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Original Research Article

Comparative Outcomes of Laparoscopic Versus Open Colectomy in Elderly Patients: A Multicenter Cohort Study

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Abstract

Background: The optimal surgical approach for colectomy in elderly patients remains debated, with concerns regarding tolerability of laparoscopic procedures in this vulnerable population. This study compared short-term and intermediate-term outcomes of laparoscopic versus open colectomy in patients aged ≥70 years.

Methods: A multicenter retrospective cohort study was conducted across tertiary hospitals. Data from 1,856 elderly patients (≥70 years) undergoing elective colectomy for colorectal neoplasms were analyzed. Patients were categorized into laparoscopic (n=1,124, 60.6%) and open (n=732, 39.4%) colectomy groups. Primary outcomes included operative time, estimated blood loss, length of hospital stay, and 30-day morbidity. Secondary outcomes comprised postoperative complications, readmission rates, and 90-day mortality. Propensity score matching and multivariable regression analyses adjusted for baseline differences.

Results: Mean age was 76.4 ± 5.2 years. After propensity score matching (n=658 pairs), laparoscopic colectomy demonstrated significantly longer operative time (178.3 ± 48.6 vs. 154.2 ± 42.8 minutes, $p < 0.001$) but reduced blood loss (82.4 ± 56.3 vs. 186.7 ± 124.5 mL, $p < 0.001$), shorter hospital stay (6.8 ± 3.2 vs. 9.4 ± 4.6 days, $p < 0.001$), and lower overall morbidity (18.4% vs. 31.2%, $p < 0.001$). Laparoscopic approach was associated with reduced wound infections (4.3% vs. 12.6%, $p < 0.001$), pneumonia (5.2% vs. 11.1%, $p < 0.001$), and ileus (8.7% vs. 15.5%, $p = 0.001$). No significant differences emerged in anastomotic leak rates (3.8% vs. 4.7%, $p = 0.452$) or 30-day mortality (1.5% vs. 2.4%, $p = 0.289$). Multivariable analysis confirmed laparoscopic surgery as an independent predictor of reduced complications (OR = 0.52, 95% CI: 0.38-0.71, $p < 0.001$).

Conclusion: Laparoscopic colectomy in carefully selected elderly patients offers significant advantages over open surgery, including reduced morbidity, shorter hospitalization, and faster recovery without compromising oncological safety. These findings support broader adoption of minimally invasive techniques in geriatric surgical populations.

Keywords: Laparoscopic Colectomy; Elderly Patients; Minimally Invasive Surgery; Colorectal Cancer; Surgical Outcomes; Geriatric Surgery; Propensity Score Matching.

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Introduction

Colorectal cancer represents the third most commonly diagnosed malignancy worldwide and the second leading cause of cancer-related mortality, with incidence rates increasing substantially with advancing age [1]. Approximately 60% of newly diagnosed colorectal cancers occur in individuals aged 70 years or older, reflecting the aging global population and cumulative exposure to environmental and genetic risk factors [2]. Surgical resection remains the cornerstone of curative treatment for localized and locally advanced colorectal malignancies, with colectomy representing one of the most frequently performed major abdominal operations in elderly patients [3]. The advent of laparoscopic surgery in the early 1990s revolutionized the surgical management of colorectal diseases, offering potential advantages of reduced postoperative pain, diminished surgical trauma, faster recovery, shorter hospitalization, and improved cosmetic outcomes compared to traditional open techniques [4]. Multiple randomized controlled trials, including landmark studies such as the Clinical Outcomes of Surgical Therapy (COST) trial, the Colon Cancer Laparoscopic or Open Resection (COLOR) trial, and the Conventional versus Laparoscopic-Assisted Surgery in Colorectal Cancer (CLASICC) trial, have established the oncological equivalence and short-term benefits of laparoscopic colectomy in adult populations [5]. Subsequent meta-analyses have confirmed these findings, demonstrating reduced blood loss, lower complication rates, and expedited return to normal activities without compromising long-term oncological outcomes [6]. Despite robust evidence supporting laparoscopic approaches in general adult populations, the application of minimally invasive techniques in elderly patients has remained a subject of considerable debate and clinical uncertainty [7].

Elderly surgical candidates present unique physiological challenges, including decreased cardiopulmonary reserve, increased prevalence of comorbidities, altered pharmacokinetics and pharmacodynamics, diminished functional status, and heightened vulnerability to perioperative complications [8]. The pneumoperitoneum required for laparoscopic surgery induces hemodynamic and respiratory changes that may be poorly tolerated in patients with limited physiological reserve [9]. Furthermore, prolonged operative times associated with laparoscopic procedures in some series have raised concerns regarding anesthetic risks in geriatric populations [10].

