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A nationwide analysis of readmission rates after colorectal cancer surgery in the US in the Era of the Affordable Care Act

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ABSTRACT

Background & aims: The Hospital Readmissions Reduction Program (HRRP), which was instituted in 2012, may have affected readmission rates for non-target conditions, including colorectal cancer (CRC). We aimed to analyze the nationwide all-cause 30-day readmission rate following CRC surgery in a US nationwide database.
Methods: We queried the 2010–2015 Nationwide Readmissions Database to estimate readmission rates. All results were weighted for national estimates.
Results: Among 616,348 index cases, the overall 2010–2015 30-day readmission rate was 14.7% (95% confidence interval, 14.5%–14.9% [n = 90,555]), with a decreasing trend from 15.5% in 2010 and 2011 to 13.5% in 2015 (p-trend<0.001). Rectal resection, longer length of stay, non-invasive cancer, surgery at a metropolitan teaching hospital, non-routine discharge, elective admission, and higher Elixhauser co-morbidity score were associated with subsequent readmission.
Conclusions: In the US, 30-day readmission rates after CRC surgery showed a decreasing trend during 2010–2015, which could represent a spillover effect of the HRRP.

Introduction

There is great interest in strategies that optimize short-term and long-term clinical outcomes while reducing costs, particularly in the context of continued increases in overall healthcare expenditures. Because surgery is the mainstay of the initial treatment of colorectal cancer (CRC), the evaluation of perioperative quality indicators is relevant to the assessment of the overall quality of care for this common cancer. Population-based databases provide the best estimates of CRC-related outcomes in the community.

Hospital readmission after surgery is relatively common, ranging from 5% to 16% by specialty.[1] After colorectal resection for benign or malignant disease, the rate of readmission within 30 days of discharge has been reported to be approximately 10%–14%.[2–5] Readmission has become a major hospital quality metric, since it often represents an adverse patient event, results in increased cost of care, and sometimes serves as an indicator of underlying sub-optimal care. Indicators of surgical quality may be used to compare performances between hospitals and may influence health care policy. For example, if optimal perioperative CRC care is found to be associated with surgeon or hospital volume within a specific healthcare system, a policy of centralization of CRC surgery may be pursued.

In an effort to reduce excess hospital readmissions, lower health care costs, and improve patient safety and outcomes, the Centers for Medicare and Medicaid Services (CMS) launched the Hospital

Abbreviations: aOR, adjusted odds ratio; APR-DRG, All Patient Refined Diagnosis-Related Groups; CI, confidence interval; CRC, colorectal cancer; HCUP, Healthcare Cost and Utilization Project; NRD, Nationwide Readmissions Database.

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Readmissions Reduction Program (HRRP) in October 2012 under the 2010 Patient Protection and Affordable Care Act. The HRRP includes penalties in reimbursement for hospitals with higher than expected readmission rates. The HRRP targets Medicare beneficiaries aged 65 year or more with specific conditions, including acute myocardial infarction, heart failure, pneumonia, chronic obstructive pulmonary disease, coronary artery bypass graft surgery, and elective primary total hip arthroplasty and/or total knee arthroplasty.[6] There has been great interest whether the HRRP exerted an influence among non-target conditions, and reports have shown a decrease in 30-day readmission rates even among the non-targeted populations.[7,8]

The Nationwide Readmissions Database (NRD) is part of a family of databases developed for the Healthcare Cost and Utilization Project (HCUP). The NRD is drawn from the HCUP State Inpatient Databases (SID), which can be used to create estimates of national readmission rates for all payers and for uninsured patients. Several reports of readmission after colorectal surgery have used the NRD.[9,10] However, these studies used only one or two years of data for analysis, and there has been no nationwide study that addressed the readmission rate after CRC surgery specifically.

In this study, we aimed to describe US nationwide 30-day readmission rates after CRC surgery, to determine the causes for readmission, to explore predictors of readmission, and to characterize the trend in readmission rates over time. We analyzed these outcomes based on NRD data from 2010 to 2015, which covers the launch of the HRRP.

Materials and methods

Data source

We used data from HCUP, representing the largest collection of longitudinal hospital care data in the US. HCUP data is developed through a federal and state partnership and is sponsored by the Agency for Healthcare Research and Quality (AHRQ). We focused on the NRD, which is designed to support various types of analyses of national readmission rates for all payers and the uninsured. The NRD includes data on discharges for patients with and without repeat hospital visits in a year, and for those who have died in the hospital.

This project used de-identified data and was therefore exempt from institutional review board review.

Identification of index admission

Index admission was defined as admission of an adult patient with CRC who underwent colorectal resection and survived until index discharge. We first identified all hospitalized persons who were 18 years old or older from January 2010 to November 2015 (6-year period) with a diagnostic code representing a primary colorectal neoplasm. The ICD-9 codes (January 2010 to September 2015) and ICD-10 codes (October and November 2015) used to define a diagnosis of CRC are listed in Supplementary Table 1. We included only malignant neoplasm and carcinoma in situ of epithelial origin. Tumors that arise from only the subepithelial layer, or the appendix or anus were not included.

