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ORIGINAL SCIENTIFIC REPORT

Readmission Adversely Affects Survival in Surgical Rectal Cancer Patients

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Abstract

Background Readmission has received attention as a potential healthcare quality metric. No studies have investigated the relationship between readmission and survival in patients undergoing rectal cancer surgery. The aims of this study were to identify factors associated with 30-day readmission after rectal cancer surgery and to determine the impact of readmission on overall survival (OS).

Methods Patients who underwent surgical treatment for rectal/rectosigmoid adenocarcinoma stages I–IV were identified using the National Cancer Database (2004–2014). Multivariable logistic regression was used to identify factors for readmission. 2:1 nearest neighbor caliper matching without replacement was used to ensure similarity of patients being compared. Survival analyses were performed using Kaplan–Meier method along with log-rank test and Cox proportional hazards model.

Results Of 110,167 patients, 7045 (6.39%) were readmitted. Factors associated with readmission included higher Charlson comorbidity score, non-private or no insurance, procedure type, hospitals in the Northeast, South, and Midwest regions, and prolonged length of stay. Within the matched cohort (13,756 non-readmitted and 6878 readmitted), readmitted patients had worse 5- and 10-year OS regardless of cancer stage ($p < 0.001$) and procedure type. Five- and 10-year OS were 58.98% and 41.01% for readmitted patients, 64.96% and 43.50% for non-readmitted patients. Readmitted patients had shorter OS by 13.14 months and increased risk of mortality (HR 1.20, 95% CI 1.15–1.25, $p < 0.001$).

Conclusions Thirty-day readmission after rectal cancer surgery is associated with decreased OS. Efforts to reduce readmissions should be considered to advance cancer care and enhance the potential for improved patient survival.

Introduction

Hospital readmission has received considerable attention as a potential healthcare quality metric. In 2013, the Center of Medicare and Medicaid Services established the Hospital Readmission Reduction Program, an initiative that decreases reimbursements to hospitals with higher than expected 30-day readmission rates [1]. Though cardiac and orthopedic procedures are the predominant surgical procedures being addressed by the HRRP, it is likely that colorectal surgery procedures will also be included in the near future [2].

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Readmission after colorectal surgery has been fairly studied in the literature, with emphasis on determining factors associated with readmission [3–8]. Recent studies have reported overall colorectal surgery 30-day readmission rates of 6–30% [2, 3, 5, 8–10]. Reported factors associated with readmission include age, comorbidities, postoperative complications, ileostomy, and non-home discharge [3, 11–14]. Readmission after rectal cancer-specific procedures, however, is less well-studied. Several studies have found socioeconomic and hospital/geographic factors such as race, insurance status, and cancer treatment facility type as being associated with readmission after rectal cancer surgery [15–17]. Though few studies have attempted to assess the relationship between readmission and survival after certain gastrointestinal cancer surgeries [7, 18–20], none to date have addressed this relationship for patients undergoing rectal cancer surgery. Even fewer studies have investigated this relationship using a nationwide database.

The aims of this study, therefore, were to use the 2004–2014 National Cancer Database (NCDB) to identify factors associated with 30-day unplanned readmission after surgical treatment for rectal cancer and to determine the impact of readmission on overall survival (OS).

Methods

Data source

This was a retrospective analysis using the 2004–2014 NCDB. This nationwide clinical oncology database is sponsored by the American College of Surgeons and the American Cancer Society [21]. The NCDB captures over 70% of newly diagnosed cancer patients from more than 1500 Commission on Cancer (CoC) accredited facilities. This study was approved by The Johns Hopkins University School of Medicine Institutional Review Board.

Study cohort

Patients diagnosed with clinical stage I–IV rectal adenocarcinoma who underwent surgical resection as part of their treatment were included in the study. Patients who underwent procedures other than total or partial proctectomies or had incomplete readmission data were excluded. Patients were stratified into unplanned readmission and no unplanned readmission groups. The NCDB defines unplanned readmission as "readmission to the same hospital for the same illness within 30-days of surgical discharge."

Factors

Patient demographic factors included age at diagnosis, gender, race, Spanish/Hispanic ethnicity, education, median household income, medical insurance status, population density of patient residence, and distance from patient's zip code to location of admitting hospital. Patient education and income were used as proxy for patient's socioeconomic status and were estimated by matching patient's zip code of residence with the American Community Survey data. The NCDB reports education as a percentage of no high school completion with predetermined categories: $<7\%$, 7–12.9%, 13–20.9%, or $\geq 21\%$. Income was adjusted for 2012 inflation.

Patient clinical and oncologic factors included Charlson/Deyo score, clinical stage, grade, procedure type (partial or total proctectomy), operative approach (available since 2010; laparoscopic, robotic, open, or conversion to open), radiation therapy, chemotherapy, immunotherapy, hormone therapy, positive nodes, pathologic T and N assignments, tumor size, margins, and length of stay (LOS). Hospital LOS was categorized as normal (25th–75th percentile: 5–7 days for partial proctectomy and 6–8 days for total proctectomy), shortened ($\leq$25th percentile: $\leq$4 days and $\leq$5 days, respectively), or prolonged ($\geq$75th percentile: $\geq$8 days and $\geq$9 days, respectively).

Hospital factors included hospital type and hospital geographic region defined by the Census regions and division of the USA [22].

Statistical analysis

The primary outcome was OS. Baseline characteristics of patients were compared between readmitted and non-readmitted groups using Pearson χ^2 test for categorical variables. Multivariable logistic regression analysis was used to identify factors associated with readmission and included variables with $p < 0.25$ in univariate analysis as recommended by Hosmer and Lemeshow [23]. To minimize variation in baseline characteristics between readmitted and non-readmitted patients, propensity score matching was performed using *Psmatch2,* a commonly used Stata statistical package [24]. 2:1 nearest neighbor caliper matching without replacement was used to match patients. This technique minimizes bias due to observed confounding and lowering of mean square errors [25, 26]. A caliper width of 0.005 was computed by multiplying the standard deviation of the logit of the propensity score by 0.2 [27]. Twenty-five clinically and/or statistically significant variables were included in the propensity score (all variables in Table 1). Patients that were not matched were removed. Matching adequacy was verified by examining the balance of each covariate. Standardized biases of <0.25

Table 1 Demographic, clinical, and operative characteristics of patients undergoing surgery for rectal cancer