Existing evidence regarding laparoscopic colectomy outcomes in elderly patients derives predominantly from single-center experiences, retrospective analyses with limited sample sizes, and heterogeneous study populations spanning wide age ranges [11].

A systematic review by Veldkamp et al. examining laparoscopic colorectal surgery in patients over 70 years suggested potential benefits in terms of reduced morbidity and shorter hospital stays, but highlighted substantial methodological limitations across included studies [12]. More recent population-based studies utilizing administrative databases have reported conflicting results, with some demonstrating clear advantages of laparoscopic approaches [13], while others question the magnitude of benefit in octogenarians and nonagenarians [14].

Several knowledge gaps persist in the current literature. First, most existing studies do not adequately control for selection bias, as elderly patients undergoing laparoscopic procedures may represent a healthier subset with fewer comorbidities and better baseline functional status [15]. Second, limited data exist comparing specific postoperative complications relevant to geriatric populations, such as delirium, functional decline, and failure to rescue following complications [16]. Third, few studies have examined intermediate-term outcomes including readmission rates, quality of life, and restoration of independent living, which hold particular relevance for elderly patients and their families [17].

The rapid expansion of enhanced recovery after surgery (ERAS) protocols, which emphasize multimodal perioperative optimization and early mobilization, has further complicated the assessment of surgical approach effects, as ERAS implementation may differentially benefit patients undergoing minimally invasive procedures [18]. Additionally, evolving surgical techniques, improved instrumentation, accumulating surgeon experience with laparoscopic approaches, and advances in anesthetic management have likely influenced outcomes over time, necessitating contemporary comparative analyses [19].

From a healthcare economics perspective, understanding the comparative effectiveness of laparoscopic versus open colectomy in elderly patients has important resource allocation implications [20]. While laparoscopic equipment and longer operative times may increase direct surgical costs, potential offsetting savings through reduced complications, shorter hospitalizations, and decreased readmissions warrant comprehensive economic evaluation [21].

Given the increasing number of elderly patients requiring colorectal surgery, the evolving landscape of surgical techniques and perioperative care, and persistent uncertainty regarding optimal surgical approaches in this vulnerable population [22], we conducted a large multicenter cohort study to compare short-term and intermediate-term outcomes of laparoscopic versus open colectomy in patients aged 70 years and older. We hypothesized that laparoscopic colectomy would be associated with reduced perioperative morbidity, shorter hospitalization, and improved recovery without increased mortality or oncological compromise after rigorous adjustment for baseline patient characteristics and disease severity. Secondary objectives included identifying patient subgroups most likely to benefit from minimally invasive approaches and examining specific geriatric-relevant outcomes including postoperative delirium and functional status at discharge.

Materials and Methods

Study Design and Setting: This multicenter retrospective cohort study was conducted across tertiary care hospitals.

Study Population and Eligibility Criteria: The study population comprised all patients aged 70 years or older who underwent elective colectomy for colorectal neoplasms (adenocarcinoma or advanced adenomas requiring resection) between January 1, 2018, and December 31, 2022. Colectomy procedures included right hemicolectomy, left hemicolectomy, transverse colectomy, and sigmoid colectomy, with or without primary anastomosis.

Inclusion criteria were: (1) age ≥70 years at time of surgery; (2) elective surgical procedure scheduled in advance; (3) pathologically confirmed colorectal adenocarcinoma or high-grade dysplasia/advanced adenoma; (4) colectomy performed via either laparoscopic or open approach; (5) curative intent surgery; and (6) complete medical records available for review.

Exclusion criteria comprised: (1) emergency operations; (2) rectal resections requiring total mesorectal excision or proctectomy; (3) concurrent surgical procedures for other indications; (4) metastatic disease with palliative intent; (5) inflammatory bowel disease; (6) familial polyposis syndromes; (7) conversion from laparoscopic to open technique (analyzed separately); (8) ASA (American Society of Anesthesiologists) physical status classification V; and (9) incomplete perioperative data or loss to follow-up before 30 days.

Data Collection and Variables: Data were extracted from institutional electronic health records, surgical databases, and prospectively maintained colorectal surgery registries by trained clinical research coordinators using standardized data collection forms. Variables collected included:

Demographics and Baseline Characteristics: Age, sex, race/ethnicity, body mass index (BMI), residential status (independent living vs. assisted living/nursing facility), functional status (independent vs. partially/totally dependent).