We then identified the subset of patients with CRC who underwent colonic and/or rectal resection during that hospitalization. ICD-9 and ICD-10 procedure codes used to define colorectal resection are described in Supplementary Table 2. Surgical procedures were classified into open vs laparoscopic using the ICD-9 procedure coding system (PCS) and ICD-10 PCS codes as shown in Supplementary Table 3 and Supplementary Table 4, respectively.

Since the NRD does not track patients across years, estimates for 30-day readmission for patients discharged in the month of December would be underestimates, given the follow-up of <30 days for many of these patients. We therefore excluded patients discharged in December in any of the study years. Patients who died during index admission were excluded from the analysis (Fig. 1).

Patient outcomes

The primary outcome was all-cause readmission within 30 days after index discharge. The diagnoses representing the top cumulative 90% of primary diagnoses during readmissions were determined based on All Patient Refined Diagnosis-Related Groups (APR-DRG) for the readmission. APR-DRGs are a patient classification system developed by the Centers for Medicare and Medicaid Services for the purposes of calculating payment, comparing hospitals, and measuring quality that considers a patient's severity of illness,

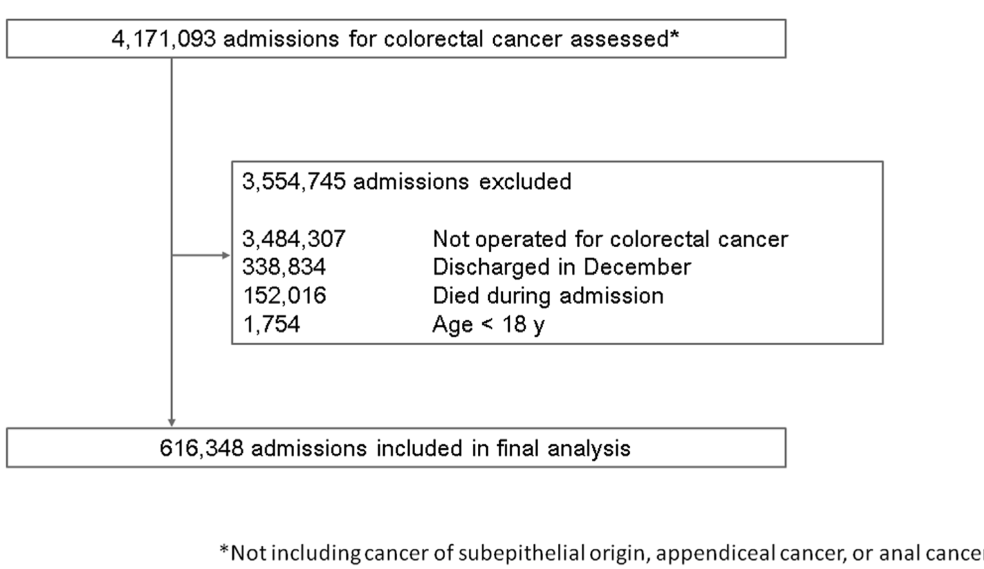

Fig. 1. Selection of index cases, US national estimates.

Table 1
Patient and hospital baseline characteristics at index admissions.

