**Name of journal:** *World Journal of Gastroenterology*

**ESPS Manuscript NO:** 20756

**Manuscript Type:** **ORIGINAL ARTICLE**

***Retrospective Cohort Study***

**Laparoscopic *vs* open partial colectomy in elderly patients: Insights from the American College of Surgeons - National Surgical Quality Improvement Program database**

Kannan U *et al*. Laparoscopic *vs* open colectomy in the elderly

Umashankkar Kannan, Vemuru Sunil K Reddy, Amar N Mukerji, Vellore S Parithivel, Ajay K Shah, Brian F Gilchrist, Daniel T Farkas

**Umashankkar Kannan, Vemuru Sunil K Reddy, Amar N Mukerji, Vellore S Parithivel, Ajay K Shah, Brian F Gilchrist, Daniel T Farkas.** Department of Surgery, Bronx-Lebanon Hospital Center, Bronx, NY 10457, United States

**Author contributions:** Kannan U conceived of the idea;Kannan U, Reddy VSK, Mukerji AN, Parithivel VS, Shah AK, Gilchrist BF, Farkas DT designed the research;Kannan U collected the data;Kannan U, Farkas DT interpreted and analyzed the data;Kannan U, Farkas DT wrote the paper;Kannan U, Reddy VSK, Mukerji AN, Parithivel VS, Shah AK, Gilchrist BF edited the paper;Farkas, DT supervised the project and performed the final revisions.

**Institutional review board statement:** This paper used public data with no protected health information (all the data is de-identified before going in the database) and is exempt from the Institutional Review Board.

**Informed consent statement:** No identifiable patients are involved in this study, and informed consent is not applicable.

**Conflict-of-interest statement:** None of the authors have any conflicts of interest related to the manuscript.

**Data sharing statement:** The original anonymous dataset is available on request from the corresponding author at dfarkas@bronxleb.org

**Open-Access:** This article is an open-access article which was selected by an in-house editor and fully peer-reviewed by external reviewers. It is distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited and the use is non-commercial. See: <http://creativecommons.org/licenses/by-nc/4.0/>

**Correspondence to:** **Daniel T Farkas,** Department of Surgery, Bronx-Lebanon Hospital Center,1650 Selwyn Avenue, Suite 4E,Bronx, NY 10457, United States.dfarkas@bronxleb.org

**Telephone:** +1-718-5901800

**Received:** June 20, 2015

**Peer-review started:** June 25, 2015

**First decision:** July 19, 2015

**Revised:** August 15, 2015

**Accepted:** October 12, 2015

**Article in press:**

**Published online:**

**Abstract**

**AIM:** To compare the outcomes between the laparoscopic and open approaches for partial colectomy in elderly patients aged 65 years and over using the American College of Surgeons - National Surgical Quality Improvement Program (ACS NSQIP) database.

**METHODS:** The ACS NSQIP database for the years 2005-2011 was queried for all patients 65 years and above who underwent partial colectomy. 1:1 propensity score matching using the nearest- neighbor method was performed to ensure both groups had similar pre-operative comorbidities. Outcomes including post-operative complications, length of stay and mortality were compared between the laparoscopic and open groups. χ2 and Fisher’s exact test were used for discrete variables and Student’s t-test for continuous variables. *P <* 0.05 was considered significant and odds ratios with 95% confidence interval were reported when applicable.

**RESULTS:** The total number of patients in the ACS NSQIP database of the years 2005-2011 was 1777035. We identified 27604 elderly patients who underwent partial colectomy with complete data sets. 12009 (43%) of the cases were done laparoscopically and 15595 (57%) were done with open. After propensity score matching, there were 11008 patients each in the laparoscopic (LC) and open colectomy (OC) cohorts. The laparoscopic approach had lower post-operative complications (LC 15.2%, OC 23.8%, *P <* 0.001), shorter length of stay (LC 6.61 d, OC 9.62 d, *P <* 0.001) and lower mortality (LC 1.6%, OC 2.9%, *P <* 0.001).

**CONCLUSION:** Even after propensity score matching, elderly patients in the ACS NSQIP database having a laparoscopic partial colectomy had better outcomes than those having open colectomies. In the absence of specific contraindications, elderly patients requiring a partial colectomy should be offered the laparoscopic approach.

**Key words:** Colectomy; Laparoscopic; Elderly; Outcomes; National Surgical Quality Improvement Program

**© The Author(s) 2015.** Published by Baishideng Publishing Group Inc. All rights reserved.

**Core tip:** Elderly patients having partial colectomies are at greater risk for complications due to a higher incidence of comorbidities. This study looked at patients aged 65 and above in a nationally validated database from the American College of Surgeons National Surgical Quality Improvement Program. Patients having a laparoscopic partial colectomy, when compared to an open partial colectomy, had fewer complications, shorter lengths of stay and decreased mortality.