Factor, *n* (%)	Original cohort		*p*	Matched cohort		*p*
	No readmission 103,122 (93.61)	Readmission 7045 (6.39)		No readmission 13,756 (66.67)	Readmission 6878 (33.33)	
Demographic factors						
Age group, years			0.335			0.912
<50	16,583 (16.08)	1140 (16.18)		2186 (15.89)	1111 (16.15)	
50–59	26,458 (25.66)	1742 (24.73)		3462 (25.17)	1698 (24.69)	
60–69	27,606 (26.77)	1889 (26.81)		3628 (26.37)	1843 (26.80)	
70–79	21,253 (20.61)	1465 (20.79)		2879 (20.93)	1429 (20.78)	
≥80	11,222 (10.88)	809 (11.48)		1601 (11.64)	797 (11.59)	
Male	62,360 (60.47)	4349 (61.73)	0.036	8495 (61.75)	4242 (61.67)	0.911
Race			<0.001			0.546
White	89,683 (86.97)	6095 (86.52)		11,937 (86.78)	5950 (86.51)	
Black	7941 (7.70)	645 (9.16)		1245 (9.05)	638 (9.28)	
Other	4643 (4.50)	266 (3.78)		518 (3.77)	253 (3.68)	
Unknown	855 (0.83)	39 (0.55)		56 (0.41)	37 (0.54)	
Origin			<0.001			0.541
Non-Spanish/Hispanic	91,566 (88.79)	6168 (87.55)		12,070 (87.74)	6025 (87.60)	
Spanish/Hispanic	5573 (5.40)	376 (5.34)		749 (5.44)	360 (5.23)	
Unknown	5983 (5.80)	501 (7.11)		937 (6.81)	493 (7.17)	
High school failure rate, %			<0.001			0.474
<7.0	23,550 (22.84)	1472 (20.89)		2974 (21.62)	1442 (20.97)	
7–12.9	33,819 (32.80)	2300 (32.65)		4494 (32.67)	2252 (32.74)	
13.0–20.9	27,022 (26.20)	1893 (26.87)		3622 (26.33)	1838 (26.72)	
≥21	17,538 (17.01)	1300 (18.45)		2539 (18.46)	1267 (18.42)	
Unknown	1193 (1.16)	80 (1.14)		127 (0.92)	79 (1.15)	
Median household income, $			<0.001			0.615
≥63,000	31,567 (30.61)	1927 (27.35)		3781 (27.49)	1880 (27.33)	
62,999–48,000	27,720 (26.88)	1895 (26.90)		3750 (27.26)	1847 (26.85)	
47,999–38,000	25,009 (24.25)	1766 (25.07)		3407 (24.77)	1717 (24.96)	
<38,000	17,580 (17.05)	1374 (19.50)		2685 (19.52)	1352 (19.66)	
Unknown	1246 (1.21)	83 (1.18)		133 (0.97)	82 (1.19)	
Insurance type			<0.001			0.979
Private	48,161 (46.70)	2988 (42.41)		5840 (42.45)	2916 (42.40)	
Medicare	42,934 (41.63)	3082 (43.75)		6010 (43.69)	3011 (43.78)	
Medicaid	5602 (5.43)	497 (7.05)		973 (7.07)	484 (7.04)	
Other government	1169 (1.13)	60 (0.85)		107 (0.78)	60 (0.87)	
Uninsured	3802 (3.69)	292 (4.14)		596 (4.33)	289 (4.20)	
Unknown	1454 (1.41)	126 (1.79)		230 (1.67)	118 (1.72)	
Patient residence			0.043			0.902
Metro	80,997 (78.54)	5455 (77.43)		10,604 (77.09)	5322 (77.38)	
Urban	16,550 (16.05)	1187 (16.85)		2371 (17.24)	1158 (16.84)	
Rural	2376 (2.30)	190 (2.70)		374 (2.72)	190 (2.76)	
Unknown	3199 (3.10)	213 (3.02)		407 (2.96)	208 (3.02)	
Distance to hospital, mi			0.241			0.526
0–5	27,442 (26.61)	1944 (27.59)		3782 (27.49)	1883 (27.38)	
5–10	21,203 (20.56)	1476 (20.95)		2921 (21.23)	1447 (21.04)	
10–25	26,671 (25.86)	1759 (24.97)		3363 (24.45)	1706 (24.80)	
≥25	26,639 (25.83)	1787 (25.37)		3567 (25.93)	1764 (25.65)	

Table 1 continued

Factor, *n* (%)	Original cohort		*p*	Matched cohort		*p*
	No readmission 103,122 (93.61)	Readmission 7045 (6.39)		No readmission 13,756 (66.67)	Readmission 6878 (33.33)	
Unknown	1167 (1.13)	79 (1.12)		123 (0.89)	78 (1.13)	
Clinical/oncologic factors						
Charlson/Deyo score			<0.001			0.971
0	79,821 (77.40)	4999 (70.96)		9742 (70.82)	4860 (70.66)	
1	18,270 (17.72)	1541 (21.87)		3022 (21.97)	1518 (22.07)	
≥2	5031 (4.88)	505 (7.17)		992 (7.21)	500 (7.27)	
Grade differentiation			0.006			0.825
Well	8397 (8.14)	527 (7.48)		1102 (8.01)	519 (7.55)	
Moderate	70,743 (68.60)	4875 (69.20)		9485 (68.95)	4764 (69.26)	
Poor	12,498 (12.12)	911 (12.93)		1766 (12.84)	880 (12.79)	
Undifferentiated	1167 (1.13)	91 (1.29)		178 (1.29)	90 (1.31)	
Unknown	10,317 (10.00)	641 (9.10)		1225 (8.91)	625 (9.09)	
Clinical stage			0.831			0.504
I	31,566 (30.61)	2137 (30.33)		4307 (31.31)	2099 (30.52)	
II	28,142 (27.29)	1914 (27.17)		3675 (26.72)	1872 (27.22)	
III	35,012 (33.95)	2400 (34.07)		4588 (33.35)	2335 (33.95)	
IV	8402 (8.15)	594 (8.43)		1186 (8.62)	572 (8.32)	
Procedure type			<0.001			0.893
Partial proctectomy	71,910 (69.73)	4641 (65.88)		9001 (65.43)	4507 (65.53)	
Total proctectomy	31,212 (30.27)	2404 (34.12)		4755 (34.57)	2371 (34.47)	
Radiation therapy			<0.001			0.410
No	35,879 (34.79)	2549 (36.18)		5122 (37.23)	2498 (36.32)	
Yes	66,595 (64.58)	4429 (62.87)		8519 (61.93)	4325 (62.88)	
Unknown	648 (0.63)	67 (0.95)		115 (0.84)	55 (0.80)	
Chemotherapy			<0.001			0.659
No	28,638 (27.77)	2076 (29.47)		4169 (30.31)	2042 (29.69)	
Yes	72,564 (70.37)	4807 (68.23)		9292 (67.55)	4688 (68.16)	
Unknown	1920 (1.86)	162 (2.30)		295 (2.14)	148 (2.15)	
Immunotherapy			0.580			0.502
No	101,445 (98.37)	6922 (98.25)		13,541 (98.44)	6778 (98.55)	
Yes	555 (0.54)	37 (0.53)		65 (0.47)	36 (0.52)	
Unknown	1122 (1.09)	86 (1.22)		150 (1.09)	64 (0.93)	
Hormone therapy			0.242			0.688
No	100,294 (97.26)	*		13,381 (97.27)	*	
Yes	164 (0.16)	*		20 (0.15)	*	
Unknown	2664 (2.58)	*		355 (2.58)	*	
Nodes			<0.001			0.618
Negative	60,094 (58.27)	4241 (60.20)		8356 (60.74)	4154 (60.40)	
Positive	35,134 (34.07)	2451 (34.79)		4767 (34.65)	2387 (34.70)	
Unknown/unexamined	7894 (7.66)	353 (5.01)		633 (4.60)	337 (4.90)	
Pathologic T			<0.001			0.782
0/IS	4815 (4.67)	374 (5.31)		704 (5.12)	367 (5.34)	
I	12,671 (12.29)	870 (12.35)		1757 (12.77)	852 (12.39)	
II	25,766 (24.99)	1803 (25.59)		3592 (26.11)	1764 (25.65)	
III	45,749 (44.36)	3138 (44.54)		6075 (44.16)	3062 (44.52)	
IV	4572 (4.43)	346 (4.91)		689 (5.01)	338 (4.91)	