Year	2010		2011		2012		2013		2014		2015		Overall	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Frequency	106,362	17.3%	104,645	17.0%	103,299	16.8%	101,265	16.4%	100,719	16.3%	100,057	16.2%	616,348	100.0%
Age														
18-44y	5458	5.1%	5485	5.2%	5206	5.0%	5266	5.2%	5377	5.3%	5440	5.4%	32,231	5.2%
45-54y	14,784	13.9%	14,459	13.8%	14,529	14.1%	14,520	14.3%	14,040	13.9%	14,354	14.4%	86,686	14.1%
55-64y	22,934	21.6%	22,526	21.5%	22,232	21.5%	22,139	21.9%	22,842	22.7%	23,157	23.1%	135,830	22.0%
65-74y	28,113	26.4%	27,531	26.3%	27,683	26.8%	26,879	26.5%	26,996	26.8%	26,803	26.8%	164,006	26.6%
75-84y	25,075	23.6%	24,428	23.3%	23,817	23.1%	22,952	22.7%	22,151	22.0%	21,310	21.3%	139,733	22.7%
85y-	9998	9.4%	10,216	9.8%	9833	9.5%	9509	9.4%	9314	9.3%	8992	9.0%	57,862	9.4%
Gender														
Male	53,388	50.2%	52,876	50.5%	52,393	50.7%	52,029	51.4%	51,363	51.0%	51,854	51.8%	313,904	50.9%
Female	52,975	49.8%	51,769	49.5%	50,906	49.3%	49,236	48.6%	49,356	49.0%	48,203	48.2%	302,444	49.1%
All patient refined DRG severity of illness subclass														
No loss specified	4	0.0%	6	0.0%	19	0.0%	6	0.0%	6	0.0%	0	0.0%	41	0.0%
Minor loss of function	25,468	23.9%	24,415	23.3%	27,148	26.3%	26,145	25.8%	25,450	25.3%	25,523	25.5%	154,149	25.0%
Moderate loss of function	45,606	42.9%	44,676	42.7%	45,156	43.7%	44,498	43.9%	44,017	43.7%	43,814	43.8%	267,767	43.4%
Major loss of function	25,582	24.1%	26,072	24.9%	23,516	22.8%	22,977	22.7%	23,635	23.5%	23,202	23.2%	144,984	23.5%
Extreme loss of function	9702	9.1%	9477	9.1%	7459	7.2%	7639	7.5%	7611	7.6%	7518	7.5%	49,406	8.0%
All patient refined DRG risk of mortality subclass														
No class specified	4	0.0%	6	0.0%	19	0.0%	6	0.0%	6	0.0%	0	0.0%	41	0.0%
Minor likelihood of dying	39,071	36.7%	38,382	36.7%	39,654	38.4%	38,964	38.5%	39,359	39.1%	39,219	39.2%	234,649	38.1%
Moderate likelihood of dying	40,562	38.1%	39,294	37.6%	38,027	36.8%	37,215	36.8%	36,102	35.8%	36,166	36.2%	227,367	36.9%
Major likelihood of dying	18,697	17.6%	19,093	18.3%	19,368	18.8%	18,639	18.4%	18,628	18.5%	18,042	18.0%	112,468	18.3%
Extreme likelihood of dying	8028	7.6%	7870	7.5%	6230	6.0%	6441	6.4%	6624	6.6%	6629	6.6%	41,823	6.8%
Elixhauser comorbidity score														
Mortality score, mean (SEM)	7.78	0.1	7.71	0.1	7.73	0.1	7.75	0.1	7.73	0.1	7.48	0.1	7.7	0.0
Readmission score, mean (SEM)	17.44	0.2	17.41	0.2	17.41	0.2	17.5	0.2	17.71	0.2	17.58	0.1	17.51	0.1
Median household income														
0-25th percentile (lowest)	29,791	28.5%	29,708	28.9%	29,439	29.0%	25,468	25.6%	24,472	24.7%	26,668	27.1%	165,547	27.3%
26th to 50th percentile	26,042	24.9%	24,941	24.2%	24,665	24.3%	27,434	27.6%	27,429	27.7%	25,434	25.8%	155,946	25.7%
51st to 75th percentile	24,620	23.5%	25,312	24.6%	23,895	23.5%	24,689	24.8%	24,029	24.3%	25,095	25.5%	147,642	24.4%
76th to 100th percentile (highest)	24,218	23.1%	22,927	22.3%	23,598	23.2%	21,936	22.0%	23,082	23.3%	21,383	21.7%	137,144	22.6%
Elective vs non-elective admission														
Non-elective	32,641	30.7%	31,482	30.1%	31,521	30.5%	30,557	30.2%	30,086	29.9%	28,503	28.5%	184,790	30.0%
Elective	73,662	69.3%	73,079	69.9%	71,721	69.5%	70,594	69.8%	70,461	70.1%	71,372	71.5%	430,890	70.0%
Primary payer														
Medicare	60,573	57.1%	59,347	56.9%	59,384	57.6%	57,988	57.3%	56,870	56.5%	55,895	55.9%	350,057	56.9%
Medicaid	6516	6.1%	6652	6.4%	6659	6.5%	6483	6.4%	7479	7.4%	7514	7.5%	41,304	6.7%
Private insurance	33,887	32.0%	33,396	32.0%	31,643	30.7%	31,526	31.2%	31,990	31.8%	32,608	32.6%	195,051	31.7%
Self-pay	2377	2.2%	2106	2.0%	2474	2.4%	2401	2.4%	1784	1.8%	1637	1.6%	12,778	2.1%
No charge	295	0.3%	262	0.3%	279	0.3%	418	0.4%	337	0.3%	226	0.2%	1817	0.3%
Other	2414	2.3%	2557	2.5%	2595	2.5%	2380	2.4%	2125	2.1%	2098	2.1%	14,169	2.3%
Admission day was weekend														
weekday	99,610	93.7%	97,930	93.6%	96,697	93.6%	94,864	93.7%	93,995	93.3%	93,526	93.5%	576,621	93.6%
weekend	6753	6.4%	6716	6.4%	6603	6.4%	6401	6.3%	6724	6.7%	6531	6.5%	39,727	6.5%
Robotic surgery														
No robotic	104,798	98.5%	101,864	97.3%	99,097	95.9%	95,331	94.1%	92,777	92.1%	90,052	90.0%	583,919	94.7%
Robotic surgery	1564	1.5%	2781	2.7%	4202	4.1%	5934	5.9%	7943	7.9%	10,005	10.0%	32,429	5.3%
Length of stay (days)														
Mean (SEM)	9.26	0.1	9.06	0.1	8.85	0.1	8.58	0.1	8.41	0.1	8.14	0.1	8.73	0.0
Resected part														
Colon	75,139	70.6%	73,906	70.6%	72,889	70.6%	71,208	70.3%	70,182	69.7%	70,034	70.0%	433,358	70.3%
Rectum	26,222	24.3%	25,372	24.3%	24,795	24.0%	24,342	24.0%	24,584	24.4%	23,899	23.9%	149,215	24.2%
Others	5001	5.1%	5368	5.1%	5615	5.4%	5714	5.6%	5954	5.9%	6124	6.1%	33,776	5.5%
Laparoscopic vs open														
Laparoscopic	31,923	30.0%	33,308	31.8%	35,426	34.3%	34,408	34.0%	35,889	35.6%	37,470	37.5%	208,424	33.8%
open	74,439	70.0%	71,337	68.2%	67,873	65.7%	66,857	66.0%	64,831	64.4%	62,587	62.6%	407,924	66.2%
Invasive cancer vs. CIS														
Carcinoma in situ	4253	4.0%	4301	4.1%	3874	3.8%	3896	3.9%	3.740	3.7%	2.921	2.9%	22,984	3.7%
Invasive cancer	102,109	96.0%	100,345	95.9%	99,425	96.3%	97,369	96.1%	96.980	96.3%	97.136	97.1%	593,365	96.3%
Disposition at discharge														
Routine	64,131	60.3%	63,335	60.5%	63,001	61.0%	62,105	61.3%	62,134	61.7%	61,792	61.8%	376,497	61.1%
transfer to short term hospital	385	0.4%	494	0.5%	424	0.4%	382	0.4%	435	0.4%	341	0.3%	2461	0.4%
other transfers, including skilled nursing facility, intermediate care, and another type of facility	14,994	14.1%	14,888	14.2%	14,506	14.0%	13,991	13.8%	14,211	14.1%	13,776	13.8%	86,367	14.0%
home health care	26,723	25.1%	25,799	24.7%	25,264	24.5%	24,668	24.4%	23,809	23.6%	23,973	24.0%	150,236	24.4%
against medical advice	90	0.1%	88	0.1%	73	0.1%	99	0.1%	94	0.1%	171	0.2%	615	0.1%
discharged alive, destination unknown	40	0.0%	42	0.0%	31	0.0%	20	0.0%	36	0.0%	4	0.0%	172	0.0%
Discharge quarter														
Jan–Mar	28,519	26.8%	27,915	26.7%	28,723	27.8%	26,432	26.1%	27,049	26.9%	26,509	26.5%	165,146	26.8%
Apr–Jun	29,822	28.0%	29,543	28.2%	28,028	27.1%	28,187	27.8%	27,766	27.6%	28,013	28.0%	171,359	27.8%
Jul–Sep	29,350	27.6%	28,506	27.2%	28,273	27.4%	27,809	27.5%	27,721	27.5%	27,440	27.4%	169,099	27.4%
Oct–Nov	18,670	17.6%	18,682	17.9%	18,275	17.7%	18,837	18.6%	18,184	18.1%	18,095	18.1%	110,744	18.0%