Kannan U, Reddy VSK, Mukerji AN, Parithivel VS, Shah AK, Gilchrist BF, Farkas DT. Laparoscopic *vs* open partial colectomy in elderly patients: Insights from the American College of Surgeons - National Surgical Quality Improvement Program database. *World J Gastroenterol* 2015; In press

**INTRODUCTION**

The role of laparoscopy has been well documented in the field of colorectal surgery[1,2]. The laparoscopic approach has been associated with reduced postoperative pain, less morbidity, shorter lengths of stay, lower costs, fewer adhesions and a lower incidence of hernias[3,4]. Despite these well-established advantages, the minimally invasive approach has been underutilized with a recent study showing adoption rates of up to 40%[5,6]. The elderly population, aged 65 years and above, is one of the higher risk groups due to the presence of comorbidities and as a result is at increased risk for post-operative events[7]. Consequently, caring for such patients can present unique challenges. Laparoscopic cholecystectomy has been shown to be safe in this age group[8,9]. A laparoscopic colectomy requires a longer operating time than a laparoscopic cholecystectomy[10] and operative duration has been shown to be correlated with postoperative complications as well as length of stay[11,12]. On the other hand, open colorectal surgery in the elderly is itself associated with increased morbidity and mortality[13]. Hence it becomes important to look specifically in this elderly cohort and analyze if the laparoscopic approach is advantageous when compared with the conventional open approach.

The aim of this study is to compare the outcomes between elderly patients undergoing laparoscopic partial colectomy (LC) and open partial colectomy (OC). There are various studies showing improved outcomes with the laparoscopic approach but there are very few reports on its impact specifically in the elderly population[14,15]. The studies that are available are generally single institution studies based on small sample sizes[16-18]. The present work is based on a very large sample size from the American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) database. ACS NSQIP is the first nationally validated, risk adjusted, outcome based program to measure and improve the quality of surgical care. The number of variables, cases and centers participating in the ACS NSQIP database have been progressively increasing over the years. In 2012, ACS NSQIP included over 150 variables involving about 543885 cases from 315 academic and community-based hospitals in United States of America (USA). The variables collected include data on preoperative risk factors, intraoperative variables, 30-d postoperative mortality and morbidity outcomes for all patients aged 18 years and older undergoing major surgical procedures in the inpatient and outpatient settings. A trained surgical clinical reviewer captures this data prospectively by a variety of methods including medical chart abstraction using an 8 d cycle. To date, the ACS NSQIP has had a 95% success rate in capturing the 30 d outcomes for all cases in the database. The accuracy and reproducibility of its data has been well documented[19].

In studies that use nonrandomized databases such as the ACS NSQIP there is a potential for selection bias. In order to minimize these problems, propensity score matching was employed in this study. This allowed the two groups of patients to be more closely matched, which provides a more accurate comparison of the outcomes between the two groups.

**Materials and Methods**

***Patient selection***

Participant user files (PUF) from the years 2005 to 2011 of the ACS NSQIP database were combined into a single database. Patients undergoing a partial colectomy were included. Current Procedural Terminology (CPT) codes 44205, 44204 and 44207 were chosen as representing laparoscopic right, left and sigmoid colectomies respectively. CPT codes 44160, 44140 and 44145 were chosen as representing open right, left and sigmoid colectomies. Rectal procedures were not included, and neither were cases with colostomies or ileostomies. We excluded emergency cases, pregnant patients and database entries with missing data.

***Propensity score matching***

A propensity 1:1 matched analysis was then performed to identify similar patients groups in the LC and OC groups. The first step of the propensity score matching consisted of fitting a logistic regression to model the probability of receiving a LC. The covariates included in the regression were age, body mass index (BMI), sex, site of surgery, American Society of Anesthesiology (ASA) class 3 and above, cardiac, pulmonary, neurological, renal and bleeding disorders, diabetes mellitus and steroid usage. In the second step, LC patients were matched with OC patients based on the predicted probability (propensity score). The result was more balanced groups in the selected covariates.

***Statistical analysis***

The two groups were then compared using a bivariate analysis approach. Patient demographics, comorbidities, intraoperative complications and post-operative complications were then compared between the two groups using bivariate analysis. χ2 test was used for categorical variables and student’s *t* test was used for continuous variables. Fisher’s exact test was used for categorical variables with very small expected frequencies. Results were reported as mean (± standard deviation) for continuous variables and frequency for nominal and ordinal variables. *P* values < 0.05 were considered significant. Odds ratio (OR) with 95% confidence intervals (CI) were reported when applicable. Analyses were performed using SPSS 20 (IBM SPSS Inc., Chicago, IL).

**RESULTS**

The NSQIP database between 2005 and 2011 had a total of 1777035 patients. Of these patients, there were 91,307 who had a partial colectomy, with 43191 aged 65 and above (Figure 1). 15587 patients were excluded on the basis of being emergent cases, pregnant patients, or the dataset not being complete in the ACS NSQIP database. This left an index unmatched database of 27604 elderly partial colectomy patients. This original group had 12009 (43%) laparoscopic patients and 15595 (57%) open patients. The preoperative characteristics of these groups are outlined in Table 1. The groups are different in almost all demographic and comorbidity categories.

After propensity matching, we were left with a total of 22016 patients – 11008 patients in each of the laparoscopic and open cohorts. These are the groups that were used for comparison in our study, and their pre-operative characteristics are compared in Table 2. As a result of the propensity matching the two groups are essentially similar in terms of their demographics and rate of comorbidities. There were no significant differences between the groups in terms of cardiac, pulmonary, neurological, renal, hematological or endocrine comorbidities.

