Hand-Assisted Laparoscopic Approach in Colon Surgery

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Abstract

Background This study sought to compare outcomes of patients who underwent hand-assisted laparoscopic (HAL) colectomy with open and laparoscopic colectomy (LP).

Study Design The NSQIP databases were used to examine the clinical data of patients who underwent elective colectomy during 2012–2013. Multivariate regression analysis was performed to compare the three surgical approaches.

Results We sampled a total of 21,090 patients who underwent colectomy. Of these, 7480 (35.5 %) had open colectomy (OC), 8751 (41.5 %) had a laparoscopic colectomy, 2860 (13.6 %) had a HAL colectomy, and 1999 (9.5 %) had an open procedure converted from LC or HAL. Multivariate regression analysis revealed HAL colectomy had a similar mortality (AOR 0.53, P=0.07) and a lower morbidity (AOR 0.37, P<0.01) compared to OC. LC had lower mortality (AOR 0.58, P=0.02) and morbidity (AOR 0.43, P<0.01) compared to OC. Mortality of patients who underwent HAL was not significantly different from LC (AOR 0.90, P=0.79); however, morbidity of such patients was significantly higher than for patients who underwent LC (AOR 1.29, P<0.01).

Conclusions HAL colectomy is a safe approach with significant advantages compared to open colectomy. Although the morbidity of patients who underwent HAL is higher than patients who underwent LC, the morbidity rate is still lower than OC.

Introduction

Since its introduction in 1990, laparoscopic colectomy has gradually become the preferred technique for colon resection.[1–4] Feasibility, safety, and advantages of laparoscopic colectomy compared to the traditional open colectomy have been reported multiple times.[5–7] However, the technical difficulties, learning curve, and limitations of laparoscopic colectomy make the adaptation of a laparoscopic approach in colon surgery slow.[8] In order to overcome the technical difficulties of laparoscopic colectomy, hand-assisted laparoscopic colectomy was introduced.[9] Hand-assisted laparoscopic (HAL) colectomy is a hybrid technique allowing surgeons to mix both open and laparoscopic techniques within the same operation.[10] It can be used to decrease the conversion rate of laparoscopic colectomy to open or to assist novice laparoscopic surgeons to climb the steps of the learning curve of laparoscopic colectomy.[10] The procedure involves insertion of a hand into the abdominal cavity through a special hand port, while otherwise maintaining the laparoscopic colectomy to facilitate colon resection.[11] A number of

studies have been reported comparing laparoscopic colectomy and HAL colectomy.[11–14] Shorter operative time and a lower conversion rate compared with laparoscopic colectomy have been reported.[15] However, the numbers of patients in these studies have been limited, and there is limited data comparing HAL colectomy with open and laparoscopic colectomy using multivariate analysis to attempt to control for population differences. Using a nationwide database, this study aims to compare outcomes of open, laparoscopic, and HAL colectomy.

Materials and Methods

This retrospective analysis was performed using the American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) database from 2012 to 2013. ACS NSQIP is a validated outcome-based database designed to improve hospital surgical quality.16 It provides pooled data from multiple institutions with over 250 variables including preoperative to 30-day postoperative information of surgical patients based on clinical data in the USA.16 Data abstraction occurs consistently with standardized definitions, and data accuracy is ensured by specifically trained nurses and audits at each participating institution.16 We analyzed the available data on patients who underwent elective colon resection. Patients with International Classification of Diseases, 9th Revision, clinical modifications (ICD-9-CM) diagnosis codes of colon cancer (153, 153.0–153.9, and 154.0), diverticular disease (562.10–562.13 and 562.1), benign colon tumors (211.3), ulcerative colitis (556 and 556.0–556.9), and Crohn's disease (555.1 and 555.2) were included only if they had procedure codes for colon resection according to the Current Procedural Terminology (CPT) codes of 44140–44160 and 44204–44212. Patients younger than 18 years, patients with an American Society of Anesthesiologists (ASA) class of five, and non-electively admitted patients were excluded from this study.

Variables of the study consisted of demographic-specific data on age, sex, race, comorbidities, type of the resection (partial colectomy vs. total colectomy), wound classification (clean, clean contaminated, contaminated, dirty), oral antibiotic and mechanical bowel preparation, surgical approach, ASA score, operation length, total hospitalization length, patient diagnosis (colon cancer, diverticular disease, ulcerative colitis, and Crohn's disease), preoperative white blood cell count, and serum albumin level which were abstracted from the database when available. All comorbidity variables reflect standardized NSQIP definitions except the obesity variable which was defined as a body mass index 30 or more according to the original variables of NSQIP. Primary end points of interest were mortality, overall morbidity, postoperative complications, total operation length, and total hospital stay.

