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Robotic proctectomy for rectal cancer in the US: a skewed population

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Abstract

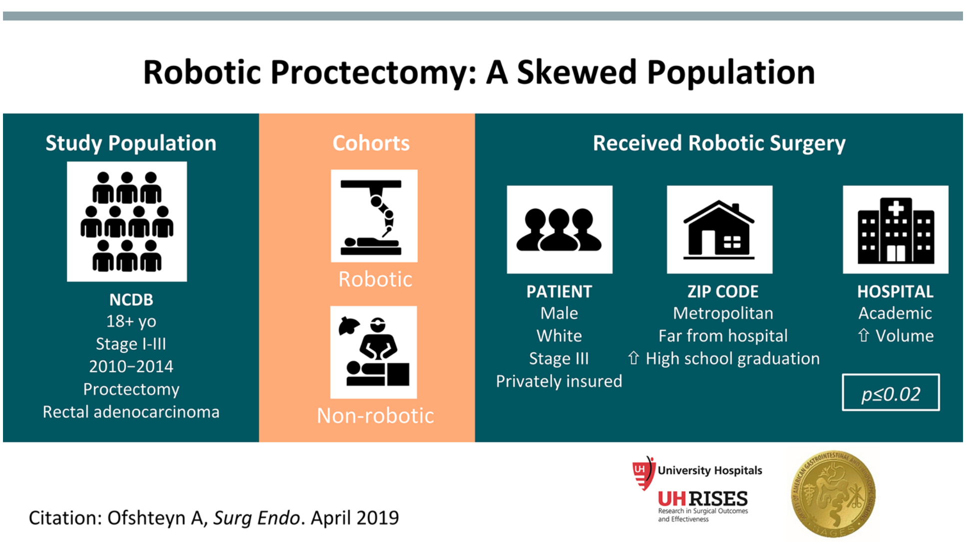
Background Socioeconomic and racial differences have been associated with disparities in cancer care within the US, including disparate access to minimally invasive surgery for rectal cancer. We hypothesized that robotic approach to rectal cancer may be associated with similar disparities.

Methods The National Cancer Database (NCDB) was used to identify patients over 18 years old with clinical stage I–III rectal adenocarcinoma who underwent a proctectomy between 2010 and 2014. Demographic and hospital factors were analyzed for association with robotic approach. Factors identified on bivariate analyses informed multivariate analysis.

Results We identified 33,503 patients who met inclusion criteria; 3702 (11.1%) underwent robotic surgery with 7.8% conversion rate. Patients who received robotic surgery were more likely to be male, white, privately insured and with stage III cancer. They were also more likely to live in a metropolitan area, more than 25 miles away from the hospital and with a higher high school graduation rate. The treating hospital was more likely to be academic and high volume.

Conclusions Robotic surgery is performed rarely and access to it is limited for patients who are female, black, older, non-privately insured and unable to travel to high-volume teaching institutions. The advantages of robotic surgery may not be available to all patients given disparate access to the robot. This inherent bias in access to robot may skew study populations, preventing generalizability of robotic surgery research.

Graphic abstract



Keywords Robotic surgery · Proctectomy · Rectal cancer · Healthcare disparities · Minimally invasive surgery

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Socioeconomic and racial disparities can place patients at a disadvantage in receiving cutting-edge healthcare. Prior studies have demonstrated that treatment and outcome disparities associated with patient demographics can alter treatment at all stages of rectal cancer care [1]. Minimally invasive (MIS) approaches to rectal cancer resection, including both laparoscopic and robotic surgery, has been previously associated with insurance status [2]. Robotic surgery for rectal cancer care may mimic these trends in disparate access.

Robotic rectal resection has experienced growing market share of proctectomies in the United States [3–5]. In urologic literature, access to hospitals performing robotic prostatectomy was noted to be disproportionately associated with race/ethnicity, income and insurance status [6]. Similarly, robotic hysterectomy is less likely to be performed in black women compared to white, women in lower income categories and women covered by Medicaid [7].

Given unequal access to robotic surgery in other disciplines, the aim of this study was to evaluate if disparities exist in robotic surgery for rectal cancer. This would characterize patient population with limited access to this technology, and to provide insight into the generalizability of clinical trials assessing long-term outcomes of robotic proctectomy. We hypothesized that there would be significant racial and socioeconomic disparities in robotic proctectomy access.