Table 1 continued

Factor, *n* (%)	Original cohort		*p*	Matched cohort		*p*
	No readmission 103,122 (93.61)	Readmission 7045 (6.39)		No readmission 13,756 (66.67)	Readmission 6878 (33.33)	
Unknown/undetermined	9549 (9.26)	514 (7.30)		939 (6.83)	495 (7.20)	
Pathologic N			<0.001			0.890
0	57,975 (56.22)	4080 (57.91)		8014 (58.26)	3994 (58.07)	
I	22,550 (21.87)	1547 (21.96)		2979 (21.66)	1507 (21.91)	
II	12,516 (12.14)	922 (13.09)		1831 (13.31)	898 (13.06)	
Unknown/undetermined	10,081 (9.78)	496 (7.04)		932 (6.78)	479 (6.96)	
Tumor size, cm			0.594			0.772
<3	27,753 (26.91)	1873 (26.59)		3652 (26.55)	1823 (26.50)	
3–4.9	30,748 (29.82)	2073 (29.43)		4114 (29.91)	2028 (29.49)	
≥5	27,662 (26.82)	1941 (27.55)		3826 (27.81)	1908 (27.74)	
Unknown	16,959 (16.45)	1158 (16.44)		2164 (15.73)	1119 (16.27)	
Margins			<0.001			0.635
Negative	93,985 (91.14)	6401 (90.86)		12,570 (91.38)	6263 (91.06)	
Positive	7220 (7.00)	569 (8.08)		1078 (7.84)	554 (8.05)	
Unknown	1917 (1.86)	75 (1.06)		108 (0.79)	61 (0.89)	
Length of stay, days			<0.001			0.979
Normal	35,881 (34.79)	2671 (37.91)		5330 (38.75)	2671 (38.83)	
Shortened	29,108 (28.23)	1649 (23.41)		3290 (23.92)	1649 (23.97)	
Prolonged	27,685 (26.85)	2559 (36.32)		5136 (37.34)	2558 (37.19)	
Unknown	10,448 (10.13)	166 (2.36)		*	*	
Hospital factors						
Hospital type			0.002			0.230
Community Cancer Program	56,045 (54.35)	3666 (52.04)		7019 (51.03)	3581 (52.06)	
Academic/Research Program	32,525 (31.54)	2357 (33.46)		4766 (34.65)	2297 (33.40)	
Integrated Network Cancer Program	10,802 (10.47)	756 (10.73)		1499 (10.90)	743 (10.80)	
Unknown	3750 (3.64)	266 (3.78)		472 (3.43)	257 (3.74)	
Hospital geographic location			<0.001			0.586
West	19,172 (18.59)	1438 (20.41)		2811 (20.43)	1377 (20.02)	
Northeast	34,984 (33.92)	2476 (35.15)		4741 (34.46)	2420 (35.18)	
South	27,445 (26.61)	2034 (28.87)		4102 (29.82)	2010 (29.22)	
Midwest	17,771 (17.23)	831 (11.80)		1630 (11.85)	814 (11.83)	
Unknown	3750 (3.64)	266 (3.78)		472 (3.43)	257 (3.74)	

*Counts suppressed due to one cell having <10 counts. Counts with $n < 10$ must be suppressed per NCDB

were considered good matches [28]. OS was defined as time in months from diagnosis to either death or last follow-up date (December 31, 2013). Of note, the NCDB only provided follow-up data through 2013 diagnoses. Survival analysis was performed for all patients and for each cancer stage. Subgroup analysis for each procedure type and operative approach was also performed. Kaplan–Meier method comparing survival curves between readmitted and non-readmitted patients with log-rank test was utilized. Cox proportional hazards model was used to examine the impact of readmission on OS while adjusting for other factors. Proportional hazards assumption was verified. Statistical significance was considered as p value < 0.05. Statistical analysis was performed with Stata/MP version 14 (StataCorp LP, College Station, TX, USA).

Results

Study cohort

Between 2004 and 2014, the NCDB captured 243,466 rectal cancer diagnoses in the USA. After applying exclusion criteria, data from 110,167 patients were available. Of these patients, 7045 (6.39%) had unplanned readmissions within 30 days of surgery. Readmitted and

non-readmitted patients differed substantially in baseline characteristics prior to propensity matching (Table 1). After 2:1 propensity score matching, all baseline variables were well-balanced, resulting in 13,756 non-readmitted and 6878 readmitted patients.