(*continued on next page*)

Table 1 (*continued*)

Year	2010		2011		2012		2013		2014		2015		Overall	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Control or ownership of hospital														
Government, nonfederal	12,359	11.6%	12,933	12.4%	11,801	11.4%	10,830	10.7%	10,837	10.8%	10,293	10.3%	69,053	11.2%
Private, non-profit	81,096	76.2%	79,286	75.8%	78,936	76.4%	78,386	77.4%	77,970	77.4%	78,140	78.1%	473,815	76.9%
Private, invest-own	12,908	12.1%	12,426	11.9%	12,562	12.2%	12,048	11.9%	11,912	11.8%	11,624	11.6%	73,481	11.9%
Teaching status of hospital														
Metropolitan nonteaching	42,936	40.4%	41,782	39.9%	38,147	36.9%	37,054	36.6%	25,073	24.9%	25,115	25.1%	210,106	34.1%
Metropolitan teaching	51,834	48.7%	52,112	49.8%	54,574	52.8%	53,631	53.0%	66,713	66.2%	66,198	66.2%	345,061	56.0%
Nonmetropolitan	11,592	10.9%	10,752	10.3%	10,578	10.2%	10,581	10.5%	8934	8.9%	8744	8.7%	61,181	9.9%
Bed size of hospital														
Small	11,653	11.0%	11,237	10.7%	12,490	12.1%	11,440	11.3%	15,554	15.4%	14,363	14.4%	76,738	12.5%
Medium	23,436	22.0%	23,342	22.3%	22,742	22.0%	23,000	22.7%	27,173	27.0%	27,363	27.4%	147,056	23.9%
Large	71,273	67.0%	70,066	67.0%	68,068	65.9%	66,825	66.0%	57,993	57.6%	58,331	58.3%	392,555	63.7%
Hospital urban-rural designation														
large metropolitan areas >1 million residents	59,115	55.6%	57,663	55.1%	57,141	55.3%	54,219	53.5%	54,468	54.1%	54,239	54.2%	336,845	54.7%
small metropolitan areas <1 million residents	35,656	33.5%	36,230	34.6%	35,580	34.4%	36,465	36.0%	37,318	37.1%	37,073	37.1%	218,322	35.4%
micropolitan areas	9601	9.0%	8940	8.5%	8685	8.4%	8364	8.3%	7023	7.0%	6834	6.8%	49,448	8.0%
not metropolitan or micropolitan	1991	1.9%	1811	1.7%	1894	1.8%	2216	2.2%	1910	1.9%	1910	1.9%	11,733	1.9%
Resident of state where procedure was performed														
Non-resident	6689	6.3%	6606	6.3%	6947	6.7%	6352	6.3%	5969	5.9%	6047	6.0%	38,611	6.3%
Resident	99,673	93.7%	98,039	93.7%	96,353	93.3%	94,913	93.7%	94,750	94.1%	94,009	94.0%	577,738	93.7%
Patient location														
Central counties of metropolitan areas of >1 million population	25,794	24.3%	24,639	23.6%	23,850	23.1%	24,065	23.8%	23,427	23.3%	22,947	23.0%	144,722	23.5%
Fringe counties of metropolitan areas of >1 million population	27,758	26.1%	27,709	26.5%	27,813	27.0%	25,189	24.9%	25,919	25.8%	25,751	25.8%	160,139	26.0%
Counties in metropolitan areas of 250,000–999,999 population	20,734	19.5%	20,886	20.0%	20,613	20.0%	19,837	19.6%	21,563	21.5%	21,658	21.7%	125,291	20.4%
Counties in metropolitan areas of 20,000–249,999 population	8676	8.2%	9073	8.7%	8839	8.6%	10,174	10.1%	10,092	10.1%	9945	10.0%	56,799	9.2%
Micropolitan counties	12,381	11.7%	12,117	11.6%	12,180	11.8%	12,338	12.2%	10,147	10.1%	10,021	10.0%	69,184	11.2%
Not metropolitan or micropolitan counties	10,847	10.2%	10,101	9.7%	9847	9.6%	9521	9.4%	9307	9.3%	9621	9.6%	59,244	9.6%