Intraoperative characteristics of the matched cohorts are shown in Table 3. The operative duration in the LC cohort is slightly higher than in the OC cohort (LC 152 min, OC 144 min, *P <* 0.001). The LC cohort had slightly lower need for transfusions (LC 2.3%, OC 2.8%, *P <* 0.001)). There was no statistically significant difference in intraoperative events, such as cardiac arrest, myocardial infarction and unplanned intubation between the groups, although these numbers were quite small.

Postoperative 30-d outcomes of both the cohorts are shown in Table 4. There were significantly fewer complications in the LC group (LC 15.2%, OC 23.8%, *P <* 0.001). These were lower in every single subcategory of cardiac, pulmonary, renal and infectious complications. Patients in the LC cohort had lower rates of unplanned return to the operating room (LC 4.1%, OC 5.3%, *P <* 0.001). Length of stay was shorter in the laparoscopic group (LC 6.61 d, OC 9.62 d, *P <* 0.001). Finally, the laparoscopic cohort had lower mortality than the open colectomy group (LC 1.6%, OC 2.9%, *P <* 0.001).

**DISCUSSION**

This study demonstrates that laparoscopic partial colectomy has better outcomes than open partial colectomy in the elderly patient. There are fewer complications, shorter lengths of stay, and lower mortality. A recent meta-analysis of colorectal surgery by Antoniou *et al*[20] involving 66,592 patients supports our conclusion of lower mortality (2.2 % in laparoscopic *vs* 5.4% in open approach) and overall morbidity (19.3 % *vs* 26.7% in open approach). Similar results are reported in the meta-analysis by Seishima *et al*[21] showing LC to have lower risk of perioperative mortality (OR = 0.55, *P <* 0.01) and postoperative complications (OR = 0.55, *P <* 0.01) when compared with open surgery. In a randomized control study involving 535 patients by Frasson *et al*[22], the laparoscopic approach was associated with an overall complication rate of 20% in comparison to 42% in the open group. Senagore *et al*[23] also report similar results in the laparoscopic group with shorter length of stay and lower direct hospital costs. These positive trends are also seen in octogenarians[16]. In a pooled analysis involving 11 studies, the laparoscopic approach was associated with lower incidence of postoperative cardiac complications, wound complications, earlier return of bowel function and shorter lengths of stay[17]. All of these small sample size studies and meta-analyses concluded that LC is safer and has better short term outcomes. Our analysis based on a large well validated ACS NSQIP database replicates these findings in a very large database of patients and confirms the benefits of the minimally invasive approach. More importantly, our study employed propensity matching to make sure the groups of patients were similar pre-operatively, and still found the same results.

The most common complication after colorectal surgery is surgical site infection (SSI)[24]. SSI in colorectal surgery is associated with significant economic burden and prolonged recovery, and it affects the quality of life significantly[25]. Our analysis showed an infection rate of 10.6% in the LC group in comparison with 17.7% in the OC group. A similar ACS NSQIP based analysis of colorectal procedures involving all age groups show an infection rate of 9.5% with the laparoscopic approach in comparison to 16% with the open approach[26]. The reasons for lower SSI with the laparoscopic approach might include reduced blood transfusions and reduced wound contact with the colon[27]. Elderly age is known to be a risk factor for respiratory and cardiac complications. This is probably due to higher incidence of comorbidities in this cohort and preoperative comorbidities have shown to be an important predictor of postoperative adverse outcomes[28,29].After matching for pre-operative cardiac, respiratory, neurological and renal comorbidities, our study showed a lower incidence of pneumonia and need for mechanical ventilation, as well as lower incidence of cardiac and renal complications with the laparoscopic approach. These lower rates of complications seen with the laparoscopic approach are probably related to there being less pain related splinting of diaphragm causing less postoperative atelectasis and pneumonia[30,31]. While our study does not explicitly look at cost, length of stay impacts the costs, and LC was associated with a significantly shorter recovery period[32].

The main strength of this study is its large sample size from a robust database. The ACS NSQIP database is one of the largest, well validated, risk adjusted current database designed to track surgical outcomes based on relevant set of perioperative variables. ACS NSQIP database has been demonstrated to improve outcomes and decrease expenses[33-35]. The hallmark of this data is that it is collected prospectively and strictly audited. This prevents the pitfalls of accruing data from small institutional databases. Another strength of our study is the use of propensity matching which further minimizes the bias associated with patient selection.

We recognize that there are limitations to our study. Although the ACS NSQIP database is one of the largest available, it does not represent every hospital as it includes only participating hospitals. In addition, we are only able to analyze the data that has been recorded. For example we can only group the patients into colectomies based on which part of the colon was removed, but any differences in surgical technique have not been recorded. And in terms of complications we have access to the number of complications in each category, but the severity of each complication (*e.g.,* Clavien-Dindo classification) is not available. Nonetheless, the extremely large size of the database allows for many of these deficiencies to not impact on the results. It is unlikely that the complications in one group were all severe while the complications in the other group were all minor.