Statistical Analysis

Data were recorded and analyzed using SPSS® software, version 22 (SPSS Inc., Chicago, IL). The length of total hospitalization and operation length were compared using a multivariate linear regression model. Multivariate analysis using logistic regression with calculation of adjusted odds ratio (AOR) and 95 % confidence interval was used to compare mortality and postoperative complications of open, laparoscopic,

and HAL colectomy groups. Also, using logistic regression, we compared different left-sided colectomy approaches with each other for diverticular disease patients in a subset analysis of data due to differential use of HAL for left and right colectomy. In order to eliminate effects of confounding variables, adjustments were done for all variables of the study which include age, sex, race, ASA classification, operation length, type of the diagnosis, type of the procedure, serum albumin level, white blood cell count, dyspnea, bleeding disorders, hypertension, weight loss, chronic steroid use, diabetes, chronic pulmonary disease, congestive heart failure, obesity, ascites, renal failure, wound classification, disseminated cancer, smoking, mechanical bowel preparation, and oral antibiotic bowel preparation. The level of significance used for retention was 0.05.

Results

A total of 21,090 patients who underwent elective colectomy were identified from the ACS NSQIP database for 2012–2013. The median age of patients was 62 years old; the majority of patients were Caucasian (86.7 %) and slightly more than half were female (50.6 %). Of the comorbidities encountered, the most common was hypertension (49.2 %) followed by diabetes (14.9 %). The summary of patient baseline characteristics by surgical approaches is shown in Table 1. Mortality of patients who underwent open colectomy was 2.1 %. Patients who underwent successfully completed laparoscopic and HAL colectomy had a mortality rate of 0.6 %. In multivariate analysis, there was no significant difference between mortality rate of laparoscopic and HAL approaches. Overall, morbidity rates of patients who underwent open, and successfully completed laparoscopic, and HAL colectomy were 44.6, 20.7, and 24.7 %, respectively. Following multivariate analysis, both laparoscopic and HAL approaches had significantly lower morbidity rates compared to open colectomy (Table 2). The median operation times of patients who underwent open, laparoscopic, and HAL colectomy were 147, 157, and 154 min, respectively. Laparoscopic colectomy had a longer operative time compared to open colectomy (mean difference=6 min, CI 3–10, $P<0.01$). Also, HAL colectomy had a significantly shorter operative time compared to laparoscopic colectomy (mean difference=8 min, CI 4–12, $P<0.01$). However, there was no significant difference in operative time between open and HAL colectomy (mean difference=3 min, $P=0.33$).

The median total hospitalization length of stay of patients who underwent open, successfully completed laparoscopic, and HAL colectomy were 7, 4, and 4 days, respectively. Both HAL colectomy (mean difference=3 days, CI 2–3, $P<0.01$) and laparoscopic colectomy (mean difference=3 day, CI 2–3, $P<0.01$) had a shorter total hospitalization length compared to open colectomy. There was no significant difference in total hospitalization length of patients between those who underwent laparoscopic and HAL colectomy (mean difference=0 day, CI 0–1, $P=0.21$).

Risk-adjusted analyses of postoperative complications of open, laparoscopic, and HAL colectomy are shown in Table 2. The risks of 13 postoperative complications were significantly lower in laparoscopic colectomy compared to open colectomy. Also, the risks of nine postoperative complications were significantly lower in HAL colectomy compared to open colectomy.

Table 5 reports risk-adjusted analysis of postoperative complications in HAL colectomy compared to laparoscopic colectomy. Although mortality risks of laparoscopic and HAL colectomy were not significantly different, morbidity of patients undergoing HAL colectomy was significantly higher than patients who underwent laparoscopic colectomy (AOR 1.29, P<0.01). Postoperative complications of sepsis (AOR 1.51, P=0.02), superficial surgical site infection (AOR 1.48, P<0.01), intra-abdominal infections (AOR 1.40, P= 0.04), and prolonged ileus (AOR 1.36, P<0.01) were significantly higher in HAL colectomy.