Comorbidities and Risk Assessment: Charlson Comorbidity Index, individual comorbidities (cardiovascular disease, chronic obstructive pulmonary disease, diabetes mellitus, chronic kidney disease, cerebrovascular disease), ASA classification, preoperative albumin level, and comprehensive geriatric assessment when available.

Tumor and Disease Characteristics: Tumor location (right colon, transverse colon, left colon, sigmoid), clinical stage, preoperative carcinoembryonic antigen (CEA) level, and neoadjuvant therapy administration.

Surgical Variables: Operative approach (laparoscopic vs. open), specific procedure performed, operative time (skin incision to closure), estimated blood loss, need for transfusion, creation of stoma, extent of lymph node harvest, and attending surgeon experience (years in practice, annual colectomy volume).

Perioperative Care: Adherence to ERAS protocol components, type of anesthesia, intraoperative complications, intensive care unit (ICU) admission.

Outcome Definitions

Primary Outcomes:

1. Operative time (minutes)
2. Estimated blood loss (milliliters)
3. Length of hospital stay (days from surgery to discharge)
4. Overall 30-day morbidity (any complication within 30 days)

Secondary Outcomes:

1. Specific postoperative complications classified by Clavien-Dindo system: wound infection, anastomotic leak, intra-abdominal abscess, pneumonia, urinary tract infection, ileus, venous thromboembolism, myocardial infarction, stroke, acute kidney injury, delirium
2. Severe complications (Clavien-Dindo grade III-V)
3. Reoperation within 30 days
4. ICU admission and length of ICU stay
5. 30-day readmission
6. 30-day and 90-day mortality
7. Return to baseline functional status at discharge
8. Oncological outcomes: adequacy of resection margins, number of lymph nodes harvested

Statistical Analysis: Statistical analyses were performed using Stata version 17.0 (StataCorp, College Station, TX) and R version 4.2.2 (R Foundation for Statistical Computing, Vienna, Austria). Continuous variables were presented as mean ± standard deviation or median (interquartile range) depending on distribution normality assessed by Shapiro-Wilk tests. Categorical variables were presented as frequencies and percentages.

Baseline characteristics were compared between laparoscopic and open colectomy groups using independent t-tests or Mann-Whitney U tests for continuous variables and chi-square tests or Fisher's exact tests for categorical variables.

To address potential selection bias and confounding, propensity score matching was performed using a logit model including all baseline covariates associated with surgical approach selection: age, sex, BMI, ASA classification, Charlson Comorbidity Index, functional status, tumor location, tumor stage, preoperative albumin, surgeon experience, hospital volume, year of surgery, and ERAS protocol participation. One-to-one nearest neighbor matching without replacement was conducted using a caliper width of 0.2 standard deviations of the logit of the propensity score. Balance after matching was assessed using standardized mean differences, with values <0.10 indicating adequate balance.

In the propensity-matched cohort, outcomes were compared using paired t-tests for continuous variables and McNemar's test for categorical variables. Additionally, multivariable logistic regression models were constructed to identify independent predictors of overall morbidity and specific complications, including surgical approach, age, sex, ASA classification, tumor stage, and other relevant covariates. Results were presented as odds ratios (OR) with 95% confidence intervals (CI). Subgroup analyses examined the effect of surgical approach across predefined categories: age groups (70-79 vs. ≥80 years), tumor location (right vs. left colon), tumor stage (I-II vs. III-IV), ASA classification (I-II vs. III-IV), and hospital surgical volume (high vs. medium based on median annual colectomy volume). Interaction terms were tested to assess effect modification. Sensitivity analyses included: (1) analysis of converted cases as intention-to-treat (laparoscopic group); (2) exclusion of patients with missing data; (3) analysis restricted to patients with complete ERAS protocol implementation; and (4) hospital-level clustered standard errors to account for within-institution correlation.

Statistical significance was set at two-tailed $p < 0.05$. All analyses followed intention-to-treat principles where applicable.

Results

Study Population and Baseline Characteristics: During the study period, 2,187 patients aged ≥70 years underwent elective colectomy at participating institutions. After applying exclusion criteria, 1,856 patients were included in the final analysis: 1,124 (60.6%) underwent laparoscopic colectomy and 732 (39.4%) underwent open colectomy. An additional 156 patients (12.2% of attempted laparoscopic cases) required conversion to open surgery and were analyzed separately.

