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ORIGINAL ARTICLE

A National study on the adoption of laparoscopic colorectal surgery in the elderly population: current state and value proposition

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Abstract

Background The economic and clinical benefits of laparoscopic colorectal surgery are proven, yet may be underutilized in appropriate cases, especially in the elderly. Since the elderly constitute the greatest colorectal surgical volume, our goal was to identify trends in utilization and impact of laparoscopy in this cohort.

Methods A national review of elective inpatient colorectal resections from the Premier Inpatient Database between 2010 and 2015 was performed. Patients were included if elderly (≥ 65 years), then grouped into open or laparoscopic procedures. The main outcome measures were trends in utilization by approach and total costs for the episode of care, length of stay (LOS), readmission, and complications by approach in the elderly. Multivariable regression models controlled for differences across platforms, adjusting for patient demographic, comorbidities and hospital characteristics.

Results In 70,655 elderly patients evaluated, laparoscopic adoption remained lower than open throughout the study period. Rates increased until 2013, then declined, with increasing rates of open surgery. Laparoscopy was associated with significantly lower mean total costs ($4012 less/case), complications and readmissions (36% and 33% less, respectively), and shorter LOS (2.6 less days) than open cases (all $p < 0.0001$). When complications occurred, they were less severe and the readmission episodes were less costly with laparoscopy than open colorectal surgery.

Conclusion The adoption of laparoscopy in the elderly has lagged behind open surgery and even declined in recent years despite being associated with improved clinical outcomes and reduced cost. With this tremendous value proposition to increase use of laparoscopic surgery in the elderly, further work needs to evaluate root causes of the disparity.

Keywords Minimally invasive surgery · Laparoscopic colorectal surgery · Elderly · Frailty · Healthcare outcomes · Healthcare costs

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Introduction

Colorectal surgery underwent a revolution with the introduction of laparoscopic surgery, with proven improvements in patient outcomes and comparable oncologic outcomes in malignant cases [1–6]. The clinical benefits for faster recovery with lower complication and readmissions rates remain undisputed, with the benefit from lower total costs during the hospital stay, the post-discharge period, and improved early quality of life now shown in benign and malignant disease [7–15]. With the demonstrated reductions in costs per case, overall healthcare costs and utilization in the postoperative period, laparoscopic surgery is a cost-effective tool that provides the greatest value to both patient and provider [16–18].

The safety, feasibility, and benefits of laparoscopy have been specifically demonstrated in the elderly population- and may be even more pronounced [19–23]. As the proportion of

the United States population that is elderly grows exponentially, and the elderly consume the largest shares of healthcare and surgical care, a way to improve quality in this group is needed. National Health Expenditures now account for 17.9% of Gross Domestic Product, healthcare spending is projected to rise 5.5% annually, with the elderly serving as the primary driver of the increased spending [24]. Among patients aged 65 and over, there was $414.3 billion in total health care expenses in 2011, over $100 billion higher than inflation-adjusted expenses in 2001, and these costs continue to climb [25]. Laparoscopy may be a method to provide the highest quality care, improving the clinical and financial outcomes in this growing segment. No work to date has evaluated the present use of laparoscopic colorectal surgery and its results in this population, though. The adoption of laparoscopic techniques may be influenced by selection bias, education, and other amendable factors. Thus, there is a need to evaluate the present use of laparoscopic colorectal surgery and its impact in this population at a national level and across all the health care sectors.

Our goal was to evaluate the current use, trends in utilization, and outcomes for laparoscopic colorectal surgery in elderly patients. We hypothesize that laparoscopy may be underutilized, with rates lower than open surgery among the elderly.

Methods

We performed a review of the use of elective colorectal resections on a national scale over a 5-year period to investigate this question. The Premier Inpatient Database™ was reviewed to identify patients aged 65 years old and greater undergoing an inpatient elective colorectal resection between 1/1/2010 through 9/30/2015. The Premier Inpatient Database™ covers over 45 million inpatient visits, providing a representative sample of approximately one out of every five inpatient discharges in the United States. The data source contains a day-stamped log of all billed items including procedures, medications, laboratory, diagnostic and therapeutic services at the individual patient level in addition to the standard data elements available in most hospital discharge files [26]. Included hospitals are a national representation of geographic region, urban versus rural, teaching versus non-teaching, and varied bed size institutions. Discharge-level data includes information on patient and provider characteristics, International Classification of Diseases (ICD) diagnosis and procedure codes, hospital resource utilization, charges, and cost data on all entries.