Methods

The National Cancer Database (NCDB) is a nationally recognized oncologic data repository sponsored by the American College of Surgeons and the American Cancer Society. It is collected from Commission on Cancer-accredited medical centers, and includes over 70% of new cancer diagnoses nationwide. The NCDB for rectal cancer was used to identify patients 18 years of age and older with clinical stage I–III rectal adenocarcinoma who underwent a proctectomy between 2010 and 2014, because data on operative approach was only available in NCDB after 2010. Patients with clinical stage I–III rectal adenocarcinoma were included in the analysis. Only patients with adenocarcinoma of the rectum were included. Partial and total proctectomies were included in the analysis; local excisions and unspecified surgery were excluded. Procedures without a specified operative approach, (open, laparoscopic or robotic), were excluded from analysis. Given de-identified nature of the publically available NCDB dataset, this study was designated as “not human subjects research” by our institutional review board, and IRB review, approval and written consent were not required.

Statistical analysis

The outcome of interest was whether a patient received robotic proctectomy. Robotic surgery was defined by intention to treat; patients who were selected for robotic proctectomy but underwent a conversion to an open procedure were included in the robotic cohort for the purpose of this analysis. Bivariate analyses were performed using Pearson χ^2 tests to evaluate for associations between receiving robotic surgery and demographic, socioeconomic, hospital, and clinical factors. Individual demographic variables comprised of sex, age, race, and type of insurance. Clinical factors included Charlson–Deyo score (as a descriptor of comorbidity) and preoperative disease stage. NCDB provides proxy variables for income and level of education based on zip code data. Percent of people living in the patient’s area of residence who obtained a high school degree (ranging from < 7 to > 21%) and median household income (ranging in quartiles from < $38,000 and > $63,000) derived from 2012 American Community Survey data were used to as estimates of individual socioeconomic status. Patient residence in metropolitan, urban or rural counties and distance from the hospital were used as estimates of physical access to a medical facility. A practice volume variable was created by stratifying all hospitals into three categories based on number of proctectomies performed annually (< 100, 100–300 and > 300). A facility identifier used was academic hospital status, defined by NCDB as a hospital that participates in postgraduate medical education and diagnosing over 500 new cancers per year.

After determining which variables were statistically significant in the bivariate analyses, a multivariable logistic regression was performed to evaluate the adjusted relationships to receiving robotic surgery. Areas under the receiver operating characteristic (ROC) curve were calculated to identify the best fitting iteration of the logistic model. Statistical significance was set at $p < 0.05$. Statistical analysis was performed using StataIC (version 15.1.635).

Results

Between 2010 and 2014, 33,503 patients met inclusion criteria; see Fig. 1 for inclusion and exclusion criteria flow diagram. Of all patients undergoing proctectomy, 20,764 (62.0%) were male and 12,739 (38.0%) were female; 26,304 (78.5%) were white, 2614 (7.8%) were black and 4585 (13.7%) were recorded as a race other than black or white (Table 1).

Robotic proctectomy was performed in 3702 (11.1%) patients, and of those, 290 (7.8%) required conversion to open. Differences between the groups that received robotic versus non-robotic proctectomy is shown in Table 1. Patients who received robotic surgery rather than laparoscopic or open were statistically more likely to be male (64.4% vs. 61.7%), white (79.3% vs. 78.4%), under 50 years of age (18.6% vs. 17.0%), clinical stage III (43.7% vs. 41.5%), and

