.76%)

		A4189	Other specified sepsis	6 (0.65%)
		A4101	Sepsis due to Methicillin susceptible Staphylococcus aureus	3 (0.33%)
		A4102	Sepsis due to Methicillin resistant Staphylococcus aureus	3 (0.33%)
		A4181	Sepsis due to Enterococcus	2 (0.22%)
		A414	Sepsis due to anaerobes	1 (0.11%)
		A4150	Gram-negative sepsis, unspecified	1 (0.11%)
		A4152	Sepsis due to Pseudomonas	1 (0.11%)
		B377	Candidal sepsis	1 (0.11%)
		R6521	Severe sepsis with septic shock	1 (0.11%)
3	INJ037	T814XXA	Infection following a procedure, initial encounter	21 (2.28%)
		T8143XA	Infection following a procedure, organ and space surgical site, initial encounter	9 (0.98%)
		T8149XA	Infection following a procedure, other surgical site, initial encounter	6 (0.65%)
		T8131XA	Disruption of external operation (surgical) wound, not elsewhere classified, initial encounter	2 (0.22%)
		T8132XA	Disruption of internal operation (surgical) wound, not elsewhere classified, initial encounter	2 (0.22%)
		T8141XA	Infection following a procedure, superficial incisional surgical site, initial encounter	2 (0.22%)
		T8144XA	Sepsis following a procedure, initial encounter	2 (0.22%)
		T8183XA	Persistent postprocedural fistula, initial encounter	2 (0.22%)
		T85698A	Other mechanical complication of other specified internal prosthetic devices, implants and grafts, initial encounter	2 (0.22%)
		T8744	Infection of amputation stump, left lower extremity	2 (0.22%)
		T80211A	Bloodstream infection due to central venous catheter, initial encounter	1 (0.11%)
		T8140XA	Infection following a procedure, unspecified, initial encounter	1 (0.11%)
		T8142XA	Infection following a procedure, deep incisional surgical site, initial encounter	1 (0.11%)
		T8189XA	Other complications of procedures, not elsewhere classified, initial encounter	1 (0.11%)
		T819XXA	Unspecified complication of procedure, initial encounter	1 (0.11%)
		T85628A	Displacement of other specified internal prosthetic devices, implants and grafts, initial encounter	1 (0.11%)
		T8571XA	Infection and inflammatory reaction due to peritoneal dialysis catheter, initial encounter	1 (0.11%)
		T8579XA	Infection and inflammatory reaction due to other internal prosthetic devices, implants and grafts, initial encounter	1 (0.11%)
		T8754	Necrosis of amputation stump, left lower extremity	1 (0.11%)
4	CIR019	I130	Hypertensive heart and chronic kidney disease with heart failure and stage 1 through stage 4 chronic kidney disease, or unspecified chronic kidney disease	22 (2.38%)
		I110	Hypertensive heart disease with heart failure	15 (1.63%)
		I5033	Acute on chronic diastolic (congestive) heart failure	10 (1.08%)
		I5043	Acute on chronic combined systolic (congestive) and diastolic (congestive) heart failure	2 (0.22%)
		I5021	Acute systolic (congestive) heart failure	1 (0.11%)
		I509	Heart failure, unspecified	1 (0.11%)
5	GEN002	N179	Acute kidney failure, unspecified	48 (5.2%)
		N170	Acute kidney failure with tubular necrosis	2 (0.22%)
High risk of frailty				
1	INF002	A419	Sepsis, unspecified organism	40 (16.19%)
		A4189	Other specified sepsis	3 (1.21%)
		A4159	Other Gram-negative sepsis	2 (0.81%)
		A408	Other streptococcal sepsis	1 (0.4%)
		A4102	Sepsis due to Methicillin resistant Staphylococcus aureus	1 (0.4%)
		A411	Sepsis due to other specified staphylococcus	1 (0.4%)
		A4150	Gram-negative sepsis, unspecified	1 (0.4%)

		A4151	Sepsis due to Escherichia coli [E. coli]	1 (0.4%)
		A4152	Sepsis due to Pseudomonas	1 (0.4%)
		A4181	Sepsis due to Enterococcus	1 (0.4%)
2	NEO015	C182	Malignant neoplasm of ascending colon	6 (2.43%)
		C184	Malignant neoplasm of transverse colon	5 (2.02%)
		C20	Malignant neoplasm of rectum	5 (2.02%)
		C183	Malignant neoplasm of hepatic flexure	3 (1.21%)
		C187	Malignant neoplasm of sigmoid colon	3 (1.21%)
		C189	Malignant neoplasm of colon, unspecified	3 (1.21%)
		C19	Malignant neoplasm of rectosigmoid junction	3 (1.21%)
		C180	Malignant neoplasm of cecum	2 (0.81%)
		C185	Malignant neoplasm of splenic flexure	2 (0.81%)
		C181	Malignant neoplasm of appendix	1 (0.4%)
		C186	Malignant neoplasm of descending colon	1 (0.4%)
		C188	Malignant neoplasm of overlapping sites of colon	1 (0.4%)
3	DIG024	K9189	Other postprocedural complications and disorders of digestive system	3 (1.21%)
		K91840	Postprocedural hemorrhage of a digestive system organ or structure following a digestive system procedure	2 (0.81%)
		K9409	Other complications of colostomy	2 (0.81%)
		K913	Postprocedural intestinal obstruction	1 (0.4%)
		K9130	Postprocedural intestinal obstruction, unspecified as to partial versus complete	1 (0.4%)
		K91870	Postprocedural hematoma of a digestive system organ or structure following a digestive system procedure	1 (0.4%)
		K9403	Colostomy malfunction	1 (0.4%)
		K9412	Enterostomy infection	1 (0.4%)
		K9423	Gastrostomy malfunction	1 (0.4%)
4	INJ034	T83511A	Infection and inflammatory reaction due to indwelling urethral catheter, initial encounter	6 (2.43%)
		T83098A	Other mechanical complication of other urinary catheter, initial encounter	1 (0.4%)
		T83512A	Infection and inflammatory reaction due to nephrostomy catheter, initial encounter	1 (0.4%)
		T83518A	Infection and inflammatory reaction due to other urinary catheter, initial encounter	1 (0.4%)
		T8351XA	Infection and inflammatory reaction due to indwelling urinary catheter, initial encounter	1 (0.4%)
		T8389XA	Other specified complication of genitourinary prosthetic devices, implants and grafts, initial encounter	1 (0.4%)
5	GEN002	N179	Acute kidney failure, unspecified	10 (4.05%)