Risk factors for readmission

Twenty-five patient and hospital factors were examined for potential associations with readmission. In adjusted analysis of the original cohort, factors most strongly associated with readmission included Charlson/Deyo comorbidity score [score 0-reference; score 1, Odds Ratio (OR) 1.25, 95% Confidence Interval (CI) 1.17–1.33, $p < 0.001$; score ≥ 2, OR 1.41, 95% CI 1.28–1.56, $p < 0.001$], hospital geographic region (West-reference; Northeast, OR 1.49, 95% CI 1.36–1.64, $p < 0.001$; South, OR 1.42, 95% CI 1.30–1.54, $p < 0.001$; Midwest, OR 1.46, 95% CI 1.34–1.59, $p < 0.001$), median household income (≥$63,000-reference; $48,000–$62,999, OR 1.10, 95% CI 1.02–1.19, $p = 0.009$; $38,000–$47,999, OR 1.11, 95% CI 1.02–1.21; <$38,000, OR 1.16, 95% CI 1.04–1.28), insurance type (private-reference; Medicaid, OR 1.31, 95% CI 1.18–1.45, $p < 0.001$; Medicare, OR 1.09, 95% CI 1.02–1.17, $p = 0.015$; uninsured, OR 1.15, 95% CI 1.01–1.30, $p = 0.031$), prolonged LOS (normal LOS-reference; OR 1.20, 95% CI 1.13–1.27, $p < 0.001$), and procedure type (partial proctectomy-reference; total proctectomy, OR 1.16, 95% CI 1.10–1.22, $p < 0.001$) (Table 2). Several factors associated with decreased odds of readmission included shortened LOS, chemotherapy, further distance to index hospital (≥25 miles), and age. Factors significant on unadjusted but not on adjusted analysis included male sex, black/other race, and no high school diploma.

Impact of readmission on overall survival

Within the matched cohort, Kaplan–Meier survival curves with log-rank test demonstrated that patients with unplanned readmissions had worse overall 5- and 10-year OS compared to patients with no readmissions ($p < 0.001$ for both) (Fig. 1). These observations were maintained after stratifying by clinical stage (Fig. 2a–d). OS rates at 5- and 10-year marks were 58.98% (95% CI: 57.56–60.37 and 41.01% (95% CI: 38.87–43.14) for readmitted patients, and 64.96% (95% CI: 63.99–65.91) and 43.50% (95% CI: 41.95–45.05) for non-readmitted patients. Median survival for all patients was 94.85 (interquartile range: 37.72, 141.96) months. Median survival for readmitted patients was 13.14 months shorter than that of non-readmitted patients (85.03 vs. 98.17 months). Difference in survival time was 18.14 months in the original, non-matched cohort

Table 2 Factors associated with 30-day readmission after surgery for rectal cancer

Factor	OR (95% CI)	*p*
Demographic factors		
Age group, years		
<50	Reference	
50–59	0.93 (0.86–1.02)	0.121
60–69	0.91 (0.83–0.99)	0.042
70–79	0.86 (0.77–0.95)	0.004
≥80	0.85 (0.75–0.95)	0.006
Male	1.05 (0.99–1.10)	0.080
Race		
White	Reference	
Black	1.05 (0.96–1.15)	0.299
Other	0.91 (0.79–1.03)	0.145
Unknown	0.68 (0.49–0.95)	0.022
No high school diploma, %		
<7.0	Reference	
7–12.9	1.03 (0.95–1.10)	0.504
13.0–20.9	1.00 (0.91–1.09)	0.921
≥21	1.03 (0.93–1.15)	0.518
Unknown	0.97 (0.24–3.94)	0.961
Median household income, $		
≥63,000	Reference	
62,999–48,000	1.10 (1.02–1.19)	0.009
47,999–38,000	1.11 (1.02–1.21)	0.016
<38,000	1.16 (1.04–1.28)	0.006
Unknown	0.98 (0.30–3.15)	0.968
Insurance type		
Private	Reference	
Medicare	1.09 (1.02–1.17)	0.015
Medicaid	1.31 (1.18–1.45)	<0.001
Other government	0.91 (0.70–1.19)	0.484
Uninsured	1.15 (1.01–1.30)	0.031
Unknown	1.38 (1.14–1.66)	0.001
Patient location		
Metro	Reference	
Urban	1.08 (1.00–1.17)	0.049
Rural	1.21 (1.03–1.42)	0.021
Unknown	1.01 (0.85–1.20)	0.881
Distance to hospital, mi		
0–5	Reference	
5–10	1.00 (0.93–1.07)	0.969
10–25	0.95 (0.88–1.02)	0.137
≥25	0.85 (0.79–0.92)	<0.001
Unknown	1.08 (0.49–2.39)	0.839
Clinical/oncologic factors		
Charlson/Deyo score		
0	Reference	
1	1.25 (1.17–1.33)	<0.001

Table 2 continued

Factor	OR (95% CI)	*p*
≥2	1.41 (1.28–1.56)	<0.001
Grade differentiation		
Well	Reference	
Moderate	1.09 (1.00–1.21)	0.050
Poor	1.14 (1.02–1.28)	0.020
Undifferentiated	1.14 (0.90–1.44)	0.271
Unknown	1.02 (0.91–1.15)	0.723
Clinical stage		
I	Reference	
II	1.12 (1.01–1.24)	0.027
III	1.12 (0.98–1.27)	0.088
IV	1.13 (0.98–1.30)	0.086
Procedure type		
Partial proctectomy	Reference	
Total proctectomy	1.16 (1.10–1.22)	<0.001
Radiation therapy		
No	Reference	
Yes	1.04 (0.96–1.13)	0.301
Unknown	1.39 (1.05–1.83)	0.021
Chemotherapy		
No	Reference	
Yes	0.90 (0.82–0.98)	0.017
Unknown	1.04 (0.87–1.24)	0.683
Hormone therapy		
No	Reference	
Yes	0.60 (0.28–1.28)	0.187
Unknown	1.06 (0.91–1.24)	0.424
Pathologic T		
0/IS	Reference	
I	0.96 (0.82–1.11)	0.560
II	0.93 (0.81–1.06)	0.296
III	0.83 (0.74–0.94)	0.003
IV	0.84 (0.71–0.99)	0.039
Unknown/undetermined	0.94 (0.79–1.13)	0.526
Pathologic N		
0	Reference	
I	0.98 (0.88–1.10)	0.739
II	1.03 (0.92–1.17)	0.528
Unknown/undetermined	0.75 (0.65–0.87)	<0.001
Tumor size, cm		
<3	Reference	
3–4.9	0.96 (0.90–1.03)	0.295
≥5.0	0.99 (0.92–1.06)	0.679
Unknown	1.05 (0.97–1.14)	0.227
Margins		
Negative	Reference	
Positive	1.11 (1.01–1.22)	0.033
Unknown	0.86 (0.68–1.09)	0.207
Length of stay, days		
Normal	Reference	
Shortened	0.78 (0.74–0.84)	<0.001
Prolonged	1.20 (1.13–1.27)	<0.001
Unknown	0.22 (0.19–0.26)	<0.001
Hospital factors		
Hospital type		
Community Cancer Program	Reference	
Academic/Research Program	1.06 (1.00–1.13)	0.034
Integrated Network Cancer Program	1.03 (0.95–1.12)	0.472
Unknown	1.48 (1.26–1.73)	<0.001
Hospital geographic location		
West	Reference	
Northeast	1.49 (1.36–1.64)	<0.001
South	1.42 (1.30–1.54)	<0.001
Midwest	1.46 (1.34–1.59)	<0.001
Unknown	–	