Another limitation is the non-randomized nature associated with any large database. These are essentially cohort studies, and there is always a chance for selection bias. However, by incorporating propensity score matching into this study, we have significantly minimized the risk of this. And finally, other factors such as the surgeon’s experience and procedure volume are known to impact the outcomes but were not explored in this study[36].

Of course, each patient and each situation needs to be evaluated individually. In some cases there might be specific reasons why an open approach might be preferable, such as extensive prior surgery, a large mass or phlegmon, or surgeon comfort level. However, in the absence of specific contraindications our study showed better results with a laparoscopic approach.

In conclusion, this ACS NSQIP based study shows that even in elderly patients laparoscopic partial colectomy has better outcomes than those seen with open partial colectomy. There were decreases in every category of complications, they had shorter lengths of stay and lower mortality. This improvement in outcomes was seen even after matching the two groups by propensity scoring, ensuring that the two groups had similar rates of pre-operative comorbidities. Although a randomized control trial could be done to further the strength of the evidence, we feel the current data indicates that elderly patients requiring a partial colectomy should be offered a laparoscopic approach unless otherwise contraindicated.

**COMMENTS**

***Background***

Traditionally colon surgeries were done with an open approach. The introduction of laparoscopic techniques and improvement in the technology and instruments enabled the surgeons to adopt the laparoscopic approach for colectomies. Patients aged 65 years and above have increased comorbidities and are at risk for more complications, especially with longer operations. The question is whether the benefits of laparoscopic colectomy extend to the elderly population as well.

***Research frontiers***

The major areas to evaluate are mortality, morbidity and lengths of stay. Mortality and morbidity are generally considered within the first 30 d, and morbidity can be further subdivided into different types of complications, such as cardiac, pulmonary, renal and infectious complications.

***Innovations and breakthroughs***

The current study used a very large national database that has been well validated, the American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) database. In addition, the current study employed propensity matching in order to minimize any pre-operative differences between the open and laparoscopic groups.

***Applications***

This study shows that the laparoscopic approach was associated with lower mortality, lower complications of every type and shorter lengths of stay. This is important when surgeons are faced with elderly patients requiring a partial colectomy. This study points to the laparoscopic approach being the preferred method in the absence of any contraindications. Future research areas would include a large scale randomized control trial in this patient population.

***Terminology***

Partial colectomy refers to removal of a part of the colon. In this particular study this included an anastomosis between the remaining parts, as colostomy cases were excluded. Elderly in this study referred to patients aged 65 and above. Propensity matching refers to the statistical methods employed in order to ensure that two different groups are matched to become similar with respect to the chosen variables.

***Peer-review***

This is a large database study of colorectal surgery in the elderly, which is overall well written and nicely structured. The conception of the study is simple but the results are robust and well backed by the rather straightforward method.

**REFERENCES**

1 **Clinical Outcomes of Surgical Therapy Study Group**. A comparison of laparoscopically assisted and open colectomy for colon cancer. *N Engl J Med* 2004; **350**: 2050-2059 [PMID: 15141043 DOI: 10.1056/NEJMoa032651]

2 **Vaid S**, Tucker J, Bell T, Grim R, Ahuja V. Cost analysis of laparoscopic versus open colectomy in patients with colon cancer: results from a large nationwide population database. *Am Surg* 2012; **78**: 635-641 [PMID: 22643256]

3 **Bartels SA**, Vlug MS, Hollmann MW, Dijkgraaf MG, Ubbink DT, Cense HA, van Wagensveld BA, Engel AF, Gerhards MF, Bemelman WA. Small bowel obstruction, incisional hernia and survival after laparoscopic and open colonic resection (LAFA study). *Br J Surg* 2014; **101**: 1153-1159 [PMID: 24977342 DOI: 10.1002/bjs.9585]

4 **Wilson MZ**, Dillon PW, Hollenbeak CS, Stewart DB. How do risk factors for mortality and overall complication rates following laparoscopic and open colectomy differ between inpatient and post-discharge phases of care? A retrospective cohort study from NSQIP. *Surg Endosc* 2014; **28**: 3392-3400 [PMID: 24928234 DOI: 10.1007/s00464-014-3609-4]

5 **Robinson CN**, Chen GJ, Balentine CJ, Sansgiry S, Marshall CL, Anaya DA, Artinyan A, Albo D, Berger DH. Minimally invasive surgery is underutilized for colon cancer. *Ann Surg Oncol* 2011; **18**: 1412-1418 [PMID: 21213059 DOI: 10.1245/s10434-010-1479-0]

6 **Simorov A**, Shaligram A, Shostrom V, Boilesen E, Thompson J, Oleynikov D. Laparoscopic colon resection trends in utilization and rate of conversion to open procedure: a national database review of academic medical centers. *Ann Surg* 2012; **256**: 462-468 [PMID: 22868361 DOI: 10.1097/SLA.0b013e3182657ec5]

7 **Finlayson E**, Fan Z, Birkmeyer JD. Outcomes in octogenarians undergoing high-risk cancer operation: a national study. *J Am Coll Surg* 2007; **205**: 729-734 [PMID: 18035254 DOI: 10.1016/j.jamcollsurg.2007.06.307]