Risk-adjusted analysis of postoperative complications in patients who had a converted procedure to open compared to successfully completed laparoscopic and HAL operations is reported in Table 3. Although mortality and morbidity of patients who had a converted procedure were not significantly higher than open colectomy, patients with a converted procedure had significantly higher morbidity compared to successfully completed laparoscopic (AOR 2.42, P<0.01) and HAL colectomy (AOR 2, P<0.01).

Tables 4 and 5 report risk-adjusted analysis of postoperative complications of the subset of patients with diverticular disease who underwent laparoscopic and HAL colectomy compared to open colectomy, to control for differential use of HALS for left-sided vs. right-sided colectomy. Both laparoscopic and HAL colectomies had significantly lower morbidity compared to open colectomy for diverticular disease patients. When comparing laparoscopic and HAL approaches in diverticular disease patients, there was no significant difference in mortality (AOR 1.61, CI 0.11–23.12, P=0.72) and morbidity of patients (AOR 1.10, CI 0.85–1.41, P=0.46).

Table 1 Demographics of patients who underwent elective colon resection by surgical approach

Variables		Open (7480)	Laparoscopy (8751)	Hand-assisted laparoscopy (2860)	Converted procedures to open (1999)
Age	Mean ± SD (year)	63±15	60±115	61±114	61±114
	Median, year	64	61	62	63
Sex	Male	3649 (48.8 %)	4250 (48.6 %)	1438 (50.3 %)	1075 (53.8 %)
Race	White	5785 86.5 %)	6961 (86.2 %)	2389 (89.9 %)	1560 (85.1 %)
	Black or African American	718 (10.7 %)	766 (9.5 %)	175 (6.6 %)	218 (11.9 %)
	Asian	165 (2.5 %)	305 (3.8 %)	81 (3 %)	42 (2.3 %)
	Others	22 (0.3 %)	39 (0.5 %)	12 (0.5 %)	13 (0.7 %)
Comorbidity	Dyspnea	709 (9.5 %)	526 (6 %)	211 (7.4 %)	163 (8.2 %)
	Bleeding disorders	345 (4.6 %)	213 (2.4 %)	84 (2.9 %)	71 (3.6 %)
	Hypertension	3799 (50.8 %)	4043 (46.2 %)	1430 (50 %)	1096 (54.8 %)
	Weight loss	580 (7.8 %)	285 (3.3 %)	78 (2.7 %)	103 (5.2 %)
	Chronic pulmonary disease	452 (6 %)	338 (3.9 %)	131 (4.6 %)	88 (4.4 %)
	Diabetes mellitus	1236 (16.5 %)	1148 (13.1 %)	403 (14.1 %)	345 (17.3 %)
	Chronic steroid use	750 (10 %)	688 (7.9 %)	180 (6.3 %)	188 (9.4 %)
	Congestive heart failure	85 (1.1 %)	44 (0.5 %)	21 (0.7 %)	15 (0.8 %)
	Renal failure need for dialysis	53 (0.7 %)	39 (0.4 %)	13 (0.5 %)	14 (0.7 %)
	Disseminated cancer	724 (9.7 %)	242 (2.8 %)	91 (3.2 %)	108 (5.4 %)
	Ascites	72 (1 %)	14 (0.2 %)	6 (0.2 %)	7 (0.4 %)
	Obesity	2467 (33.3 %)	2818 (32.4 %)	1014 (35.6 %)	817 (41.1 %)
ASA class	I	108 (1.4 %)	318 (3.6 %)	86 (3 %)	38 (1.9 %)
	II	2843 (38 %)	4836 (55.3 %)	1474 (51.5 %)	904 (45.2 %)
	III	4047 (54.1 %)	3331 (38.1 %)	1224 (42.8 %)	980 (49 %)
	IV	482 (6.4 %)	266 (3 %)	76 (2.7 %)	77 (3.9 %)
Operation length	Mean ± SD (min)	170±1102	173±183	169±185	210±1101
	Median, min	147	157	154	192
Diagnosis	Colon cancer	4526 (60.5 %)	3912 (44.7 %)	1293 (45.2 %)	987 (49.4 %)
	Diverticular disease	1627 (21.8 %)	2431 (27.8 %)	940 (32.9 %)	596 (29.8 %)
	Ulcerative colitis	140 (1.9 %)	249 (2.8 %)	58 (2 %)	42 (2.1 %)
	Crohn's disease	669 (8.9 %)	540 (6.2 %)	114 (4 %)	155 (7.8 %)
	Benign colon tumors	518 (6.9 %)	1619 (18.5 %)	455 (15.9 %)	219 (11 %)
Procedure	Partial colectomy	7086 (94.7 %)	8386 (95.8 %)	2766 (96.7 %)	1907 (95.4 %)
	Total colectomy	394 (5.3 %)	365 (4.2 %)	94 (3.3 %)	92 (4.6 %)
Serum albumin level	Mean ± SD (g/dL)	3.6±10.6	3.9±10.5	3.9±10.5	3.7±10.6
	Median, g/dL	3.7	4	4	3.9
White blood cell count	Mean ± SD (cells/mm^3)	7.9±13.2	7.2±12.6	7.3±12.5	7.7±12.8
	Median, cells/mm^3	7.2	6.9	6.9	7.3
Other factors	Smoking	1393 (18.6 %)	1410 (16.1 %)	439 (15.3 %)	371 (18.6 %)
	Mechanical bowel preparation	3940 (63.8 %)	5322 (73.9 %)	1713 (75.4 %)	1124 (67.7 %)
	Oral antibiotic bowel preparation	1748 (28.2 %)	2303 (31.9 %)	717 (30.7 %)	545 (32.7 %)