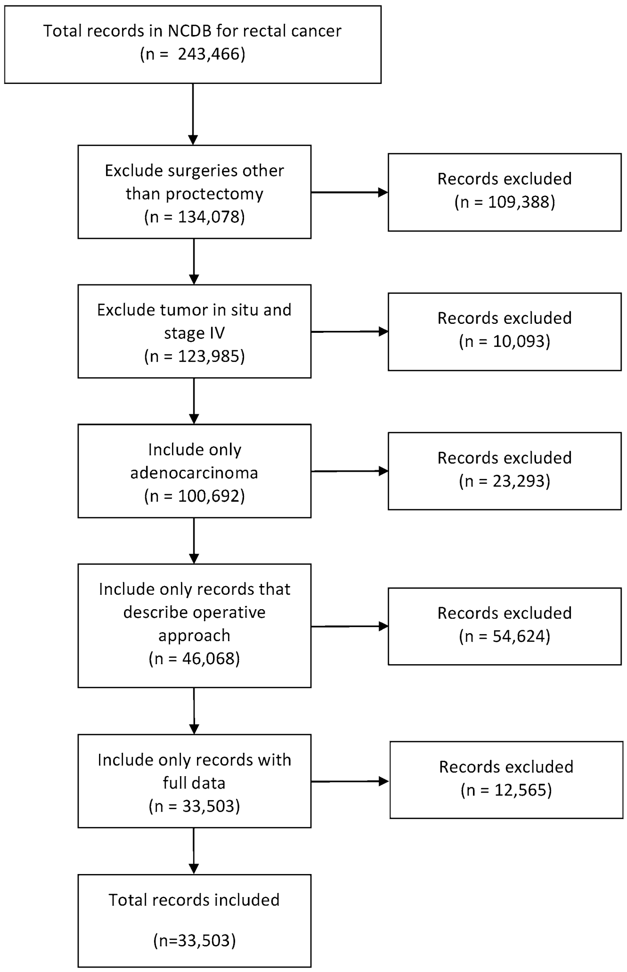

Fig. 1 Flow diagram demonstrating inclusion and exclusion criteria

privately insured (53.4% vs. 46.3%) all $p < 0.011$. Patients receiving robotic proctectomy were more likely to be living in a metropolitan area (82.7% vs. 80.1%), 20–25 miles away from the hospital (16.5% vs. 13.9%), in a zip code area with the highest income quartile (35.6% vs. 31.0%) and highest rate of high school graduation (27.0% vs. 23.1%), all $p \leq 0.001$. In addition, patients undergoing robotic proctectomy were more likely to be treated at an academic (65.6% vs. 52.8%) and high volume (30.6% vs. 25.1%) medical center, all $p < 0.001$.

Effect of race on robotic approach

Black patients were significantly less likely to undergo robotic proctectomy on both unadjusted (OR 0.75, 95% CI 0.65–0.87, $p < 0.001$) and adjusted analyses (OR 0.79, 95% CI 0.68–0.91, $p = 0.002$) (Tables 1 and 2). There was no significant association with robotic approach for other racial groups on unadjusted analysis (Table 2).

Effect of socioeconomic factors on robotic approach

Patient insurance, zip code area, and distance from the treating hospital were all significant factors on adjusted multivariate analysis. Patients with Medicare/Medicaid or VA insurance (OR 0.94 95% CI 0.90–0.98, $p = 0.004$) and no insurance (OR 0.46, 95% CI 0.37–0.58, $p < 0.001$) were less likely to undergo robotic surgery for rectal cancer. Living less than 25 miles away from the hospital was associated with a smaller likelihood of robotic approach (OR 0.79, 95% CI 0.72–0.86, $p < 0.001$). Compared to metropolitan residents, patients who lived in urban or rural settings were less likely to undergo robotic surgery (OR 0.8, 95% CI 0.72–0.90, $p < 0.001$ and OR 0.77, 95% CI 0.60–0.99, $p = 0.043$, respectively). Patients who resided in a zip code with a larger percentage of high school graduates were more likely to undergo surgery using the robotic approach (Table 2).

Effect of hospital factors on robotic approach

On adjusted multivariate analysis, patients who received a proctectomy at an academic medical center (OR 1.43 95% CI 1.33–1.55 $p < 0.001$) were more likely to have a robotic procedure than those admitted to a non-academic hospital. Similarly, patients at moderate-volume (OR 1.69 95% CI 1.53–1.86 $p < 0.001$), and high-volume centers (OR 1.59 95% CI 1.42–1.78 $p < 0.001$) also more likely to undergo a robotic procedure when compared to low-volume rectal cancer surgery centers (Table 2).

Discussion

The purpose of this study was to determine if access to robotic rectal cancer resection varies by patient population. These data show that patients are less likely to have access to robotic surgery if they are female, black, non-privately insured, do not travel for surgical care, are residents of non-metropolitan settings, or reside in less educated areas. Conversely, patients who receive their surgical care in academic, high-volume hospitals have a higher chance of undergoing robotic proctectomy.

Our study found that for robotic surgery, both socioeconomic status and race correlate independently, similar to prior studies of robotic gynecologic and urologic procedures [6, 7]. Previous studies of patients with rectal cancer suggested that insurance, but not race, was associated with access to MIS approaches for cancer resection; of note, the studied patient populations predominantly underwent laparoscopic intervention [2, 8, 9]. This study suggests that factors associated with variations in access to robotic surgery may differ from laparoscopic approach or MIS overall.