risk of mortality and resource use.[11]

Statistical analysis

Analyses were performed separately for the index admission and for readmissions. To analyze the baseline factors associated with 30-day readmission, covariates for the index admission were selected *a priori*.

We considered the following patient-level covariates: age (grouped by decade), open vs laparoscopic surgical approach, resected site (rectum *vs.* colon), APR-DRG severity of illness subclass, APR-DRG risk of mortality subclass, gender, median household income quartiles, log-transformed length of stay (LOS) (accounting for the skewness of the data), primary payer, disposition at discharge, elective vs non-elective admission, admission day (weekend vs weekday), patient location and discharge month. Resections were categorized into open- and laparoscopic procedures by ICD-9 and ICD-10 codes. Tumors were classified as either carcinoma in situ or invasive cancer according to the ICD-9 and ICD-10 codes. The Elixhauser comorbidity scores for mortality and for readmission were calculated.[12,13]

Hospital-level covariates considered included hospital bed size, hospital ownership, and hospital teaching/metropolitan status (rural, urban teaching, urban non-teaching).

We used logistic regression to estimate the odds of being readmitted within 30 days of index discharge, after accounting for the complex survey design and sampling of the data. Discharge-level weights provided with the dataset were used for national estimates and to account for yearly changes in the sampling design. Appropriate survey-procedures in STATA 15.1 and SAS 9.4 were used to analyze the data taking into consideration the sampling design, strata and weight of the observations. The trend analysis for readmission rate during the study period was performed using the nptrend command in STATA. The nptrend command is the nonparametric test for trend across ordered groups, which is an extension of the Wilcoxon rank-sum test.[7]

Results

Study population

The US national estimate for the number of overall index cases of surgical resection of CRC during 2010–2015 was 616,348. Fig. 1 shows the patient selection procedure. The characteristics of patients and of the hospitals where they received treatment are summarized in Table 1 for the entire study period, and for individual years.

Most patients were 55–84 years old, underwent elective admission during a weekday, and had a routine discharge or a discharge with home health care. There were comparable numbers of men and women, with only a minority classified as having major loss of function or major likelihood of dying. The ratio of colon to rectal operations was approximately 3 to 1, most cases were open, and only 3.7% of operations were for carcinoma in situ. Most hospitals were large, private non-profit, and designated as metropolitan teaching hospitals.

Readmission rates

Among the 616,348 index cases during the entire study period, 90,555 (14.7%; 95% CI 14.5%–14.9%) were readmitted within 30 days of discharge (Table 2). The readmission rate ranged from 15.5% (95% CI 15.0%–16.0%) in 2010 to 13.5% (95% CI 13.1–13.8%) in 2015.

Reasons for readmission

The most common diagnoses at the 30-day readmissions were gastrointestinal (54.8%), infectious (10.6%), and cardio/

Table 2
30-Day readmission rate by year, US national estimates.

Year	2010		2011		2012		2013		2014		2015		Overall	
	N	% (95% CI)	N	% (95% CI)	N	% (95% CI)	N	% (95% CI)	N	% (95% CI)	N	% (95% CI)	N	% (95% CI)
Not readmitted	89,882	84.5% (84.0–85.0)	88,371	84.5% (83.8–85.0)	87,968	85.2% (84.6–85.7)	86,557	85.5% (85.0–85.9)	86,444	85.8% (85.4–86.2)	86,571	86.5% (86.2–86.9)	525,793	85.3% (85.1–85.5)
Readmitted	16,480	15.5% (15.0–16.0)	16,274	15.5% (15.0–16.2)	15,331	14.8% (14.3–15.4)	14,708	14.5% (14.1–15.0)	14,275	14.2% (13.8–14.6)	13,486	13.5% (13.1–13.8)	90,555	14.7% (14.5–14.9)
Total	106,362	100%	104,645	100	103,299	100	101,265	100	100,719	100	100,057	100	616,348	100

95% CI, 95% confidence interval.

cerebrovascular (6.3%) (Supplementary Table 5). The single most common diagnosis code for readmission was "post-operative, post-traumatic, other device infections," accounting for 11.9% of readmissions. This was followed by "malfunction, reaction and complication of GI device or procedure" (8.7%), "intestinal obstruction" (5.9%), and "septicemia and disseminated infections" (5%). For patients who underwent operations for carcinoma in situ, the diagnosis codes at readmission were similar to those for patients who underwent operations for invasive cancer (Supplementary Table 6).