SD standard deviation

Table 2 Risk-adjusted analysis for postoperative complications of laparoscopic and hand-assisted laparoscopic colectomy compared to open colectomy

Complication	Open surgery	Laparoscopic approach			Hand-assisted laparoscopic approach		
		Rate	AOR and 95 % CI	*P* value	Rate	AOR and 95 % CI	*P* value
Mortality	2.1 %	0.6 %	0.58 (0.37–0.92)	0.02	0.6 %	0.53 (0.26–1.05)	0.07
Overall morbidity[a]	44.6 %	20.7 %	0.43 (0.38–0.48)	<0.01	24.7 %	0.37 (0.18–0.74)	<0.01
Hemorrhagic complications	13.8 %	5.1 %	0.58 (0.48–0.69)	<0.01	5.5 %	0.61 (0.47–0.78)	<0.01
Hospitalization >30 days	2.6 %	0.9 %	0.52 (0.35–0.79)	<0.01	0.8 %	0.40 (0.20–0.79)	<0.01
Return to operation room	6 %	3.7 %	0.77 (0.62–0.96)	0.02	3.7 %	0.63 (0.46–0.88)	<0.01
Urinary tract infection	3.6 %	1.7 %	0.54 (0.40–0.74)	<0.01	1.9 %	0.54 (0.35–0.83)	<0.01
Prolonged ileus	19.8 %	7.4 %	0.38 (0.33–0.45)	<0.01	9.1 %	0.53 (0.44–0.65)	<0.01
Superficial SSI	8.5 %	3.8 %	0.46 (0.38–0.57)	<0.01	5.6 %	0.69 (0.53–0.90)	0.01
Deep incisional SSI	1.7 %	0.5 %	0.26 (0.15–0.45)	<0.01	0.7 %	0.34 (0.17–0.71)	<0.01
Anastomosis leakage	4.5 %	2.7 %	0.60 (0.46–0.78)	<0.01	3.2 %	0.68 (0.47–0.97)	0.03
Unplanned intubation	2.4 %	1 %	0.80 (0.55–1.15)	0.23	0.7 %	0.41 (0.21–0.79)	<0.01
Pneumonia	2.6 %	1 %	0.64 (0.44–0.93)	0.02	1.1 %	0.59 (0.34–1.02)	0.06
Progressive renal insufficiency	0.9 %	0.3 %	0.24 (0.11–0.52)	<0.01	0.4 %	0.55 (0.24–1.28)	0.17
Organ space SSI	5.8 %	2.7 %	0.57 (0.45–0.72)	<0.01	3.7 %	0.78 (0.57–1.06)	0.11
Sepsis	5 %	2 %	0.57 (0.43–0.75)	<0.01	2.7 %	0.88 (0.63–1.25)	0.50
Wound disruption	1.5 %	0.5 %	0.62 (0.37–1.04)	0.07	0.6 %	0.66 (0.32–1.34)	0.25
Deep vein thrombosis	1.7 %	0.8 %	0.80 (0.53–1.22)	0.31	0.8 %	0.96 (0.55–1.67)	0.89
Central vascular accident	0.3 %	0.2 %	1.51 (0.63–3.61)	0.35	0.2 %	1.46 (0.43–4.98)	0.53
Myocardial infarction	0.8 %	0.4 %	0.56 (0.28–1.10)	0.09	0.5 %	0.94 (0.42–2.12)	0.89
Pulmonary embolism	1 %	0.4 %	0.70 (0.41–1.20)	0.20	0.4 %	0.46 (0.19–1.12)	0.09
Cardiac arrest	0.5 %	0.3 %	0.83 (0.41–1.67)	0.60	0.2 %	0.45 (0.13–1.54)	0.20
Ventilator dependency	2.1 %	0.7 %	0.67 (0.43–1.04)	0.08	0.8 %	0.50 (0.24–1.02)	0.05
Septic shock	1.9 %	0.7 %	0.78 (0.50–1.22)	0.28	0.6 %	0.53 (0.26–1.10)	0.08