Open and laparoscopic cases were identified by the ICD Ninth Edition (ICD-9) and Current Procedural Terminology/Healthcare Common Procedure Coding System procedure codes for colorectal resections in the primary procedure of the claim. Converted cases were included in their initial cohort using intention-to-treat analysis. Cases were excluded if the procedure was performed through an anorectal or endoscopic approach only, patients were less than 18 years of age, the case performed was emergent, or the patient left against medical advice (incomplete record). Robotic-assisted laparoscopic cases were also excluded (identified with add-on modifiers, when used), as there was no information on how much of the case was performed with robotic assistance and large discrepancies in use of the modifier codes. Codes used for inclusion and exclusion are seen in Table 3 in Appendix.

The patient and provider demographics, outcomes, and costs were compared for laparoscopic and open procedures. Patient demographic data fields evaluated included age, gender, comorbidity by Charlson Comorbidity Index, the All Patient Refined Diagnosis Related Group (APR DRG) severity of illness, and individual comorbidity [chronic obstructive pulmonary disease (COPD), congestive heart failure, myocardial infarction, dementia, rheumatoid arthritis, chronic renal failure, cancer, metastatic solid tumor, peptic ulcer disease, obesity, diabetes, hypertension, peripheral vascular disease, cardiovascular disease, liver disease, paralysis, and acquired immunodeficiency syndrome (AIDS)]. The data fields evaluated for provider included: payor, geographic region (South, Northeast, Midwest and West), hospital teaching status, hospital bed size, and hospital location (rural/urban). The outcome variables assessed included hospital length of stay (LOS, days), complications [overall and by the individual categories of ileus/small bowel obstruction, anastomotic leak/organ space superficial site infection (SSI), superficial SSI and wound complications, Clostridium difficile colitis, pulmonary infection, thromboembolic disease, urinary tract infection, dehydration/acute renal failure, bleeding requiring transfusion, peritonitis, gastrointestinal complications, delirium/confusion/accidental fall], and 30-day all-cause readmissions. The costs outcomes evaluated were the total cost of the inpatient hospital stay, and the total cost of 30-day all-cause readmissions. The main outcome measures were the trends in utilization by approach, total costs for the episode of care (considering the inpatient and 30-day post-discharge periods), hospital LOS, readmission, and complications by approach in the elderly.

Statistical analysis

For statistical analysis, the Cochran-Armitage test was used to compare the rates of laparoscopy in elderly cohorts between 1/1/2010 and 9/30/2015. Descriptive statistics included means (with standard deviation) for continuous variables and count (percent) for categorical variables, to compare the demographics between open and laparoscopic platforms in elderly for the most recent year, 1/1/2014

through 9/30/2015, for the most relevant cost and outcomes analysis. Univariate analysis was conducted with two-sample *t* tests for continuous variables and Chi-squared or fisher-exact tests to compare categorical variables, as appropriate. Depending on the data attributes, Generalized Estimating Equation (GEE) models with Gamma distribution and log link function were used to evaluate the impact of the surgical approach (open vs laparoscopic) on cost, Negative Binomial distribution and log link function for LOS (days), and multivariate logistic regression for complications, across approach in the elderly adjusting for all patient demographic, comorbidities and hospital characteristics (age, gender, race, Charlson comorbidity index value, prior surgery, All Patient Refined Diagnosis Related Group (APR DRG) severity of illness, insurance type, hospital region, teaching status, bed size, urban or rural hospital, comorbidities of myocardial infarction, congestive heart failure, dementia, COPD, rheumatoid arthritis, peptic ulcer disease, paralysis, chronic renal failure, cancer, metastatic solid tumor, AIDS, obesity, diabetes, hypertension, peripheral vascular disease, cardiovascular disease, and liver disease). A p value less than 0.05 was considered as statistically significant. All statistical analyses were performed using SAS Version 9.4 (SAS Institute Inc., Cary, NC, USA).