Predictors of readmission

Non-adjusted and multivariable adjusted logistic regression analyses for 30-day readmission are shown in Table 3. In multivariable-adjusted analysis, the odds of readmission decreased with advancing age (Table 3), women had lower odds of readmission compared with men (adjusted OR [aOR], 0.941 [95% CI, 0.916–0.966]), and persons with invasive cancer had lower odds of readmission compared with those with carcinoma in situ (aOR, 0.304 [95% CI, 0.288–0.321]). Patients with higher Elixhauser comorbidity score, elective admission (vs non-elective; aOR, 1.072 [95% CI, 1.034–1.111]), longer length of stay, rectal resection (vs. non-rectal resection; aOR, 1.372 [95% CI, 1.324–1.422]), open laparotomy (vs laparoscopic; aOR, 1.172 [95% CI, 1.134–1.212]), non-routine discharge, and teaching status of the hospital for index treatment (vs nonteaching; aOR, 1.109 [95% CI, 1.072–1.147]) had increased odds for readmission.

Trend in readmission rates over time

During the study period, the readmission rate showed a statistically significant decreasing trend from 2010 through 2015 (p-trend < 0.001; Fig. 2). The readmission rate stayed the same at 15.5% in years 2010 and 2011, but decreased from 15.5% in 2011 to 14.8% in 2012, and it then decreased steadily to 13.5% in 2015 (Table 2).

Discussion

In this study, the overall 30-day readmission rate following CRC surgery was 14.7%, with a decreasing trend from 15.5% in 2010 and 2011 to 13.5% in 2015. The most common diagnoses for readmission were gastrointestinal and infectious, followed by a relatively small fraction of cardio/cerebrovascular diagnoses.

Some predictors of readmission identified in our study are not clinically surprising. Higher comorbidity, longer LOS, open laparotomy, and non-routine discharge were associated with increased readmission rate, as was rectal resection. These characteristics are thought to represent a clinically higher risk for postoperative complications. For example, preoperative treatment is often more complex for rectal cancers, pelvic *vs*. abdominal surgical approaches differ, and rectal cancers tend to require higher rates of diverting stomas. However, there were also some characteristics that were not expected to be associated with increased readmission rate. These characteristics were younger age, carcinoma in situ, and elective admission. In a study using the HCUP State Inpatient Database 2007–2011 for Florida acute care hospitals, younger age was also associated with a higher readmission rate after colorectal surgery.[14] It was postulated that older patients with higher risk may not have been offered surgery due to the expectation of poor outcomes and short life expectancy, and hence a selection bias might have caused a better outcome among the elderly patients. Insurance status was also thought to have played a role. Some younger patients without insurance might have presented in a sicker state,

Table 3
Non-adjusted and multivariable adjusted logistic regression for factors associated with 30-day readmission.