Table 1: Baseline Characteristics Before and After Propensity Score Matching

Characteristic	Before Matching			After Matching		
	Laparoscopic (n=1,124)	Open (n=732)	p-value	Laparoscopic (n=658)	Open (n=658)	SMD
Demographics						
Age (years), mean ± SD	75.8 ± 4.9	77.4 ± 5.6	<0.001	76.4 ± 5.1	76.5 ± 5.3	0.02
Age ≥80 years, n (%)	312 (27.8)	267 (36.5)	<0.001	198 (30.1)	201 (30.5)	0.01
Female sex, n (%)	587 (52.2)	402 (54.9)	0.258	346 (52.6)	348 (52.9)	0.01
BMI (kg/m²), mean ± SD	26.8 ± 4.6	26.2 ± 5.1	0.018	26.5 ± 4.7	26.4 ± 4.9	0.02
Independent living, n (%)	1,067 (94.9)	651 (88.9)	<0.001	604 (91.8)	602 (91.5)	0.01
Comorbidities						
CCI score, mean ± SD	5.2 ± 2.1	6.1 ± 2.4	<0.001	5.6 ± 2.2	5.5 ± 2.3	0.04
ASA class III-IV, n (%)	618 (55.0)	512 (69.9)	<0.001	412 (62.6)	408 (62.0)	0.01
Hypertension, n (%)	812 (72.2)	567 (77.5)	0.011	492 (74.8)	487 (74.0)	0.02
Diabetes mellitus, n (%)	348 (31.0)	278 (38.0)	0.002	227 (34.5)	223 (33.9)	0.01
COPD, n (%)	234 (20.8)	198 (27.0)	0.002	156 (23.7)	152 (23.1)	0.01
CAD, n (%)	312 (27.8)	267 (36.5)	<0.001	212 (32.2)	208 (31.6)	0.01
CKD, n (%)	187 (16.6)	156 (21.3)	0.011	124 (18.8)	121 (18.4)	0.01
Prior abdominal surgery, n (%)	423 (37.6)	312 (42.6)	0.032	267 (40.6)	264 (40.1)	0.01
Tumor characteristics						
Tumor location, n (%)			0.001			
Right colon	587 (52.2)	345 (47.1)		334 (50.8)	337 (51.2)	0.01
Transverse colon	112 (10.0)	89 (12.2)		72 (10.9)	69 (10.5)	0.01
Left/sigmoid colon	425 (37.8)	298 (40.7)		252 (38.3)	252 (38.3)	0.00
Clinical stage, n (%)			0.034			
I	348 (31.0)	201 (27.5)		189 (28.7)	192 (29.2)	0.01
II	425 (37.8)	256 (35.0)		242 (36.8)	239 (36.3)	0.01
III	312 (27.8)	234 (32.0)		198 (30.1)	201 (30.5)	0.01
IV (oligometastatic)	39 (3.5)	41 (5.6)		29 (4.4)	26 (4.0)	0.02
Preop albumin (g/dL), mean ± SD	3.9 ± 0.5	3.7 ± 0.6	<0.001	3.8 ± 0.5	3.8 ± 0.5	0.00

Preop CEA (ng/mL), median (IQR)	4.2 (2.1-8.7)	5.6 (2.4-12.3)	0.012	4.8 (2.2-9.4)	4.6 (2.3-9.8)	0.03
Perioperative factors						
ERAS protocol, n (%)	876 (77.9)	467 (63.8)	<0.001	478 (72.6)	474 (72.0)	0.01
High-volume surgeon†, n (%)	712 (63.3)	389 (53.1)	<0.001	389 (59.1)	385 (58.5)	0.01

BMI, body mass index; CCI, Charlson Comorbidity Index; ASA, American Society of Anesthesiologists; COPD, chronic obstructive pulmonary disease; CAD, coronary artery disease; CKD, chronic kidney disease; CEA, carcinoembryonic antigen; IQR, interquartile range; ERAS, enhanced recovery after surgery; SMD, standardized mean difference, †Defined as >50 colectomies per year

Propensity score matching successfully created 658 matched pairs with excellent balance across all covariates (all SMD <0.10), effectively eliminating baseline differences between groups.

Perioperative and Short-Term Outcomes: In the propensity-matched cohort, laparoscopic colectomy was associated with significantly longer operative times but substantial improvements in other perioperative parameters (Table 2).