OR odds ratio, *CI* confidence interval

Adjusted for factors with $p < 0.25$ in the unadjusted analysis

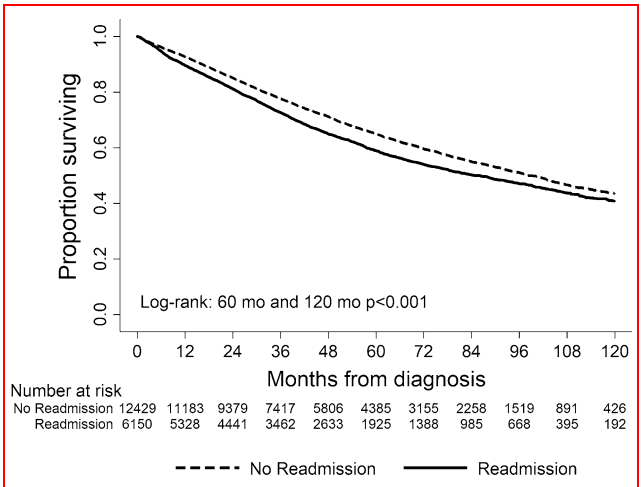

Fig. 1 Kaplan–Meier overall survival curves for surgical rectal cancer patients who were readmitted compared with those who were not readmitted (matched cohort)

(87.98 vs. 106.12 months). Cox proportional regression analysis produced similar results, with readmitted patients at increased risk of mortality on unadjusted [Hazard Ratio (HR) 1.26, 95% CI 1.21–1.32, $p < 0.001$] and adjusted analyses (HR 1.20, 95% CI 1.15–1.25, $p < 0.001$) (Table 3). OS continued to be significantly worse for readmitted patients even after stratifying by cancer stage.

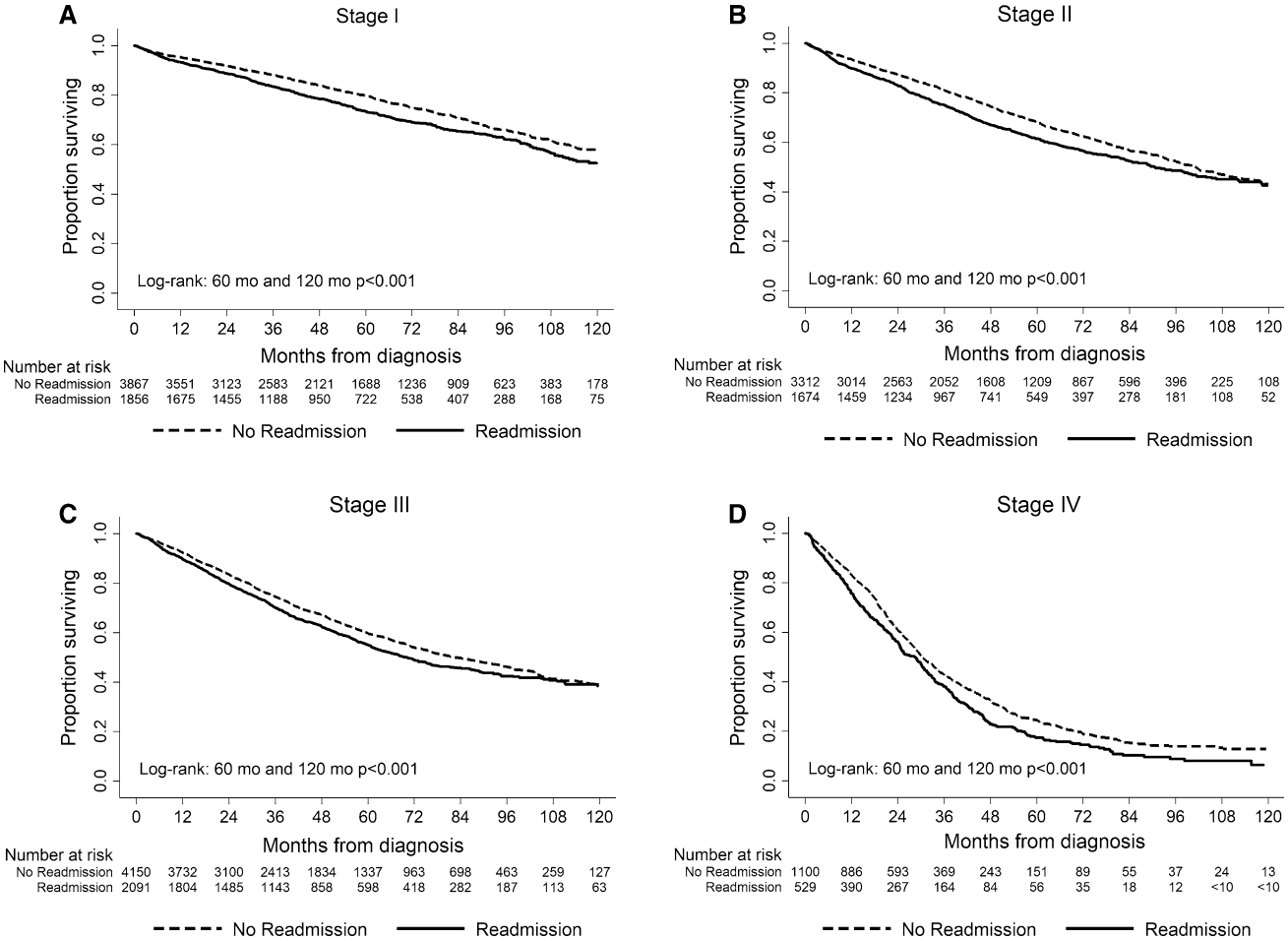

Fig. 2 **a–d** Kaplan–Meier overall survival curves by disease stage for surgical rectal cancer patients who were readmitted compared with those who were not readmitted (matched cohort)

In subgroup analysis, OS was evaluated for procedure type and surgical approach. In the matched cohort, 5- and 10-year OS was significantly worse for patients readmitted after partial proctectomy or total proctectomy ($p < 0.001$) (Fig. 3a–b). Five-year unadjusted OS was significantly worse for readmitted patients after laparoscopic ($p = 0.009$) and open procedures (<0.001), but not after robotic ($p = 0.972$) and conversion to open ($p = 0.814$). However, adjusted Cox proportional regression analysis of the original cohort demonstrated that only patients after open procedure ($p < 0.001$) had increased risk of mortality when readmitted.