Variables	n	Crude OR	P-value	95% CI		Adjusted OR	P-value	95% CI	
Age group									
18-44y	32,231	1				1			
45-54y	86,686	0.882	0.000	0.827	0.94	0.906	0.003	0.849	0.968
55-64y	135,830	0.922	0.012	0.866	0.982	0.913	0.006	0.856	0.974
65-74y	164,006	0.95	0.105	0.894	1.011	0.860	0.000	0.800	0.924
75-84y	139,733	1.022	0.506	0.959	1.089	0.839	0.000	0.778	0.904
>84y	57,862	1.087	0.019	1.014	1.165	0.790	0.000	0.727	0.858
Gender									
male	313,904	1				1			
female	302,444	0.925	0.000	0.902	0.949	0.941	0.000	0.916	0.966
APR DRG severity of illness subclass									
No or minor loss of function	154,190	1							
Moderate loss of function	267,767	1.428	0.000	1.369	1.49				
Major loss of function	144,984	2.302	0.000	2.201	2.409				
Extreme loss of function	49,406	3.232	0.000	3.068	3.404				
Elixhauser comorbidity score for readmission, increase in 1		1.017	0.000	1.016	1.018	1.009	0.000	1.008	1.010
Median household income, quartiles									
1st (lowest)	165,547	1				1			
2nd	155,946	0.933	0.000	0.898	0.97	0.976	0.220	0.938	1.015
3rd	147,642	0.918	0.000	0.883	0.955	0.968	0.124	0.929	1.009
4th (highest)	137,144	0.873	0.000	0.839	0.908	0.942	0.006	0.903	0.983
Elective vs non-elective admission									
non-elective	184,790	1				1			
elective	430,890	0.738	0.000	0.717	0.761	1.072	0.000	1.034	1.111
Primary payer									
Medicare	350,057	1				1			
Medicaid	41,304	1.229	0.000	1.169	1.293	1.085	0.010	1.020	1.155
private insurance	195,051	0.779	0.000	0.756	0.803	0.872	0.000	0.831	0.915
self-pay	12,778	0.894	0.013	0.818	0.977	0.906	0.061	0.818	1.004
no charge	1817	0.978	0.833	0.793	1.206	0.983	0.888	0.778	1.243
other	14,169	0.89	0.009	0.815	0.972	0.911	0.057	0.828	1.003
Admission day									
weekday	576,621	1				1			
weekend	39,727	1.335	0.000	1.274	1.4	1.020	0.461	0.968	1.075
Length of stay									
log(LOS)+0.5, increase in 1		1.814	0.000	1.778	1.85	1.395	0.000	1.358	1.432
Rectal resection									
not rectal resection	433,358	1				1			
rectal resection	149,215	1.453	0.000	1.407	1.5	1.372	0.000	1.324	1.422
other	33,776	1.231	0.000	1.165	1.302	1.152	0.000	1.086	1.223
Laparoscopic vs open									
Laparoscopic	208,424	1				1			
open	407,924	1.637	0.000	1.588	1.687	1.172	0.000	1.134	1.212
Invasive cancer vs CIS									
Carcinoma in situ	22,984	1				1			
Invasive cancer	593,365	0.285	0.000	0.271	0.300	0.304	0.000	0.288	0.321
Patient disposition at discharge									
routine	376,497	1				1			
transfer to short term hospital	2461	2.625	0.000	2.21	3.117	1.617	0.000	1.336	1.957
other transfers, including skilled nursing facility, intermediate care, and another type of facility	86,367	2.382	0.000	2.293	2.474	1.623	0.000	1.547	1.702
home health care	150,236	1.911	0.000	1.851	1.972	1.409	0.000	1.360	1.459
against medical advice	615	2.948	0.000	2.246	3.869	2.251	0.000	1.675	3.025
discharged alive, destination unknown	172	0.453	0.063	0.197	1.044	0.295	0.004	0.127	0.684
Discharge quarter									
Jan–Mar	165,146	1				1			
Apr–Jun	171,359	0.991	0.624	0.957	1.027	1.000	1.000	0.964	1.037
Jul–Sep	169,099	0.953	0.011	0.919	0.989	0.971	0.124	0.935	1.008
Oct–Nov	110,744	0.976	0.248	0.937	1.017	1.011	0.600	0.969	1.055
Ownership of hospital									
Government, non-federal	69,053	1				1			
private, not-for-profit [voluntary]	473,815	0.962	0.109	0.918	1.009	0.972	0.250	0.927	1.020
private, investor-owned [propriety]	73,481	0.973	0.332	0.922	1.028	0.978	0.440	0.924	1.035
Teaching status of hospital									
metropolitan nonteaching	210,106	1				1			
metropolitan teaching	345,061	1.115	0.000	1.078	1.153	1.109	0.000	1.072	1.147
non-metropolitan	61,181	0.901	0.000	0.854	0.951	0.898	0.000	0.848	0.952
Hospital bed size									
small	76,738	1				1			
medium	147,056	1.006	0.849	0.948	1.068	1.013	0.667	0.955	1.075
large	392,555	1.071	0.016	1.013	1.132	1.042	0.140	0.987	1.100

APR DRG, all patient refined diagnosis-related groups; CI, confidence interval; CIS, carcinoma in situ; LOS, length of hospital stay.

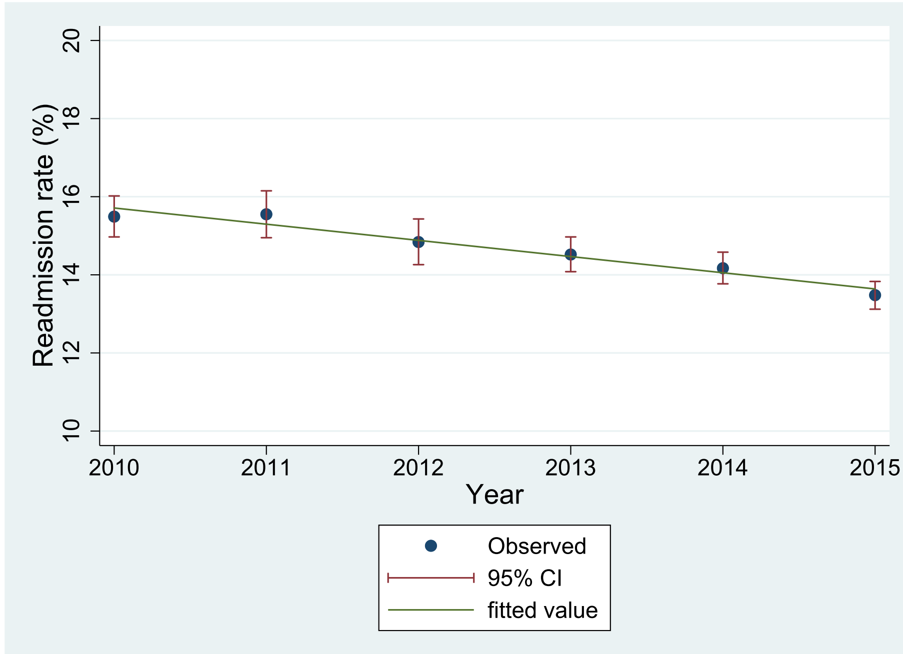

Fig. 2. 30-Day readmission rate in each year and trend over time. The readmission rate showed a statistically significant decreasing trend from 2010 through 2015 (p-trend < 0.001; Table 2).