Results

During the study period, 236,165 total patients were identified that underwent an inpatient colorectal procedure. After applying the initial exclusion criteria, 151,235 cases were identified. After excluding the 5439 robotic cases, 145,796 total cases were included in the analysis between 1/1/2010 and 9/30/2015. Overall, these cases were 49.5% ($n=73,685$) open and 50.5% ($n=72,111$) laparoscopic. In the cohort less than 65 years old ($n=75,131$), cases were 54.5% ($n=40,946$) laparoscopic and 45.5% (34, 145) open.

In focusing on patients 65 and over, 70,655 elderly patients were included in the analysis. Overall, the cases were 44.6% ($n=31,517$) laparoscopic and 55.6% ($n=39,148$) open. Looking at the utilization trends of each platform by year in the elderly, the rates of open colorectal surgery were significantly higher than laparoscopy every year from 2010 to 2015 (all $p<0.01$). The utilization rate for laparoscopy increased small but significant amounts between 2010 and 2013, then decreased between 2013 and 2015, with corresponding decreases in open surgery from 2010 to 2013, which increased between 2013 and 2015. The trends over time by platform are seen in Fig. 1.

For the comparative analysis in the 2014–2015 time period, there were 19,054 colorectal resections performed in the elderly-10,400 open (54.6%) and 8654 laparoscopic (45.4%). In the unadjusted analysis, compared with patients who underwent an open approach, laparoscopic patients were younger, and had less severity of illness (all p values <0.001). The open cohort had significantly greater comorbidity, higher rates of obesity, congestive heart failure ($p=0.020$), COPD ($p<0.001$), and chronic renal failure ($p<0.001$). For the hospital demographics, there were significant differences in laparoscopic use by region, bed size and urban/rural location, with more laparoscopic procedures at larger hospitals and urban hospitals (all $p<0.001$). There were no significant differences in use by teaching/non-teaching hospital status in the elderly ($p=0.30$; Table 1). In adjusted analysis, controlling for all differences in the patient and hospital characteristics across open and laparoscopic platforms in the elderly, there were significantly lower total inpatient costs, lengths of stay, complication and readmission rates with laparoscopy (all $p<0.001$). When elderly patients were readmitted, the readmission episodes were less expensive with laparoscopy, but did not reach statistical significance ($p=0.5$). In the elderly, use of laparoscopy was associated with a 36% lower risk of complications (OR = 0.64, 95% CI [0.59–0.69]), a 33% lower risk of readmission (OR = 0.67, 95% CI [0.6–0.74]), a hospital course 2.6 days shorter (95% CI [2.40–2.78], and over $4012 less total cost (95% CI [3343, 4669]) than open procedures (Table 2).

Discussion

The elderly population is rapidly growing, and this group consumes the largest amount of healthcare and colorectal surgical services [14, 27]. Given the need to improve outcomes and reduce costs in this population, methods of improving surgical value are needed, such as with the increasing use of laparoscopic colorectal surgery. Our goal was to evaluate the current national use, trends in utilization, and outcomes for laparoscopic colorectal surgery in elderly patients and across all the health care sectors. We

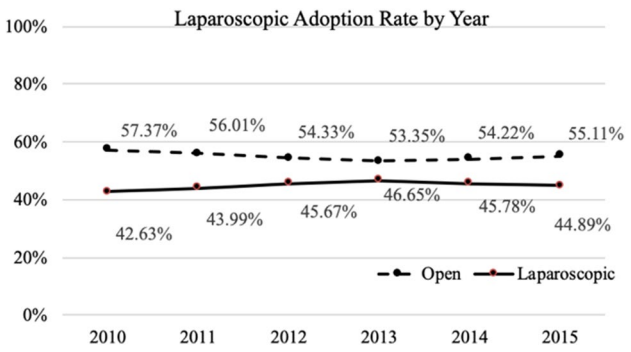

Fig. 1 Laparoscopic and open colorectal surgery utilization rates in elderly patients from 2010 through September 2015

Table 1 Patient and hospital demographic data (unadjusted analysis) for open and laparoscopic resections in the elderly