Discussion

Hospital readmission has undergone increased scrutiny. This is the first study using the NCDB to determine the impact of 30-day readmission on 5- and 10-year OS in patients undergoing rectal cancer surgery. Our study demonstrates that matched cohort patients readmitted within 30 days after discharge from rectal cancer surgery had significantly decreased 5- and 10-year OS, with median survival time 13.14 months less than that of non-readmitted patients. Adjusted Cox proportional regression analysis of the original cohort showed that readmitted patients had a 1.20 times hazard rate of mortality. Similar findings were maintained after clinical stage stratification. These findings suggest that readmission after surgery may have important implications on survival outcomes for patients with rectal cancer.

Factors associated with readmission after rectal cancer surgery in our study are consistent with those reported in the literature. In our study, sociodemographic factors including hospital geographic region, household income, and insurance status were found to impact readmission after rectal cancer surgery. This is consistent with study findings that described non-privately insured patients as

Table 3 Overall survival rates and survival time; Cox proportional hazard models: impact of readmission on overall survival

Models	Readmission status	Matched cohort			Original cohort
		5-year OS % (95% CI)	10-year OS % (95% CI)	Median (IQR) OS Months	Adjusted HR (95% CI)
All patients		62.98 (62.18–63.77)	42.66 (41.41–43.92)	94.85 (37.72, 141.96)	
	No Readmission	64.96 (63.99–65.91)	43.50 (41.95–45.05)	98.17 (40.48, 141.04)	Reference
	Readmission	58.98 (57.56–60.37)	41.01 (38.87–43.14)	85.03 (32.59, 141.96)	1.20 (1.15–1.25)[a]
Stage					
Stage I patients	No Readmission	79.66 (78.16–81.07)	57.33 (54.38–60.17)	130.33 (71.43, 141.04)	Reference
	Readmission	73.57 (71.19–75.78)	52.73 (48.42–56.84)	129.08 (56.77, *)	1.28 (1.16–1.39)[b]
Stage II patients	No Readmission	68.15 (66.28–69.94)	43.28 (40.07–46.45)	101.19 (47.18, *)	Reference
	Readmission	61.40 (58.69–64.00)	42.88 (38.77–46.93)	90.41 (36.01, 141.96)	1.22 (1.13–1.32)[b]
Stage III patients	No Readmission	59.70 (57.96–61.39)	39.01 (36.42–41.58)	82.30 (35.38, 140.32)	Reference
	Readmission	55.08 (52.59–57.49)	38.43 (34.91–41.93)	69.68 (30.29, *)	1.15 (1.08–1.24)[b]
Stage IV patients	No Readmission	24.65 (21.76–27.64)	12.86 (9.97–16.13)	30.23 (17.45, 58.18)	Reference
	Readmission	17.48 (13.97–21.31)	6.33 (3.00–11.39)	28.39 (12.52, 46.55)	1.18 (1.07–1.31)[b]
Procedure type					
Partial proctectomy patients	No Readmission	66.27 (65.07–67.43)	46.56 (44.65–48.44)	106.48 (42.15, 141.04)	Reference
	Readmission	60.27 (58.54–61.97)	43.53 (40.99–46.04)	90.68 (33.58,1 41.96)	1.22 (1.16–1.29)[c]
Total proctectomy patients	No Readmission	62.55 (60.87–64.17)	37.89 (35.23–40.55)	87.59 (38.01, NA)	Reference
	Readmission	56.51 (54.05–58.89)	36.13 (32.27–40.00)	74.35 (31.15, NA)	1.16 (1.09–1.25)[c]

OS overall survival, *IQR* interquartile range, *NA* not applicable, *HR* hazard ratio, *CI* confidence interval

*Unable to estimate 75th percentile as more than 25% of patients have not died

[a]Adjusted for age, gender, race, origin, high school failure, household income, insurance, location, distance to hospital, Charlson/Deyo, grade, clinical stage, procedure type, radiation therapy, chemotherapy, immunotherapy, pathologic T, pathologic N, tumor size, margins, length of hospital stay, hospital type, and hospital geographic location

[b]Adjusted for age, gender, race, origin, high school failure, household income, insurance, location, distance to hospital, Charlson/Deyo, grade, procedure type, radiation therapy, chemotherapy, immunotherapy, pathologic T, pathologic N, tumor size, margins, length of hospital stay, hospital type, and hospital geographic location

[c]Adjusted for age, gender, race, origin, high school failure, household income, insurance, location, distance to hospital, Charlson/Deyo, grade, clinical stage, radiation therapy, chemotherapy, immunotherapy, pathologic T, pathologic N, tumor size, margins, length of hospital stay, hospital type, and hospital geographic location

having significantly worse 30-day morbidity rates, readmission, ICU stay, and LOS following rectal cancer surgery [15]. That hospital geographic region was associated with readmission may be due to healthcare resource availability. Several studies have investigated the association of readmission and the postdischarge environment, with patients living in low healthcare resource areas having higher risk of readmission [17, 29]. One study utilizing the NCDB demonstrated that geographic access to rectal cancer care may impact whether a patient receives radiation therapy for stage II/III rectal cancer; patients living in areas with limited resource availability were less likely to receive radiation therapy, as that necessitated the need to travel greater distances to receive care [30, 31]. Such geographic barriers may not only hinder access to cancer care, but may also reduce adherence to cancer guidelines. Clinical or hospital-level factors associated with increased odds of readmission in our study included positive margins, prolonged LOS, and academic/research hospitals—all factors that can be attributed to increased complication rates, complexity of disease, and recurrence rates.

Interestingly, shortened LOS and further distance to index hospital were associated with decreased odds of readmission. We hypothesize that patients with shortened LOS did well during their postoperative stay and were therefore more likely to be discharged from the hospital sooner. Some studies have found that longer LOS may be associated with increased odds of readmission due to more complicated perioperative course [19]. Though patients residing further away from the index hospital may appear to have decreased odds of readmission, they may actually have been readmitted to hospitals closer to their residence, which would not have been captured by the NCDB. In fact, increased travel distance to hospital has been found to be associated with increased readmission after major cancer surgery [32].