Table 1 Descriptive demographic, socioeconomic, hospital and clinical factors and their non-adjusted association with robotic surgery

Descriptor	Variable	Total	Robotic approach *n* (%)	Non-robotic approach *n* (%)	*p* value
Sex	Male	20,764 (62.0%)	2383 (61.7%)	18,381 (64.4%)	**0.001**
	Female	12,739 (38.0%)	1319 (38.3%)	11,420 (35.6%)	
Age	Under 50	27,756 (82.9%)	690 (18.6%)	5057 (17.0%)	**0.011**
	Over 50	5747 (17.2%)	3012 (81.4%)	24,744 (83.0%)	
Race	White	26,304 (78.5%)	2937 (79.3%)	23,367 (78.4%)	**< 0.001**
	Black	2614 (7.80%)	226 (6.10%)	2388 (8.01%)	
	Other	4585 (13.7%)	539 (14.6%)	4046 (13.6%)	
Insurance	Uninsured	1453 (4.34%)	87 (2.35%)	1366 (4.58%)	**< 0.001**
	Private	15,779 (47.1%)	1978 (53.4%)	13,801 (46.3%)	
	Government-funded	15,854 (47.3%)	1602 (43.3%)	14,252 (47.8%)	
	Unknown	417 (1.24%)	35 (1.28%)	382 (0.95%)	
Income (quartiles)	< $38,000	5722 (17.1%)	556 (15.0%)	5166 (17.3%)	**< 0.001**
	$38,000-$47,999	8162 (24.4%)	867 (23.4%)	7295 (24.5%)	
	$48,000-$62,999	9060 (27.0%)	963 (26.0%)	8097 (27.2%)	
	$63,000+	10,559 (31.5%)	1316 (35.6%)	9243 (31.0%)	
Living area	Metropolitan	26,937 (80.4%)	3060 (82.7%)	23,877 (80.1%)	**0.001**
	Urban	5746 (17.2%)	564 (15.2%)	5182 (17.4%)	
	Rural	820 (2.45%)	78 (2.11%)	742 (2.49%)	
Distance to hospital facility	≤ 10 miles	15,326 (45.8%)	1531 (41.4%)	13,795 (46.3%)	**< 0.001**
	10–25 miles	9006 (26.9%)	983 (26.6%)	8023 (26.9%)	
	25–50 miles	4760 (14.2%)	611 (16.5%)	4149 (13.9%)	
	50–100 miles	2745 (8.19%)	377 (10.2%)	2368 (7.95%)	
	Over 100 miles	1666 (4.97%)	200 (5.40%)	1466 (4.92%)	
Percent of residents without high school degree in patient's zip code	≥ 21%	5687 (17%)	520 (14.1%)	5167 (17.3%)	**< 0.001**
	13–20.9%	8830 (26.4%)	959 (25.9%)	7871 (26.4%)	
	7–12.9%	11,099 (33.1%)	1223 (33.0%)	9876 (33.1%)	
	< 7%	7887 (23.5%)	1000 (27.0%)	6887 (23.1%)	
Rectal surgery volume	Smaller volume	9269 (27.7%)	626 (16.9%)	8643 (29.0%)	**< 0.001**
	Moderate volume	15,619 (46.6%)	1945 (52.5%)	13,674 (45.9%)	
	Larger volume	8615 (25.7%)	1131 (30.6%)	7484 (25.1%)	
Academic versus non-academic	Academic	21,505 (64.2%)	1746 (65.6%)	10,252 (52.8%)	**< 0.001**
	Non-academic	11,998 (35.8%)	1956 (34.4%)	19,549 (47.2%)	
Charlson–Deyo score	0	25,623 (76.5%)	2817 (76.1%)	22,806 (76.5%)	0.396
	1	6166 (18.4%)	712 (19.2%)	5454 (18.3%)	
	2	1714 (5.12%)	173 (4.67%)	1543 (5.17%)	
Clinical stage	I	6976 (20.8%)	707 (19.1%)	6269 (21.0%)	**0.007**
	II	12,542 (37.4%)	1377 (37.2%)	11,165 (37.5%)	
	III	13,985 (41.7%)	1618 (43.7%)	12,367 (41.5%)	

Statistically significant values ($p < 0.05$) are given in bold

There are patient factors that may inform the choice of a robotic proctectomy. For one, patient preference may explain some difference in populations that undergo robotic approach, as certain patient populations are more mistrustful of newer medical technology [10]. Some surgeons prefer robotic proctectomy for male patients as robotic surgery increases ease of operation in the narrow male pelvis. The ROLARR trial demonstrated lower conversion rates for robotic approach compared to laparoscopic in male patients [11]. A study by Ackerman et al. found that male patients were more likely to undergo conversion overall, but robotic surgery was protective against conversion compared to laparoscopic surgery [12]. The difficulty of the dissection in the narrow male pelvis may be a driver of the disparities for the increased selection of males having robotic surgery [13–15].