Elderly colorectal resections	Open ($n=10,400$)		Laparoscopy ($n=8654$)		p value
	n	%	n	%	
Age (mean ± SD)	74.6 ± 6.91		73.64 ± 6.49		< 0.001
Gender—Female	6009	57.78	4814	55.63	
Charlson Comorbidity Index (mean ± SD)	2.99 ± 2.95		2.31 ± 2.45		< 0.001
APR severity of illness					< 0.001
Extreme	1186	11.40	215	2.48	
Major	2690	25.87	1130	13.06	
Moderate	4068	39.12	3420	39.52	
Minor	2456	23.62	3889	44.94	
Insurance					< 0.001
Medicare	9380	91.60	7730	90.39	
Medicaid	106	1.04	83	0.97	
Managed care	754	7.36	739	8.64	
Self-pay/other	160	1.54	102	1.18	
Comorbid condition					
Cancer	5424	52.15	4361	50.39	0.02
Hypertension	7356	70.73	5835	67.43	< 0.001
Diabetes	2791	26.84	2101	24.28	< 0.001
Chronic obstructive pulmonary disease	2224	21.38	1437	16.61	< 0.001
Obesity	1527	14.68	1121	12.95	0.006
Chronic renal failure	1266	12.17	728	8.41	< 0.001
Congestive heart failure	1020	9.81	511	5.90	< 0.001
Myocardial infarction	696	6.69	510	5.89	< 0.001
Cardiovascular disease	346	3.33	198	2.29	< 0.001
Hospital region					< 0.001
South	5624	54.08	4506	52.07	
Northeast	1252	12.04	1299	15.01	
Midwest	2104	20.23	1555	17.97	
West	1420	13.65	1294	14.95	
Teaching hospital	3936	37.85	3207	37.06	0.26
Hospital Bed size					< 0.001
< 200	2013	19.36	1640	18.95	
200–500	5513	53.01	4111	47.50	
> 500	2874	27.63	2903	33.55	
Hospital location					< 0.001
Rural	1828	17.58	1110	12.83	
Urban	8572	82.42	7544	87.17	

found that laparoscopy was associated with clear benefits for quality and cost outcomes in the elderly over open surgery when accounting for multiple confounding variables, but utilization is not growing and remains underused in appropriate cases.

Our study confirmed the clinical benefits, using a recent national inpatient sample, with significantly lower lengths of stay, complication and readmission rates with laparoscopy compared to open surgery in the elderly. This is consistent with previously published work that demonstrate faster postoperative recovery and lower morbidity and mortality with minimally invasive colorectal surgery in the elderly [20, 21, 28–31].

Prior research has demonstrated that age is associated with higher morbidity and worse postoperative outcomes in laparoscopic surgery, even with all patient factors and comorbidities controlled for [27, 32, 33]. Our work however adds to the literature in showing the health care value of laparoscopic surgery in the elderly with lower total costs of $4012 less than open procedures per patient. With the improved outcomes and lower costs, especially in a population with associated comorbidities and rates of frailty, the benefits of laparoscopy are even more pronounced [21, 22,

Table 2 Adjusted analysis for quality outcomes after colorectal resections in the elderly cohort

Elderly outcomes	Open ($n = 10,400$)		Laparoscopy ($n = 8654$)		p value
Unadjusted results	Mean	SD	Mean	SD	
Total inpatient costs	$22,375	$20,785	$15,631	$11,825	< 0.001
Total readmission costs	$15,929	$23,828	$16,437	$22,468	0.520
Length of stay (Days)	8.61	7.24	5.28	4.13	< 0.001
Complications (n, %)	6555	63.03%	3480	40.21%	< 0.001
Readmissions (n, %)	1256	12.08%	606	7.00%	< 0.001
Adjusted results (laparoscopy compared to open)	Mean difference		95% CI (Lower, Upper)		p value
Total costs	− $4012		(− $4669, − $3343)		< 0.001
Total readmission costs	− $457		(− $1747, $1021)		0.520
Length of stay	− 2.59		(− 2.78, 2.40)		< 0.001
Any complication (Odds Ratio)	0.64		(0.59, 0.69)		< 0.001
Readmission (Odds Ratio)	0.67		(0.6, 0.74)		< 0.001

All costs in US Dollars

Complication and readmission rates considered within 30-days of the index procedure

27, 34]. Laparoscopic colorectal surgery should be offered as the standard of care to elderly patients when appropriate to optimize surgical value.