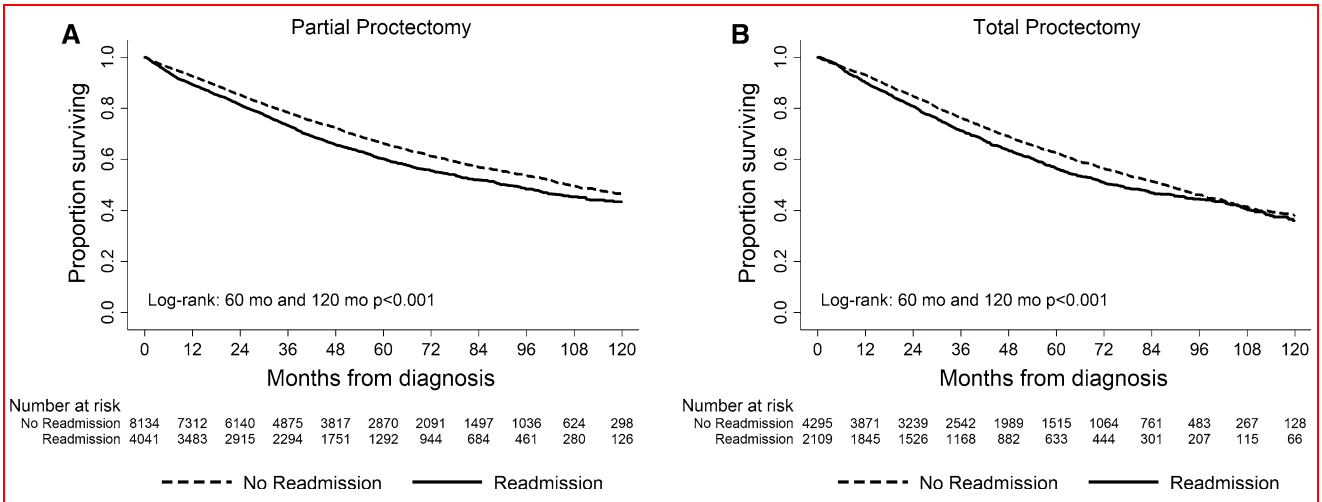

Fig. 3 **a–b** Kaplan–Meier overall survival curves by procedure type for surgical rectal cancer patients who were readmitted compared with those who were not readmitted (matched cohort)

Despite studies on readmission after surgery, the relationship between readmission and survival following cancer resection has not been well elucidated. Of existing studies, readmission has been associated with poorer survival outcomes following lung cancer [33], gastric cancer [20], and colon cancer [18] surgeries. One study showed that 30-day readmission after colectomy for colon cancer was associated with 2.44 times increased odds of 1-year mortality in readmitted versus non-readmitted patients [7]. Interestingly, another study showed that readmission after colorectal cancer resection (of which 41.3% were rectal cancer patients) alone did not significantly impact 5-year OS [34, 35]. As the authors noted, their study may have been limited by sample size and lack of additional oncological factors. Our study differs from the aforementioned study by including potential differences in cancer care practice and resource utilization.

Our study demonstrated statistically significantly decreased 5- and 10-year OS on Kaplan–Meier analysis and log-rank test for patients readmitted within 30 days after discharge from rectal cancer surgery, even after stratifying by clinical stage and performing subgroup analyses for procedure type and surgical approach. Median survival time was 13.14 months less for readmitted patients. Readmitted patients may have delayed adjuvant therapy initiation, resulting in potentially decreased tumor control, higher local recurrence rate with pelvic sepsis, and higher risk of micrometastases. In some studies, postoperative complications and readmissions were risk factors for delayed chemotherapy, and patients who received chemotherapy $\geq$8 weeks postoperatively had worse disease-free and OS [36]. Patients undergoing rectal cancer surgery may be readmitted for reasons such as wound infection, dehydration, anastomotic leak, and pelvic sepsis. These complications may increase local recurrence rates and decrease survival. Given that 30-day readmission was an independent predictor of OS after rectal cancer surgery, efforts to reduce readmission for this specific patient population should be highly considered. Preventing and reducing readmissions after rectal cancer surgery may improve long-term patient outcomes by reducing delays in adjuvant chemotherapy while decreasing financial burdens placed on the healthcare system.

Our study is subject to limitations relating to the data available in the NCDB. Although 2:1 caliper nearest neighbor matching without replacement resulted in excellent covariate balance between readmitted and non-readmitted patients, the potential for unmeasured confounders could have influenced our findings. Several variables known to have significant effects on readmission such as non-cancer-related comorbidities were not available in the NCDB. We attempted to account for this by including the Charlson/Deyo score in our matched and Cox proportional hazards regression analyses, in addition to other patient and clinical characteristics. Additional limitations include the lack of information on disease-free or cancer-specific survival and specific chemotherapy regimens. In terms of unplanned readmission, the NCDB only captures readmission to the index hospital. Our reported readmission rates after rectal cancer surgery were therefore more likely conservative estimates. Furthermore, reasons for readmission are not available in the NCDB, nor is data determining completion or delays of appropriate stage adjuvant therapy. Nevertheless, overall survival rates may be reduced to some extent due to complications leading to readmissions. Such complication-related deaths are therefore likely to

impact overall survival. The numerous strengths of the NCDB overcome the weaknesses otherwise found in administrative/billing datasets, including more detailed information on specific clinical cancer pathology, treatment, hospital-level factors, and sociodemographic factors. These positive attributes enable more granular analysis to be performed.

This study is the first to demonstrate the association of 30-day readmission on poorer 5- and 10-year OS in patients undergoing surgery for rectal cancer. Our findings suggest that hospital readmission after surgery may have important implications on long-term survival outcomes of rectal cancer patients. Efforts to reduce readmission in this patient population should therefore be considered to improve quality of rectal cancer care and enhance overall patient survival.

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Author contributions *Study design* was carried out by SYC, MS, JEE. *Data acquisition and analysis* was performed by SYC, MS, JEE. *Interpretation of data* was handled by SYC, MS, SLG, BS, SHF, NSA, AGM, AKN, CLW, JEE. *Drafting work* was done SYC, MS, JEE. *Critical revision* was carried out by SYC, MS, SLG, BS, SHF, NSA, AGM, AKN, CLW, JEE. *Final approval/accountability* was performed by SYC, MS, SLG, BS, SHF, NSA, AGM, AKN, CLW, JEE.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