8 **Dubecz A**, Langer M, Stadlhuber RJ, Schweigert M, Solymosi N, Feith M, Stein HJ. Cholecystectomy in the very elderly--is 90 the new 70? *J Gastrointest Surg* 2012; **16**: 282-285 [PMID: 22143419 DOI: 10.1007/s11605-011-1708-2]

9 **Nielsen LB**, Harboe KM, Bardram L. Cholecystectomy for the elderly: no hesitation for otherwise healthy patients. *Surg Endosc* 2014; **28**: 171-177 [PMID: 23996332 DOI: 10.1007/s00464-013-3144-8]

10 **Daley BJ**, Cecil W, Clarke PC, Cofer JB, Guillamondegui OD. How slow is too slow? Correlation of operative time to complications: an analysis from the Tennessee Surgical Quality Collaborative. *J Am Coll Surg* 2015; **220**: 550-558 [PMID: 25728140 DOI: 10.1016/j.jamcollsurg.2014.12.040]

11 **Evans C**, Lim J, Gatzen C, Huang A. Factors influencing laparoscopic colorectal operative duration and its effect on clinical outcome. *Surg Laparosc Endosc Percutan Tech* 2012; **22**: 437-442 [PMID: 23047389 DOI: 10.1097/SLE.0b013e31826020a3]

12 **Turrentine FE**, Wang H, Simpson VB, Jones RS. Surgical risk factors, morbidity, and mortality in elderly patients. *J Am Coll Surg* 2006; **203**: 865-877 [PMID: 17116555 DOI: 10.1016/j.jamcollsurg.2006.08.026]

13 **Alves A**, Panis Y, Mathieu P, Mantion G, Kwiatkowski F, Slim K. Postoperative mortality and morbidity in French patients undergoing colorectal surgery: results of a prospective multicenter study. *Arch Surg* 2005; **140**: 278-83, discussion 284 [PMID: 15781793 DOI: 10.1001/archsurg.140.3.278]

14 **Senagore AJ**, Stulberg JJ, Byrnes J, Delaney CP. A national comparison of laparoscopic vs. open colectomy using the National Surgical Quality Improvement Project data. *Dis Colon Rectum* 2009; **52**: 183-186 [PMID: 19279409 DOI: 10.1007/DCR.0b013e31819ad4a4]

15 **Webb S**, Rubinfeld I, Velanovich V, Horst HM, Reickert C. Using National Surgical Quality Improvement Program (NSQIP) data for risk adjustment to compare Clavien 4 and 5 complications in open and laparoscopic colectomy. *Surg Endosc* 2012; **26**: 732-737 [PMID: 22038161 DOI: 10.1007/s00464-011-1944-2]

16 **Lian L**, Kalady M, Geisler D, Kiran RP. Laparoscopic colectomy is safe and leads to a significantly shorter hospital stay for octogenarians. *Surg Endosc* 2010; **24**: 2039-2043 [PMID: 20174947 DOI: 10.1007/s00464-010-0900-x]

17 **Grailey K**, Markar SR, Karthikesalingam A, Aboud R, Ziprin P, Faiz O. Laparoscopic versus open colorectal resection in the elderly population. *Surg Endosc* 2013; **27**: 19-30 [PMID: 22752280 DOI: 10.1007/s00464-012-2414-1]

18 **Chautard J**, Alves A, Zalinski S, Bretagnol F, Valleur P, Panis Y. Laparoscopic colorectal surgery in elderly patients: a matched case-control study in 178 patients. *J Am Coll Surg* 2008; **206**: 255-260 [PMID: 18222377 DOI: 10.1016/j.jamcollsurg.2007.06.316]

19 American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) available at https: //www.facs.org/quality-programs/acs-nsqip

20 **Antoniou SA**, Antoniou GA, Koch OO, Pointner R, Granderath FA. Laparoscopic colorectal surgery confers lower mortality in the elderly: a systematic review and meta-analysis of 66,483 patients. *Surg Endosc* 2015; **29**: 322-333 [PMID: 24986017 DOI: 10.1007/s00464-014-3672-x]

21 **Seishima R**, Okabayashi K, Hasegawa H, Tsuruta M, Shigeta K, Matsui S, Yamada T, Kitagawa Y. Is laparoscopic colorectal surgery beneficial for elderly patients? A systematic review and meta-analysis. *J Gastrointest Surg* 2015; **19**: 756-765 [PMID: 25617077 DOI: 10.1007/s11605-015-2748-9]

22 **Frasson M**, Braga M, Vignali A, Zuliani W, Di Carlo V. Benefits of laparoscopic colorectal resection are more pronounced in elderly patients. *Dis Colon Rectum* 2008; **51**: 296-300 [PMID: 18197453 DOI: 10.1007/s10350-007-9124-0]

23 **Senagore AJ**, Madbouly KM, Fazio VW, Duepree HJ, Brady KM, Delaney CP. Advantages of laparoscopic colectomy in older patients. *Arch Surg* 2003; **138**: 252-256 [PMID: 12611568]

24 **Wick EC**, Vogel JD, Church JM, Remzi F, Fazio VW. Surgical site infections in a "high outlier" institution: are colorectal surgeons to blame? *Dis Colon Rectum* 2009; **52**: 374-379 [PMID: 19333034 DOI: 10.1007/DCR.0b013e31819a5e45]