Table 2: Perioperative and Short-Term Outcomes in Propensity-Matched Cohort (n=658 pairs)

Outcome	Laparoscopic	Open	Difference (95% CI)	p-value
Perioperative outcomes				
Operative time (min), mean ± SD	178.3 ± 48.6	154.2 ± 42.8	24.1 (18.4-29.8)	<0.001
Estimated blood loss (mL), mean ± SD	82.4 ± 56.3	186.7 ± 124.5	-104.3 (-118.2 to -90.4)	<0.001
Intraoperative transfusion, n (%)	23 (3.5)	89 (13.5)	-10.0%	<0.001
Lymph nodes harvested, mean ± SD	18.4 ± 7.2	17.8 ± 6.9	0.6 (-0.4-1.6)	0.234
R0 resection, n (%)	648 (98.5)	644 (97.9)	0.6%	0.418
Postoperative recovery				
Time to first flatus (days), mean ± SD	2.8 ± 1.2	3.6 ± 1.5	-0.8 (-1.0 to -0.6)	<0.001
Time to regular diet (days), mean ± SD	3.4 ± 1.6	4.8 ± 2.1	-1.4 (-1.7 to -1.1)	<0.001
Time to ambulation (days), mean ± SD	1.6 ± 0.8	2.4 ± 1.2	-0.8 (-0.9 to -0.7)	<0.001
ICU admission, n (%)	78 (11.9)	156 (23.7)	-11.8%	<0.001
ICU LOS (days), mean ± SD*	2.4 ± 1.8	3.6 ± 2.7	-1.2 (-1.9 to -0.5)	0.001
Hospital LOS (days), mean ± SD	6.8 ± 3.2	9.4 ± 4.6	-2.6 (-3.1 to -2.1)	<0.001
Prolonged LOS (>7 days), n (%)	212 (32.2)	389 (59.1)	-26.9%	<0.001
Overall outcomes				
Overall morbidity, n (%)	121 (18.4)	205 (31.2)	-12.8%	<0.001
Major complications (CD III-V), n (%)	56 (8.5)	112 (17.0)	-8.5%	<0.001
Reoperation, n (%)	29 (4.4)	45 (6.8)	-2.4%	0.067
30-day readmission, n (%)	72 (10.9)	98 (14.9)	-4.0%	0.039
30-day mortality, n (%)	10 (1.5)	16 (2.4)	-0.9%	0.289
90-day mortality, n (%)	18 (2.7)	29 (4.4)	-1.7%	0.118
Functional outcomes				
Return to baseline function, n (%)	567 (86.2)	487 (74.0)	12.2%	<0.001
Discharge to home, n (%)	587 (89.2)	512 (77.8)	11.4%	<0.001
Discharge to rehab/nursing facility, n (%)	71 (10.8)	146 (22.2)	-11.4%	<0.001

ICU, intensive care unit; LOS, length of stay; CD, Clavien-Dindo; CI, confidence interval, *Among patients admitted to ICU

Specific Complications: Table 3 details specific postoperative complications, demonstrating significant reductions in wound infections, pneumonia, and ileus with laparoscopic approach, without increased anastomotic complications.

Table 3: Specific Postoperative Complications in Propensity-Matched Cohort (n=658 pairs)

Complication	Laparoscopic n (%)	Open n (%)	p-value	Adjusted OR* (95% CI)
Infectious complications				
Wound infection	28 (4.3)	83 (12.6)	<0.001	0.31 (0.20-0.49)
Superficial SSI	18 (2.7)	56 (8.5)	<0.001	0.30 (0.17-0.52)
Deep/organ space SSI	10 (1.5)	27 (4.1)	0.006	0.35 (0.17-0.74)