References

1. Centers for Medicare & Medicaid Services (2016) Readmissions Reduction Program (HRRP). https://www.cms.gov/medicare/medicare-fee-for-service-payment/acuteinpatientpps/readmissions-reduction-program.html. Accessed 10 November 2016
2. Wick EC, Shore AD, Hirose K et al (2011) Readmission rates and cost following colorectal surgery. Dis Colon Rectum 54:1475–1479
3. Damle RN, Alavi K (2016) Risk factors for 30-d readmission after colorectal surgery: a systematic review. J Surg Res 200:200–207
4. Almussallam B, Joyce M, Marcello PW et al (2016) What factors predict hospital readmission after colorectal surgery? Am Surg 82:433–438
5. Doumouras AG, Tsao MW, Saleh F, Hong D (2016) A population-based comparison of 30-day readmission after surgery for colon and rectal cancer: how are they different? J Surg Oncol 114:354–360
6. Shah PM, Johnston L, Sarosiek B et al (2017) Reducing readmissions while shortening length of stay: the positive impact of an enhanced recovery protocol in colorectal surgery. Dis Colon Rectum 60:219–227
7. Curtis NJ, Noble E, Salib E et al (2017) Does hospital readmission following colorectal cancer resection and enhanced recovery after surgery affect long term survival? Color Dis 19:723–730
8. Slankamenac K, Slankamenac M, Schlegel A et al (2017) Impact of postoperative complications on readmission and long-term survival in patients following surgery for colorectal cancer. Int J Colorectal Dis 32:805–811
9. Kelly KN, Iannuzzi JC, Aquina CT et al (2015) Timing of discharge: a key to understanding the reason for readmission after colorectal surgery. J Gastrointest Surg 19:418–428
10. Bliss LA, Maguire LH, Chau Z et al (2015) Readmission after resections of the colon and rectum: predictors of a costly and common outcome. Dis Colon Rectum 58:1164–1173
11. Bartlett EK, Hoffman RL, Mahmoud NN, Karakousis GC, Kelz RR (2014) Postdischarge occurrences after colorectal surgery happen early and are associated with dramatically increased rates of readmission. Dis Colon Rectum 57:1309–1316
12. Faiz O, Haji A, Burns E, Bottle A, Kennedy R, Aylin P (2011) Hospital stay amongst patients undergoing major elective colorectal surgery: predicting prolonged stay and readmissions in NHS hospitals. Color Dis 13:816–822
13. Hendren S, Morris AM, Zhang W, Dimick J (2011) Early discharge and hospital readmission after colectomy for cancer. Dis Colon Rectum 54:1362–1367
14. Addae JK, Gani F, Fang SY et al (2017) A comparison of trends in operative approach and postoperative outcomes for colorectal cancer surgery. J Surg Res 208:111–120
15. Chan SY, Suwanabol PA, Damle RN et al (2016) Characterizing short-term outcomes following surgery for rectal cancer: the role of race and insurance status. J Gastrointest Surg 20(11):1891–1898
16. Yeo HL, Abelson JS, Mao J, O'Mahoney PRA, Milsom JW, Sedrakyan A (2017) Surgeon annual and cumulative volumes predict early postoperative outcomes after rectal cancer resection. Ann Surg 265:151–157
17. Lin CC, Bruinooge SS, Kirkwood MK et al (2016) Association between geographic access to cancer care and receipt of radiation therapy for rectal cancer. Int J Radiat Oncol Biol Phys 94:719–728
18. Greenblatt DY, Weber SM, O'Connor ES, LoConte NK, Liou J-I, Smith MA (2010) Readmission after colectomy for cancer predicts one-year mortality. Ann Surg 251:659–669
19. Stitzenberg KB, Chang Y, Smith AB, Nielsen ME (2015) Exploring the burden of inpatient readmissions after major cancer surgery. J Clin Oncol 33:455–464
20. Merchant S, Ituarte P, Choi A et al (2015) Hospital readmission following surgery for gastric cancer: frequency, timing, etiologies, and survival. J Gastrointest Surg 19:1769–1781
21. National Cancer Database. https://www.facs.org/qualitypograms/cancer/ncdb. Accessed 13 February 2017

22. Census regions and divisions of the United States (2017) https://www2.census.gov/geo/pdfs/maps-data/maps/reference/us_regdiv.pdf. Accessed 16 May 2017
23. Hosmer DW, Lemeshow S, Sturdivant RX (2000) Applied logistic regression, 2nd edn. Wiley, New York
24. Leuven E, Sianesi B (2017) PSMATCH2: stata module to perform full Mahalanobis and propensity score matching, common support graphing, and covariate imbalance testing. Stat Softw Compon. https://ideas.repec.org/c/boc/bocode/s432001.html. Accessed 17 May 2017
25. Austin PC (2010) Statistical criteria for selecting the optimal number of untreated subjects matched to each treated subject when using many-to-one matching on the propensity score. Am J Epidemiol 172:1092–1097
26. Austin PC (2014) A comparison of 12 algorithms for matching on the propensity score. Stat Med 33:1057–1069
27. Austin PC (2011) Optimal caliper widths for propensity-score matching when estimating differences in means and differences in proportions in observational studies. Pharm Stat 10:150–161
28. Ho DE, Imai K, King G, Stuart EA (2007) Matching as nonparametric preprocessing for reducing model dependence in parametric causal inference. Polit Anal 15:199–236
29. Cerullo M, Gani F, Chen SY, Canner JK, Pawlik TM (2016) Readmission after major surgery: effect of the postdischarge environment. J Surg Res 205:318–326
30. Damle RN, Cherng NB, Flahive JM et al (2014) Clinical and financial impact of hospital readmissions after colorectal resection: predictors, outcomes, and costs. Dis Colon Rectum 57:1421–1429
31. Kiran RP, Delaney CP, Senagore AJ, Steel M, Garafalo T, Fazio VW (2004) Outcomes and prediction of hospital readmission after intestinal surgery. J Am Coll Surg 198:877–883
32. Fernandez FG, Khullar O, Force SD et al (2015) Hospital readmission is associated with poor survival after esophagectomy for esophageal cancer. Ann Thorac Surg 99:292–297
33. Puri V, Patel AP, Crabtree TD et al (2015) Unexpected readmission after lung cancer surgery: a benign event? J Thorac Cardiovasc Surg 150:1496–1504 **1505.e1–1505.e15; discussion 1504–1505**
34. Tevis SE, Kohlnhofer BM, Stringfield S et al (2013) Postoperative complications in patients with rectal cancer are associated with delays in chemotherapy that lead to worse disease-free and overall survival. Dis Colon Rectum 56:1339–1348
35. Jamnagerwalla M, Tay R, Steel M et al (2016) Impact of surgical complications following resection of locally advanced rectal adenocarcinoma on adjuvant chemotherapy delivery and survival outcomes. Dis Colon Rectum 59:916–924
36. Paun BC, Cassie S, Maclean AR, Dixon E, Buie WD (2010) Postoperative complications following surgery for rectal cancer. Ann Surg 251:807–818

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