25 **Mahmoud NN**, Turpin RS, Yang G, Saunders WB. Impact of surgical site infections on length of stay and costs in selected colorectal procedures. *Surg Infect (Larchmt)* 2009; **10**: 539-544 [PMID: 19708769 DOI: 10.1089/sur.2009.006]

26 **Kiran RP**, El-Gazzaz GH, Vogel JD, Remzi FH. Laparoscopic approach significantly reduces surgical site infections after colorectal surgery: data from national surgical quality improvement program. *J Am Coll Surg* 2010; **211**: 232-238 [PMID: 20670861 DOI: 10.1016/j.jamcollsurg.2010.03.028]

27 **Poon JT**, Law WL, Wong IW, Ching PT, Wong LM, Fan JK, Lo OS. Impact of laparoscopic colorectal resection on surgical site infection. *Ann Surg* 2009; **249**: 77-81 [PMID: 19106679 DOI: 10.1097/SLA.0b013e31819279e3]

28 **Liu LL**, Leung JM. Predicting adverse postoperative outcomes in patients aged 80 years or older. *J Am Geriatr Soc* 2000; **48**: 405-412 [PMID: 10798467]

29 **Masoomi H**, Kang CY, Chen A, Mills S, Dolich MO, Carmichael JC, Stamos MJ. Predictive factors of in-hospital mortality in colon and rectal surgery. *J Am Coll Surg* 2012; **215**: 255-261 [PMID: 22640532 DOI: 10.1016/j.jamcollsurg.2012.04.019]

30 **Frazee RC**, Roberts JW, Okeson GC, Symmonds RE, Snyder SK, Hendricks JC, Smith RW. Open versus laparoscopic cholecystectomy. A comparison of postoperative pulmonary function. *Ann Surg* 1991; **213**: 651-63; discussion 651-63; [PMID: 1828139]

31 **Schwenk W**, Böhm B, Witt C, Junghans T, Gründel K, Müller JM. Pulmonary function following laparoscopic or conventional colorectal resection: a randomized controlled evaluation. *Arch Surg* 1999; **134**: 6-12; discussion 13 [PMID: 9927122]

32 **Noblett SE**, Horgan AF. A prospective case-matched comparison of clinical and financial outcomes of open versus laparoscopic colorectal resection. *Surg Endosc* 2007; **21**: 404-408 [PMID: 17180293 DOI: 10.1007/s00464-006-9016-8]

33 **McNelis J**, Castaldi M. "The National Surgery Quality Improvement Project" (NSQIP): a new tool to increase patient safety and cost efficiency in a surgical intensive care unit. *Patient Saf Surg* 2014; **8**: 19 [PMID: 24817910 DOI: 10.1186/1754-9493-8-19]

34 **Ingraham AM**, Richards KE, Hall BL, Ko CY. Quality improvement in surgery: the American College of Surgeons National Surgical Quality Improvement Program approach. *Adv Surg* 2010; **44**: 251-267 [PMID: 20919525]

35 **Hall BL**, Hamilton BH, Richards K, Bilimoria KY, Cohen ME, Ko CY. Does surgical quality improve in the American College of Surgeons National Surgical Quality Improvement Program: an evaluation of all participating hospitals. *Ann Surg* 2009; **250**: 363-376 [PMID: 19644350 DOI: 10.1097/SLA.0b013e3181b4148f]

36 **Liu CJ**, Chou YJ, Teng CJ, Lin CC, Lee YT, Hu YW, Yeh CM, Chen TJ, Huang N. Association of surgeon volume and hospital volume with the outcome of patients receiving definitive surgery for colorectal cancer: A nationwide population-based study. *Cancer* 2015; **121**: 2782-2790 [PMID: 25892632 DOI: 10.1002/cncr.29356]

**P-Reviewer:** Diener MK, Galvao FHF, Li XX, Symeonidis NG **S-Editor:** Yu J

**L-Editor:** **E-Editor:**



**Figure 1 Flowchart outlining patient selection.**

**Table 1 Preoperative characteristics of elderly patients undergoing partial colectomy before propensity score matching *n* (%)**