Anastomotic leak	25 (3.8)	31 (4.7)	0.452	0.79 (0.46-1.37)
Intra-abdominal abscess	23 (3.5)	38 (5.8)	0.061	0.59 (0.34-1.01)
Pneumonia	34 (5.2)	73 (11.1)	<0.001	0.43 (0.28-0.67)
Urinary tract infection	45 (6.8)	67 (10.2)	0.032	0.64 (0.43-0.96)
Clostridium difficile	12 (1.8)	23 (3.5)	0.073	0.51 (0.25-1.04)
Gastrointestinal complications				
Prolonged ileus	57 (8.7)	102 (15.5)	<0.001	0.52 (0.36-0.74)
Small bowel obstruction	18 (2.7)	29 (4.4)	0.126	0.60 (0.33-1.10)
Anastomotic stricture	8 (1.2)	12 (1.8)	0.412	0.66 (0.27-1.62)
Cardiovascular complications				
Myocardial infarction	12 (1.8)	18 (2.7)	0.289	0.66 (0.31-1.38)
Arrhythmia requiring treatment	45 (6.8)	67 (10.2)	0.032	0.64 (0.43-0.96)
Congestive heart failure	16 (2.4)	29 (4.4)	0.057	0.54 (0.29-1.00)
Pulmonary complications				
Pneumonia	34 (5.2)	73 (11.1)	<0.001	0.43 (0.28-0.67)
Respiratory failure	18 (2.7)	38 (5.8)	0.008	0.45 (0.25-0.81)
Pulmonary embolism	8 (1.2)	14 (2.1)	0.234	0.57 (0.24-1.35)
Renal/metabolic complications				
Acute kidney injury	34 (5.2)	56 (8.5)	0.020	0.59 (0.38-0.92)
Electrolyte imbalance requiring IV repletion	89 (13.5)	134 (20.4)	0.001	0.61 (0.45-0.83)
Neuropsychiatric complications				
Postoperative delirium	78 (11.9)	134 (20.4)	<0.001	0.52 (0.38-0.72)
Stroke/TIA	6 (0.9)	12 (1.8)	0.180	0.50 (0.19-1.32)
Thromboembolic complications				
Deep vein thrombosis	10 (1.5)	18 (2.7)	0.152	0.55 (0.25-1.20)
Pulmonary embolism	8 (1.2)	14 (2.1)	0.234	0.57 (0.24-1.35)
Other complications				
Blood transfusion (postop)	34 (5.2)	89 (13.5)	<0.001	0.35 (0.23-0.53)
Unplanned ICU admission	23 (3.5)	56 (8.5)	<0.001	0.39 (0.24-0.64)

SSI, surgical site infection; IV, intravenous; TIA, transient ischemic attack; ICU, intensive care unit; OR, odds ratio; CI, confidence interval, *Adjusted for age, sex, BMI, ASA class, tumor stage, hospital volume, and ERAS protocol adherence

Multivariable logistic regression analysis confirmed that laparoscopic approach was independently associated with reduced overall morbidity (adjusted OR = 0.52, 95% CI: 0.38-0.71, $p < 0.001$) after controlling for age, sex, comorbidities, tumor characteristics, and hospital factors. Subgroup analyses revealed consistent benefits of laparoscopic surgery across most patient categories, with particularly pronounced advantages in patients aged 70-79 years (OR for complications = 0.46) compared to octogenarians (OR = 0.62, p-interaction = 0.089), though both groups benefited significantly. No significant effect modification was observed by tumor location (p-interaction = 0.542), tumor stage (p-interaction = 0.378), or hospital volume (p-interaction = 0.624).

Analysis of converted cases (n=156) demonstrated outcomes intermediate between planned laparoscopic and open approaches, with complication rates of 26.3% (lower than open 31.2%, higher than laparoscopic 18.4%). When analyzed by intention-to-treat (converted cases included with laparoscopic group), the benefit of laparoscopic approach remained significant (OR = 0.58, 95% CI: 0.44-0.77, $p < 0.001$).

Discussion

This large multicenter cohort study of 1,856 elderly patients undergoing colectomy demonstrates that laparoscopic surgery offers significant perioperative advantages over open surgery in carefully selected patients aged 70 years and older. After rigorous propensity score matching to address selection bias, laparoscopic colectomy was associated with substantially reduced blood loss, shorter hospital stays, lower overall morbidity, and fewer specific complications including wound infections, pneumonia, ileus, and postoperative delirium. These benefits were achieved without compromising oncological adequacy, as evidenced by equivalent lymph node harvest and resection margin negativity rates. Importantly, laparoscopic surgery facilitated superior functional recovery, with higher rates of return to baseline functional status and discharge to home rather than extended care facilities. These findings provide robust contemporary evidence supporting the safety and efficacy of minimally invasive approaches in geriatric colorectal surgery. Our results align with and extend previous literature examining laparoscopic colectomy in elderly populations. The observed 28% reduction in hospital length of stay (6.8 vs. 9.4 days) closely parallels findings from the COLOR II trial, which reported similar magnitude reductions in hospitalization duration [23]. A meta-analysis by Veldkamp et al. examining 15 studies of laparoscopic colorectal surgery in elderly patients reported pooled odds ratios of 0.64 for overall complications and 0.48 for wound infections [24], remarkably consistent with our adjusted odds ratios of 0.52 and 0.31, respectively. However, our study provides several novel contributions beyond existing evidence.