Table 2 Multivariate logistic regression of factors associated with receiving robotic proctectomy

	Odds Ratio	95% Confidence Interval	*p* value
Male sex	1.12	1.04–1.20	**0.002**
Age	1	0.99–1.00	0.063
Race			
White (reference)	1	–	–
Black	0.79	0.68–0.91	**0.002**
Other	1.11	1.00–1.23	**0.048**
Insurance			
Private	1	–	–
Government	0.94	0.90–0.98	**0.004**
Uninsured	0.46	0.37–0.58	**<0.001**
Unknown	0.86	0.77–0.97	**0.014**
Income level in patient's zip code			
First quartile (< $38,000)	1	–	–
Second quartile ($38,00–$47.999)	1.02	0.9–1.15	0.764
Third quartile ($48,000–$62,999)	0.95	0.84–1.08	0.455
Fourth quartile ($63,000)	1.03	0.89–1.19	0.660
Percent residents without a high school degree in patient's zip code			
≥ 21% (reference)	1	–	–
13–20.9%	1.2	1.07–1.36	**0.002**
7–12.9%	1.18	1.04–1.34	**0.011**
< 7%	1.29	1.11–1.49	**0.001**
Living < 25 miles away from hospital	0.79	0.72–0.86	**< 0.001**
Area designation			
Metro (reference)	1	–	–
Urban	0.8	0.72–0.90	**< 0.001**
Rural	0.77	0.60–0.99	**0.043**
Academic hospital designation	1.43	1.33–1.55	**< 0.001**
Rectal cancer surgery volume			
Low volume (reference)	1	–	–
Moderate volume	1.69	1.53–1.86	**< 0.001**
High volume	1.59	1.42–1.78	**< 0.001**
Clinical stage			
Stage III (reference)	1	–	–
Stage I	0.9	0.82–0.99	**0.025**
Stage II	0.99	0.92–0.781	0.781

Statistically significant values ($p < 0.05$) are given in bold

Covariate determined from backwards selection from bivariate analysis

Institutional factors also appear to contribute to differences in access to robotic rectal surgery [16]. Ability to afford the robot varies among institutions and access to the robot may attract a particular type of surgeon. Robotic surgery is used in advertising for both hospitals and colorectal surgeons [17]. Hospitals serving more affluent, well-educated and privately insured patients may offer robotic operations to attract those drawn to a high-tech approach to surgery, contributing to socioeconomic disparities [17, 18]. These forces, which concentrate resources, equipment, and expertise, may also inadvertently affect access to patients who are unable to travel to receive their care, such as those with lower socioeconomic status.

This study is limited by its retrospective nature and lack of data granularity inherent in large databases like NCDB. For example, there is no data on number of prior abdominal surgeries which may influence decision of operative approach nor patient or surgeon preference on choice of robotic surgery. Another limitation is that this time period was limited by the availability of data. More than half of all rectal resections or 63,686 patients were excluded because operative approach was not specified in the NCDB prior to 2010. At time of data analysis, our institution only had NCDB data up to 2014. During this time period, robotic surgery faced a period of expansion and, compared to now, training opportunities were less available. This could have influenced the results of this study and therefore alter the generalizability of our findings. Nonetheless, NCDB is a large database, capturing close to 70% of cancer patients; [19] therefore, we believe that the findings of this study are sufficient to represent trends in access to robotic rectal surgery in the United States.

All patient populations do not undergo robotic proctectomy in equal proportions. Herein, using the NCDB we demonstrate a clear association of specific populations to access to robotic surgery, including patients who are male, non-black, privately insured, who have ability to travel for medical care and reside in metropolitan, highly educated areas. This data does not demonstrate that having access to robot improves patient care, but given this bias, surgeon researchers must be cognizant of study population diversity and generalizability of robotic surgery research. Further areas of investigation should evaluate why these discrepancies exist.

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Compliance with ethical standards

Disclosures Dr. Stein has been a speaker for Merck and advisory consultant for Medtronics. Dr. Towe is a consultant for Medtronic, Atricure, Sig Medical, and Zimmer Biomet. Drs. Steinhagen, Bingmer and Ofshteyn have no conflicts of interest or financial ties to disclose.

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