|  |  |  |  |
| --- | --- | --- | --- |
| **Characteristics** | **Laparoscopic colectomy,*****n =* 12009**  | **Open colectomy,*****n =* 15595**  | ***P* value** |
| Age, mean ± SD  | 75.94 ± 7.15 | 74.87 ± 6.92 | < 0.001 |
| BMI, mean ± SD  | 27.30 ± 6.38 | 27.17 ± 7.09 | < 0.001 |
| Gender FemaleMale  | 7401 (61.6)4608 (38.4) | 9536 (61.1)6059 (38.9) | 0.416 |
| ProcedureRight partial colectomyLeft partial colectomySigmoidectomy | 3122 (25.9)6614 (55.1)2273 (19.0) | 3773 (24.2)8492 (54.5)3330 (21.3) | < 0.001 |
| IndicationBenignMalignantUnknown | 4769 (39.7)4544 (37.8)2696 (22.4) | 5447 (34.9)7454 (47.8)2694 (17.3) | < 0.001 |
| ASA class IIIIIIIVV ASA III, IV or V | 155 (1.2)5418 (45.2)5956 (49.6)477 (4.0)3 (0.02)6436 (53.6) | 115 (0.7)4960 (31.8)9225 (59.2)1278 (8.2)17 (0.1)10,520 (67.5) | < 0.001 |
| Alcohol Current smoker  | 359 (2.9)1062 (8.8) | 408 (2.6)1689 (10.8) | 0.061< 0.001 |
| Cardiac diseasesHypertensionHistory of CHF History of MIHistory of angina History of PCIHistory of PCS | 8489 (70.7)8232 (68.5)119 (1.0)56 (0.5)80 (0.7)957 (8.0)959 (8.0) | 11350 (72.8)10936 (70.1)297 (1.9)169 (1.1)200 (1.3)1431 (9.2)1495 (9.6) | < 0.001.005< 0.001< 0.001< 0.001< 0.001< 0.001 |
| Pulmonary diseasesDyspneaHistory of COPD Ventilator dependent Pneumonia  | 836 (7.0)1600 (13.3)821 (6.8)4 (0.02)20 (0.2) | 1519 (9.7)2723 (17.4)1428 (9.2)58 (0.4)71 (0.5) | < 0.001< 0.001< 0.001< 0.001< 0.001 |
| Neurological diseaseHistory of CVA History of CVANO History of TIA History of Tumor CNS | 994 (8.3)347 (2.9)355 (3.0)516 (4.3)11 (0.1) | 1689 (10.8)613 (3.9)591 (3.8)801 (5.1)18 (0.1) | < 0.001< 0.001< 0.0010.0020.545 |
| Renal diseasesHistory of renal failure Dialysis dependent  | 62 (0.5)15 (0.1)52 (0.4) | 173 (1.1)56 (0.4)137 (0.9) | < 0.001< 0.001< 0.001 |
| Bleeding disorders | 487 (4.1) | 1009 (6.5) | < 0.001 |
| Steroid use1 | 365 (3.0) | 580 (3.7) | 0.002 |
| Diabetes | 3166 (26.4) | 3193 (20.5) | < 0.001 |

1Use of steroid in the 30 d prior to surgery for a chronic medical condition. BMI: Body Mass Index; ASA: American Society of Anesthesiologists; CHF: Congestive heart failure; MI: Myocardial infarction; PCI: Percutaneous coronary intervention; PCS: Previous cardiac surgery; PVD: Peripheral vascular disease; COPD: Chronic pulmonary obstructive disease; CVA: Cerebrovascular accident with neurological deficit; CVANO: Cerebrovascular accident without neurological deficit; TIA: Transient ischemic attack; Tumor CNS: Tumor involving central nervous system.

**Table 2 Preoperative characteristics of elderly patients undergoing partial colectomy after propensity score matching *n* (%)**

|  |  |  |  |
| --- | --- | --- | --- |
| **Characteristics** | **Laparoscopic colectomy** ***n =* 11008**  | **Open colectomy*****n =* 11008**  | ***P* value** |
| Age |  |  |  |
| mean ± SD median ± IQR | 75.12 ± 6.9774 ± 11 | 75.21 ± 6.9874 ± 12 | 0.8570.332 |
| BMI (Mean/SD)  | 27.31 ± 6.42 | 27.23 ± 7.05 | 0.368 |
| Gender FemaleMale  | 6685 (60.7)4323 (39.3) | 6852 (62.2)4156 (37.8) | 0.021 |
| ProcedureRight partial colectomyLeft partial colectomySigmoidectomy | 2549 (23.2)6237 (56.7)2222 (20.1) | 2736 (24.8)6099 (55.4)2173 (19.8) | 0.0130.0030.0610.409 |
| IndicationBenignMalignantUnknown | 4361 (39.6)4193 (38.1)2454 (22.3) | 3966 (36.0)5431 (49.3)1611 (14.6) | < 0.001 |
| ASA class IIIIIIIVVASA III, IV or V | 127 (1.1)4563 (41.5)5852 (53.2)463 (4.2)3 (0.02)6318 (57.4) | 110 (1.0)4563 (41.5)5673 (51.5)658 (6.0)4 (0.03)6335 (57.5) | 0.817 |
| Alcohol Current smoker  | 341 (3.0)1051 (9.5) | 289 (2.6)993 (9.0) | 0.0360.178 |
| Cardiac diseasesHypertensionHistory of CHF History of MIHistory of angina History of PCIHistory of PCS | 7905 (71.8)7654 (69.5)116 (1.1)51 (0.5)75 (0.6) 902 (8.2)924 (8.4) | 7845 (71.3)7614 (69.2)134 (1.2)57 (0.5)86 (0.7)807 (7.3)894 (8.1) | 0.3700.5590.2520.5630.3840.0170.463 |
| Pulmonary diseasesDyspneaHistory of COPD Ventilator dependent Pneumonia | 815 (7.4)1526 (13.7)801 (7.3)3 (0.02) 18 (0.2) | 778 (7.1)1513 (13.7)758 (6.9) 3 (0.02)24 (0.2) | 0.3360.4320.2591.0000.354 |
| Neurological diseaseHistory of CVA History of CVANO History of TIA History of Tumor CNS | 921 (8.4)333 (3.0)323 (2.9)347 (3.2)10 (0.1) | 896 (8.1)305 (2.8)307 (2.8)353 (3.2)6 (0.1) | 0.5400.2610.5180.8180.317 |
| Renal diseasesHistory of renal failure Dialysis dependent  | 57 (0.5)12 (0.1) 49 (0.4) | 55 (0.5)13 (0.1)48 (0.4) | 0.8500.8410.919 |
| Bleeding disorders | 466 (4.2) | 425 (3.9) | 0.161 |
| Steroid use1 | 353 (3.2) | 318 (2.9) | 0.170 |
| Diabetes | 2077 (18.9) | 2040 (18.5) | 0.522 |