due to less access to preventive and routine outpatient services.[14]

There is no immediate explanation for why carcinoma in situ and routine admission would be associated with higher odds of readmission. We analyzed the diagnosis codes for readmission with carcinoma in situ, and found a similar distribution to that with invasive cancer. It is possible that a less experienced surgeon might have performed the operation with carcinoma in situ, but the data on surgeon's level of expertise was not available. Regarding elective admission, it is possible that a patient with better access could have had both elective index admission and more ready access to readmission for problems that could possibly be handled on an outpatient basis, resulting in higher readmission rate. Because statistical significance can be achieved with administrative data analyses based on large sample sizes, clinical relevance has to be taken into account when interpreting our results.[15] The potential clinical significance of these curious observations is not clear at this time.

Our results are in contrast with those of a previous Florida State Inpatient Database analysis, which found no overall decreasing trend in readmissions during 2007–2011.[14] We found a significant decrease of 2% in the national readmission rate during our 2010–2015 study period. We believe that this difference could relate to the implementation of the HRRP, which was started in October 2012 by CMS.[6] The HRRP reduced payments to hospitals with excess readmissions among Medicare patients with certain medical conditions.[16] The fact that the readmission rate after CRC surgery began to decrease steadily in 2012 supports a possible association between our findings and the national CMS policy. Although CRC is not included in the HRRP target conditions, a spillover effect is possible. A recent report showed a decreasing trend in 30-day readmissions even among non-target Medicare patients during 2010–2014, an effect that was interpreted as a spillover effect.[8] In another study that compared the readmission rates among target and non-target conditions during 2010–2015, there was a modest, but significant decrease of readmission rates among non-target conditions.[7] We believe that the decreasing trend in readmissions after CRC surgery shown in our study may be another example of the spillover effect reflecting a positive influence of the CMS policy implemented in 2012. However, we cannot determine in the current study design whether our findings resulted from concerted efforts directed at improving care during the index admission for CRC resection specifically, broader initiatives aimed at decreasing readmission rates overall, or secular changes in practice patterns that raise the threshold for readmission, and whether these might have been in response to the HRRP.

A strength of our study is its focus on CRC. Previous studies have focused on post-operative readmission after colorectal operations in general.[9,14] CRC represents a distinct clinical setting compared to benign colorectal conditions such as bleeding, diverticulitis, or inflammatory bowel disease. For this reason, we decided to explore it as a unique entity. Our results should be placed in the context of previous research. In a study of readmission after major cancer surgery using the 2013 NRD, the 30-day readmission rate after colectomy was 13.1%, but that study did not include proctectomies.[10] Other studies appear not to have used NRD strata and sampling weights to calculate the number of readmissions.[9,10] We believe that our results based on 2010–2015 data that include both proctectomy cases and proper weighting provides the most reliable US national estimates.

Our study has several limitations. Analysis of administrative data is subject to errors in patient classification and coding.[7] Potentially important clinical data are not available, such as the rate of anastomotic leak, specific preoperative patient conditions, or cancer staging at the time of surgery. Intraoperative data including operative time, specific operative techniques, intraoperative complications, American Society of Anesthesiologists classification, and stability at the time of procedure completion were also not available. There are inherent limitations in the NRD itself. Race, which is captured by other HCUP databases, such as the Nationwide Inpatient Sample, is not available in the NRD.[17–19] The NRD also only captures intrastate readmissions. The national rate of readmission to a different hospital across state lines after colorectal surgery is unknown.[9] The travel distance to hospital, which could impact readmission rate,[20] could also not be analyzed with NRD.

Despite these limitations, to the best of our knowledge, this study is the first to assess the temporal changes in readmission after CRC surgery before and after implementation of the HRRP. We used multiple years of data from the NRD, which is a nationally-representative database with a large sample size and a complex sampling design that can be used to create estimates of national readmission rates for all payers and the uninsured. The NRD also provides sufficient data for analysis across different types of hospital, and includes data on reasons for returning to the hospital for care.[6]

In conclusion, this study provides national estimates of hospital readmission rates after surgery for CRC and the leading reasons for readmission, as well as characterizing factors associated with readmission. The temporal trend in readmission rates may reflect a spillover effect from the HRRP. The minimum readmission rate that is achievable after CRC surgery is unknown. It remains to be determined whether intensified quality improvement efforts can further decrease the rates of specific complications such as obstruction, leak or infection, or whether predictors of complications can influence the care of individual patients. Further reductions in the readmission rate after CRC resection will provide clinical benefits to patients, as well as operational and economic benefits to healthcare systems.

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Author contributions

Study concept and design: JWK, UL and GS; acquisition of data: MS, A Mithal, GS and A Mannalithara; analysis and interpretation of data: JWK, A Mannalithara, GS and UL; drafting of the manuscript: JWK; critical revision of the manuscript for important intellectual content: all authors; statistical analysis: JWK; obtained funding: JWK and GS; administrative, technical, or material support: GS; study supervision: UL and GS.

Declaration of competing interest

The authors disclose no conflicts.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.amjsurg.2020.04.013.

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