Our study also showed the utilization of laparoscopy in the elderly was substantially lower than the general population, and the population under 65 years. This agrees with published work, with our rates in the elderly in contrast to rates and trends for non-elderly patients and the overall population [18, 35, 36]. We found that use of laparoscopy in the elderly for elective colorectal resections in 2010 was 42.6%, and grew small amounts between 2010 and 2013, topping off at 46.6%, before decreasing again between 2013 and 2015; the decline was met with corresponding increases in open surgery from 2013 on. There are many possible reasons for this disparity, including a selection bias in which elderly patients are offered laparoscopy, insufficient training of residents and surgeons in practice on laparoscopic techniques, and a lack of awareness by patients on the availability, safety, and benefits of minimally invasive approaches. Analyzing the National Inpatient Sample over a 10-year period, Jafari et al. found laparoscopy was half as likely to be used in the elderly for colorectal cancer resections [27]. The authors hypothesized that this finding may be secondary to elderly patients being sicker, with a higher percentage needing urgent operations. In the present work, the elderly patients were adjusted for all patient demographic, comorbidities and hospital characteristics, and cases deemed inappropriate, such as metastatic cancer diagnoses were excluded, reducing the bias of sicker patients seen in prior work.

With this evidence base, policy changes, education, and investigation are warranted into the reasons why rates of laparoscopy are not higher or increasing in the elderly. It has been reported that the main limiting factor for the use of laparoscopic colorectal surgery in the elderly and every other patient group is the number of surgeons with adequate skills to perform a laparoscopic resection rather than the tumor or patient's characteristics [37]. A recent survey querying practicing surgeons on the barriers of adoption of laparoscopy cited lack of adequate surgical volume, reluctance of managing unexpected surgical scenarios, difficulty with video-eye-hand coordination, altered depth perception, and laparoscopic suturing as additional reasons [38]. This highlights the importance and continued need for surgical mentorship training models, such Lapco Train-the-Trainer and SAGES ADOPT, for successful implementation of laparoscopic colorectal surgery in general [39–42]. In addition, educational modules specific to care in the elderly could be added to reduce discrimination, affirm the feasibility, and help increase utilization. Direct patient education from providers on the benefits of laparoscopy in the elderly is another way to potentially increase utilization. Study showed that outcomes traditionally important to surgeons after colorectal resection, such as use of laparoscopy, were least important to patients. Avoiding complications and fast recovery- items that are proven benefits of laparoscopy- were reported as primary priorities for patients. However, when asked specifically about use of laparoscopy, patients rated approach as a low priority [43]. Thus, efforts to focus patient education and communication from the patient's perspective could better align surgeon and patient priorities while increasing utilization of laparoscopic colorectal surgery in the elderly. Finally, with the movement towards value-based care and bundled payment systems, payers could look at methods to implement rewards and incentives for laparoscopic approaches over open surgery in the elderly, which would likely improve

outcomes in this patient population as well as healthcare costs and utilization.

We recognize limitations in this work. The data source offers a large sample size, which is valuable for power and determining trends and outcomes. However, we used a retrospective design, which has associated limitations in the fields available and inherent biases. There is no information available on frailty or use of enhanced recovery, which can impact outcomes but this data describe the current practice and its outcome in this large sample size. There could be a selection bias in the patients that were offered laparoscopic surgery, which we attempted to account for with the robust case-mix adjustment and multivariate analysis. In addition, there is the risk of confounding variables affecting the results and conclusions. We attempted to control for any risks of confounding on outcomes with the multivariate analysis but due to the nature and large scale of the study, other confounders may exist that were not available in the database. With the data source, there is also the potential for coding and capture errors, but this would not be expected to make a substantial impact with the large sample size. However, the corresponding increase in open surgery suggests that the decline in laparoscopic surgery noted in the study are not entirely due to a shift of MIS from the laparoscopic to a robotic approach. Regardless of the limitations, this work offers a valuable addition to the current literature in showing the clinical benefits in addition to the financial benefits, of laparoscopic colorectal surgery in the elderly, and the continued slow adoption in this patient population—a target for future work.