SSI surgical site infection

[a] Includes prolonged ileus, hospitalization more than 30 days, pneumonia, superficial surgical site infection, cardiac arrest, myocardial infarction, organ space surgical site infection, deep incisional surgical site infection, unplanned intubation, ventilator dependency, hemorrhagic complications, wound disruption, deep vein thrombosis, central vascular accident, pulmonary embolism, sepsis, return to operation room, anastomosis leakage, urinary tract infection, progressive renal insufficiency, and septic shock

Table 3 Risk-adjusted analysis for postoperative complications of hand-assisted laparoscopic colectomy compared to laparoscopic colectomy

Complication	Laparoscopic approach	Hand-assisted laparoscopic approach	Adjusted-odds ratio	95 % confidence interval	*P* value
Mortality	0.6 %	0.6 %	0.90	0.42–1.92	0.79
Overall morbidity[a]	20.7 %	24.7 %	1.29	1.11–1.49	<0.01
Sepsis	2 %	2.7 %	1.51	1.04–2.19	0.02
Superficial SSI	3.8 %	5.6 %	1.48	1.12–1.96	<0.01
Organ space SSI	2.7 %	3.7 %	1.40	1.01–1.93	0.04
Prolonged ileus	7.4 %	9.1 %	1.36	1.10–1.69	<0.01
Unplanned intubation	1 %	0.7 %	0.46	0.23–1.07	0.06
Hospitalization >30 days	0.9 %	0.8 %	0.82	0.38–1.74	0.61
Return to operation room	3.7 %	3.7 %	0.86	0.61–1.20	0.39
Pneumonia	1 %	1.1 %	0.99	0.54–1.80	0.98
Deep incisional SSI	0.5 %	0.7 %	1.30	0.57–2.98	0.52
Myocardial infarction	0.4 %	0.5 %	1.52	0.62–3.76	0.35
Hemorrhagic complications	5.1 %	5.5 %	1.01	0.77–1.33	0.89
Wound disruption	0.5 %	0.6 %	1.16	0.54–2.46	0.69
Deep vein thrombosis	0.8 %	0.8 %	1.29	0.72–2.31	0.39
Anastomosis leakage	2.7 %	3.2 %	1.15	0.79–1.67	0.45
Central vascular accident	0.2 %	0.2 %	0.87	0.25–2.99	0.82
Urinary tract infection	1.7 %	1.9 %	1.10	0.70–1.75	0.66
Progressive renal insufficiency	0.3 %	0.4 %	1.86	0.65–5.30	0.24
Pulmonary embolism	0.4 %	0.4 %	0.70	0.27–1.76	0.45
Cardiac arrest	0.3 %	0.2 %	0.49	0.13–1.81	0.29
Ventilator dependency	0.7 %	0.8 %	0.67	0.31–1.44	0.30
Septic shock	0.7 %	0.6 %	0.61	0.28–1.30	0.20

SSI surgical site infection

[a] Includes prolonged ileus, hospitalization more than 30 days, pneumonia, superficial surgical site infection, cardiac arrest, myocardial infarction, organ space surgical site infection, deep incisional surgical site infection, unplanned intubation, ventilator dependency, hemorrhagic complications, wound disruption, deep vein thrombosis, central vascular accident, pulmonary embolism, sepsis, return to operation room, anastomosis leakage, urinary tract infection, progressive renal insufficiency, and septic shock