1Use of steroid in the 30 d prior to surgery for a chronic medical condition. BMI: Body Mass Index; ASA: American Society of Anesthesiologists; CHF: Congestive heart failure; MI: Myocardial infarction; PCI: Percutaneous coronary intervention; PCS: Previous cardiac surgery; PVD: Peripheral vascular disease; COPD: Chronic pulmonary obstructive disease; CVA: Cerebrovascular accident with neurological deficit; CVANO: Cerebrovascular accident without neurological deficit; TIA: Transient ischemic attack; Tumor CNS: Tumor involving central nervous system.

**Table 3 Intraoperative characteristics of elderly patients undergoing partial colectomy after propensity score matching**

|  |  |  |  |
| --- | --- | --- | --- |
| **Characteristics** | **Laparoscopic colectomy*****n =* 11008** | **Open colectomy*****n =* 11008** | ***P* value** |
| Operative time (min), mean ± SD | 151.75 ± 66.15 | 143.56 ± 78.60 | < 0.001 |
| Anesthesia time (min),mean ± SD | 209.47 ± 78.54 | 200.72 ± 91.29 | < 0.001 |
| Blood transfusions, *n* (%) | 250 (2.3%) | 307 (2.8%) | < 0.001 |
| Intraoperative occurrenceCardiac Arrest Myocardial Infarction Unplanned Intubation | 135 | 5511 | 0.143 |

**Table 4 Post-operative outcomes of elderly patients undergoing partial colectomy after propensity score matching *n* (%)**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Characteristics | **Laparoscopic colectomy*****n =* 11008** | **Open colectomy*****n =* 11008** | ***P* value** | **Odds Ratio/****Confidence Interval** |
| Overall complications1 | 1676 (15.2) | 2622 (23.8) | < 0.001 | 1.56 (1.48-1.65) |
| Cardiac complicationsCardiac arrest Myocardial infarction | 109 (1.0)50 (0.4)71 (0.6) | 160 (1.5)80 (0.7)88 (0.8) | 0.0020.0080.176 | 1.47 (1.15-1.87)1.60 (1.13-2.28)1.24 (0.91-1.69) |
| Pulmonary complicationsPneumonia Unplanned Intubation Ventilated for more than 48 hPulmonary emboli Deep Venous Thrombosis  | 489 (4.4)239 (2.2)217 (2.0)165 (1.5)69 (0.6 )97 (0.9) | 729 (6.6)375 (3.4)326 (3.0)294 (2.7)87 (0.8)179 (1.6) | < 0.001< 0.001< 0.001< 0.0010.148< 0.001 | 1.49 (1.33-1.67)1.57 (1.34-1.84)1.50 (1.27-1.78)1.78 (1.48-2.15)1.26 (0.92-1.73)1.85 (1.44-2.36) |
| Renal complications:Progressive renal insufficiency Acute Renal failureUrinary tract infection | 421 (3.8)54 (0.4)50 (0.4)339 (3.1) | 656 (6.0)98 (0.9)72 (0.7)524 (4.8) | < 0.001< 0.0010.046< 0.001 | 1.56 (1.38-1.76)1.81 (1.30-2.53)1.44 (1.01-2.06)1.55 (1.35-1.77) |
| InfectionsSepsis Septic shock Superficial Incisional infection Deep Incisional infectionOrgan space infectionWound disruption | 1170 (10.6)274 (2.5)156 (1.4)582 (5.3)96 (0.9)206 (1.9)84 (0.8) | 1951 (17.7)468 (4.3)284 (2.6)968 (8.8)150 (1.4)347 (3.2)144 (1.3) | < 0.001< 0.001< 0.001< 0.0010.001< 0.001< 0.001 | 1.67 (1.56-1.78)1.71 (1.46-1.98)1.82 (1.50-2.21)1.66 (1.51-1.84)1.56 (1.21-2.02)1.68 (1.42-1.99)1.71 (1.31-2.24) |
| Return to operating room  | 451 (4.1) | 588 (5.3) | < 0.001 | 1.30 (1.16-1.47) |
| Length of stay (d), mean ± SD  | 6.61 ± 6.73 | 9.62 ± 8.33 | < 0.001 | - |
| 30-d mortality | 173 (1.6) | 316 (2.9) | < 0.001 | 1.83 (1.52-2.19) |

1Any one of cardiac, pulmonary, renal or infectious complications.