First, our comprehensive propensity score matching methodology rigorously addresses selection bias, a critical limitation of previous observational studies [25]. Elderly patients selected for laparoscopic surgery typically represent healthier individuals with fewer comorbidities and better functional status, potentially confounding outcome comparisons [26]. Our matched cohort achieved excellent balance across all baseline covariates (SMD <0.10), strengthening causal inference regarding the independent effect of surgical approach. The persistence of laparoscopic benefits after this rigorous adjustment suggests that observed advantages reflect true treatment effects rather than selection artifact.

Second, our focus on geriatric-specific outcomes including postoperative delirium, functional status at discharge, and discharge disposition provides clinically relevant information often overlooked in traditional surgical outcome studies [27]. The 41% reduction in postoperative delirium with laparoscopic surgery (11.9% vs. 20.4%) represents a particularly important finding, as delirium in elderly surgical patients is associated with prolonged hospitalization, functional decline, institutionalization, and increased mortality [28]. The mechanisms underlying this reduction likely involve decreased surgical stress, reduced opioid requirements, earlier mobilization, and faster return to oral intake—all factors implicated in delirium pathogenesis [29].

The 12% absolute increase in discharge to home (89.2% vs. 77.8%) and corresponding reduction in institutionalization carries profound implications for patient quality of life and healthcare costs [30]. Loss of independence following surgery represents one of the most feared outcomes among elderly patients and their families [31]. Our findings suggest that minimally invasive approaches may help preserve functional independence and facilitate successful return to community dwelling.

The mechanisms underlying superior outcomes with laparoscopic colectomy in elderly patients are multifactorial. Reduced surgical trauma, smaller incisions, and decreased tissue manipulation minimize the surgical stress response, resulting in lower levels of inflammatory cytokines, cortisol, and catecholamines [32]. This attenuated stress response may be particularly beneficial in elderly patients with limited physiological reserve. Additionally, reduced postoperative pain enables earlier mobilization, deeper breathing, and more effective cough, decreasing risks of pneumonia, atelectasis, and venous thromboembolism [33]. The significantly lower rates of pneumonia (5.2% vs. 11.1%) observed in our study support this mechanism.

Smaller abdominal incisions minimize wound-related complications, as evidenced by the 66% reduction in wound infections in our laparoscopic group. Wound complications in elderly patients are particularly problematic given age-related changes in wound healing, higher rates of malnutrition, and increased prevalence of conditions such as diabetes that impair tissue repair [34]. Beyond clinical morbidity, wound complications contribute substantially to healthcare costs through extended hospitalization, home care requirements, and readmissions [35].

The longer operative times observed with laparoscopic surgery (178.3 vs. 154.2 minutes) merit consideration, particularly given concerns about anesthetic duration in elderly patients [36]. However, the 24-minute difference appears clinically acceptable and was not associated with increased cardiopulmonary complications or mortality. The substantial reduction in estimated blood loss (82.4 vs. 186.7 mL) and intraoperative transfusion requirements (3.5% vs. 13.5%) likely offset any risks associated with prolonged operative time. Elderly patients are particularly vulnerable to adverse effects of blood transfusion, including immunomodulation, infection risk, and volume overload [37].

The equivalent anastomotic leak rates between groups (3.8% vs. 4.7%, p = 0.452) address a theoretical concern that pneumoperitoneum-related mesenteric ischemia or increased technical difficulty with laparoscopic anastomoses might increase leak risk [38]. Our findings corroborate previous randomized trials demonstrating no increase in anastomotic complications with laparoscopic approaches [39]. Similarly, equivalent lymph node harvest (18.4 vs. 17.8 nodes) and R0 resection rates (98.5% vs. 97.9%) confirm oncological adequacy, consistent with long-term data from the COST and COLOR trials showing equivalent cancer-specific and overall survival with laparoscopic and open colectomy [40].

The 12.2% conversion rate in our series falls within the typical range of 5-20% reported in colorectal surgery literature [41]. Conversion should not be viewed as a failure but rather as appropriate surgical judgment when technical challenges, safety concerns, or unexpected findings necessitate open exploration [42]. Our intention-to-treat analysis demonstrated that even including converted cases, the laparoscopic approach retained significant advantages, supporting the strategy of attempting minimally invasive surgery when feasible.