In conclusion, this work shows the overall adoption of laparoscopic colorectal surgery in the elderly remains slow, and has even declined slightly in recent years, despite evidence of its safety, feasibility, and clinical benefits. The financial benefits of laparoscopy in the elderly population were demonstrated, furthering the argument for laparoscopy to be standard of care. Considering the reduced overall cost with improved clinical outcomes, there is a tremendous value proposition, in addition to the clinical benefits, for patients and hospitals with increased use of laparoscopic colorectal surgery in the elderly. Future efforts may focus on improving communication and education for patients and providers, as well as exploring options for payers to increase value by rewarding minimally invasive approaches in the elderly.

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Compliance with ethical standards

Conflict of interest Ms. Qiu is employed by Medtronic, but there was no payment for the work. Dr. Keller: no conflicts of interest or financial ties to disclose. Dr. Kiran: no conflicts of interest or financial ties to disclose.

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

Informed consent For this type of study formal consent is not required.

Appendix

See Tables 3, 4.

Table 3 Case selection and exclusions codes for colorectal surgery

Inclusion	
DRG codes	329, 330, 331
ICD-9 procedure codes	
Open	45.71, 45.72, 45.73, 45.74, 45.75, 45.76, 45.79, 45.82, 45.83
Laparoscopic:	17.31, 17.32, 17.33, 17.34, 17.35, 17.36, 17.39, 45.81
CPT/HCPCS Codes	
Open	44,140, 44,141, 44,143, 44,144, 44,145, 44,146, 44,150, 44,151, 44,155, 44,156, 44,157, 44,158, 44,160, 45,113, 45,121
Laparoscopic	44,204, 44,205, 44,206, 44,207, 44,208, 44,210, 44,211, 44,212
Exclusion	
ICD-9 procedure codes	
Robotic assistance (add-on procedure code)	17.41, 17.42, 17.43, 17.44, 17.45, 17.49
CPT/HCPCS Codes	
Robotic assistance	S2900

CPT/HCPCS Current Procedural Terminology/Healthcare Common Procedure Coding System, *DRG* Diagnostic Related Group, *ICD-9* International Classification of Disease, Ninth edition

Table 4 Complications

General category	ICD-9-CM Code
Ileus/Small Bowel Obstruction (including constipation and PONV)	560.1, 560.2, 560.81, 560.89, 560.9, 997.4, 787.01, 564.3, 564.09, E937.9
Anastomotic Leak. Organ space SSI	569.5, 567.22, 566, 567.21, 567.23, 567.29, 567.89, 567.9, 599.0, 996.64, 567.38
Superficial SSI and wound complications (Hematoma/Seroma, Wound Infection, Dehiscence)	682.2, 682.8, 682.9, 686.8, 686.9, 998.59, 958.3, 998.30, 998.31, 998.32, 998.33, 998.13, 998.51, 998.59, 998.6, 729.91, 998.12
Clostridium difficile colitis	008.45
Pulmonary infection	481, 482.0, 482.1, 482.2, 482.30, 482.31, 482.32, 482.39, 482.40, 482.41, 482.42, 482.49, 482.81, 482.82, 482.83, 482.89, 482.9, 483.0 485, 486, 507.0, 997.31, 997.32, 997.3, 518.5
Deep venous thrombosis	453.40, 453.41, 453.42, 453.82, 453.83
Urinary tract infection	599.0, 996.64, 788.2
Dehydration/acute renal failure	584.9, 276.51
Bleeding	998.11, 578.9, 285.1, 459.0, 285.1, 998.12, 569.3, 568.81, 569.3
Bleeding requiring transfusion	99.00, 99.01, 99.02, 99.03, 99.04, 99.05, 99.06, 99.07, 99.09
Peritonitis	567.38, 567.39, 567.2, 567.21, 567.22, 567.39, 567.8, 567.89, 567.9, 568.81
GI complications (Fistula)	997.4, 569.81, 593.82, 599.1, 596.1
Delirium/Confusion/Accidental Fall	780.09, 293.9, 780.97, E884.4

SSI superficial site infection, *PONV* postoperative nausea and vomiting, *GI* gastrointestinal

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