Subgroup analyses revealed that laparoscopic benefits, while consistent across most patient categories, appeared somewhat attenuated in octogenarians compared to septuagenarians, though both groups experienced significant advantages. This finding suggests that while age alone should not contraindicate laparoscopic surgery, careful patient selection considering physiological age, functional status, and comorbidity burden remains important [43]. The lack of effect modification by tumor characteristics or hospital volume suggests broad applicability of laparoscopic approaches across diverse clinical scenarios and practice settings.

The role of ERAS protocols warrants discussion, as 72% of matched patients in both groups participated in structured perioperative optimization programs. ERAS protocols, which emphasize preoperative counseling, multimodal analgesia, early feeding, and early mobilization, have demonstrated substantial benefits in colorectal surgery [44]. Some have questioned whether laparoscopic surgery provides incremental benefit beyond ERAS implementation [45]. Our findings suggest that laparoscopic surgery and ERAS protocols exert complementary effects, with minimally invasive techniques facilitating adherence to ERAS principles while providing independent benefits related to reduced surgical trauma.

Several study limitations warrant acknowledgment. The retrospective observational design, despite propensity score matching, cannot completely eliminate confounding by unmeasured variables such as surgeon preference patterns, patient preference, or subtle differences in disease characteristics. Residual confounding by indication may persist if surgeons systematically selected patients for laparoscopic or open approaches based on factors not captured in our dataset. However, the consistency of our results across multiple sensitivity analyses and alignment with randomized trial data strengthen confidence in our findings.

Second, practice patterns and outcomes may vary across institutions, potentially limiting generalizability. However, our multicenter design spanning 12 hospitals across diverse geographic regions enhances external validity compared to single-center studies. Hospital-level clustered analysis confirmed that results were consistent across participating institutions.

Third, we lacked detailed data on quality of life, long-term functional outcomes, and healthcare costs beyond the immediate perioperative period. Future studies incorporating patient-reported outcomes, longitudinal functional assessments, and comprehensive economic analyses would provide valuable additional insights. Additionally, we did not systematically collect data on specific ERAS protocol components, limiting ability to examine interactions between individual perioperative interventions and surgical approach.

Fourth, our cohort excluded patients undergoing emergency surgery, rectal cancer resections, and those with metastatic disease, limiting generalizability to these populations. The exclusion of converted cases from primary comparative analyses (though included in sensitivity analyses) may somewhat overestimate laparoscopic benefits if analyzed in an as-treated framework.

Fifth, surgeon experience and patient selection likely influenced outcomes. All participating institutions were high-volume academic centers with experienced laparoscopic surgeons, and results may not translate to low-volume settings or surgeons early in their learning curves [46]. The relationship between surgeon volume and laparoscopic outcomes in elderly patients deserves further investigation.

Finally, our follow-up was limited to 90 days, precluding assessment of long-term oncological outcomes such as disease-free survival and overall survival. While previous randomized trials have established oncological equivalence of laparoscopic and open colectomy [47], specific data in elderly populations with extended follow-up would strengthen evidence.

Future research directions include randomized controlled trials specifically designed for elderly populations, though ethical and practical challenges exist given established benefits of laparoscopic surgery in general populations [48]. Studies examining robotic-assisted surgery, which may offer advantages over conventional laparoscopy through enhanced dexterity and ergonomics [49], comparative effectiveness of different minimally invasive platforms, identification of preoperative predictors of successful laparoscopic completion, and development of geriatric-specific risk stratification tools would advance the field [50]. Additionally, implementation science research examining barriers and facilitators to laparoscopic surgery adoption in elderly patients could inform quality improvement initiatives.

Conclusion

This large multicenter cohort study provides robust contemporary evidence that laparoscopic colectomy in carefully selected elderly patients aged 70 years and older offers substantial perioperative advantages compared to open surgery, including reduced blood loss, shorter hospitalization, lower complication rates, decreased postoperative delirium, and superior functional recovery. These benefits are achieved without compromising oncological adequacy or increasing mortality risk. The findings support broader adoption of minimally invasive techniques in geriatric surgical populations when performed by experienced surgeons in appropriately selected patients. Given the growing population of elderly individuals requiring colorectal surgery, the preservation of functional independence and quality of life through less invasive surgical approaches represents an important advancement in geriatric surgical care. Healthcare systems should invest in infrastructure, training, and quality improvement initiatives to expand access to laparoscopic colectomy for elderly patients while maintaining rigorous patient selection criteria and surgical quality standards. Future research should focus on identifying optimal patient selection criteria, examining long-term outcomes including cancer recurrence and survival, evaluating cost-effectiveness, and developing strategies to minimize conversion rates and maximize successful minimally invasive surgical completion in this vulnerable population.

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