Discussion

Hand-assisted laparoscopic colectomy is a safe and feasible surgical technique. Minimally invasive approaches to colectomy are becoming more common.[5, 6, 17] However, laparoscopic colectomy has a substantial learning curve and requires advanced laparoscopic skills.[17] Insertion of a hand during laparoscopic colectomy with restoration of spatial orientation can help surgeons to do complex colon procedures which they may find difficult to perform laparoscopically. Our study results show that while patients who underwent HAL colectomy had higher morbidity compared to patients who underwent laparoscopic colectomy, outcomes of patients who underwent HAL colectomy are still significantly better than patients who underwent open colectomy. Our results apply for patients who underwent all colonic resectional procedures. Also, in subset analysis of data for diverticular disease patients who underwent left colectomy, we found similar results compared to open colectomy, and the differences seen between LC and HAL were not apparent. Advantages of HAL colectomy compared to open colectomy have been cited multiple times.[18, 19] Also, recently published articles have reported on the safety of HAL colectomy for colorectal cancer.[19, 20] Before converting a laparoscopic

colectomy to open, the possibility of HAL approach should be evaluated. However, presence of selection bias for patients who underwent open, laparoscopic, and HAL colectomy limit our ability to draw more firm conclusions as these three groups of patients are not homogeneous groups of patients regarding demographic data, disease stage, and comorbidities. Patient with advanced disease more frequently underwent open surgery and HAL colectomy may be chosen in situations where laparoscopic surgery is suboptimal. On the other hand, designing a prospective study with three homogeneous groups of patients to compare open, laparoscopic, and HAL approaches is not practical, and retrospective studies which control for perioperative factors are more accessible and realistic.

Our study results show that HAL colectomy has a shorter hospitalization length of stay with fewer postoperative complications compared to open colectomy. We found a significant decrease in frequency of ten postoperative complications using the hand-assisted approach to colectomy compared to the open approach. Shorter hospitalization length, lower wound infection, and postoperative ileus for hand-assisted approach compared to open colectomy were reported previously.[11, 18, 19] Although in subset analysis of data for patients with diverticulitis who underwent left-sided colectomy we found similar results, differences in case selection of open surgery and HAL colectomy make any firm conclusions difficult to make. Also, the role of the HAL approach in emergent cases that more likely are done with the open approach is unclear and beyond the scope of the current study. Further studies are indicated to compare open and HAL colectomy with two homogeneous groups of patients.

Hand-assisted colectomy procedures can also be used as a bridge toward totally laparoscopic colectomy. Our study results show that while HAL colectomy has significant benefits compared to open colectomy, laparoscopic colectomy has better overall outcomes compared to the hand-assisted approach. We found that superficial surgical site infection, sepsis, intra-abdominal infections, and prolonged ileus are significantly higher in HAL approach compared to laparoscopic colectomy. Previous studies reported similar outcomes of laparoscopic and HAL colectomy.[15, 17, 21] This may be attributed to the fact that previous studies were generally underpowered with a limited number of patients. However, Tjandra reported a higher rate of ileus for HAL colorectal resection compared to laparoscopic resection which is in line with our study results.[22] The role of a HAL approach to colectomy remains controversial, and there is a debate whether it helps or hinders.[17] Despite disadvantages of HAL colectomy over laparoscopic colectomy, hand-assisted approach may be more likely done for complex colon procedures which have more limited opportunity for laparoscopic surgery.[13, 23] Considering that it is easier for some surgeons to perform HAL colectomy compared to laparoscopic colectomy,[24] it is reasonable to utilize hand-assisted colectomy in complex cases which a particular surgeon does not consider suitable for laparoscopic surgery. Also, our study results show that converted procedures have a twofold increased morbidity risk compared to successfully completed HAL colectomy. We have no information on conversion of a laparoscopic colon procedure to the hand-assisted approach, which needs further investigation.

Table 4 Risk-adjusted analysis for postoperative complications of patients with converted procedures to open compared to other approaches

Complication	Open approach		Laparoscopic approach		Hand-assisted laparoscopic approach	
	AOR and 95 % CI	*P* value	AOR and 95 % CI	*P* value	AOR and 95 % CI	*P* value
Mortality	1.29 (0.77–2.16)	0.32	1.88 (0.99–3.56)	0.05	2.06 (0.90–4.71)	0.08
Overall morbidity[a]	1.02 (0.88–1.18)	0.74	2.42 (2.07–2.82)	<0.01	2 (1.66–2.41)	<0.01
Prolonged ileus	1.05 (0.89–1.25)	0.53	2.67 (2.18–3.27)	<0.01	2.13 (1.67–2.70)	<0.01
Superficial SSI	1.25 (0.99–1.58)	0.05	2.81 (2.14–3.68)	<0.01	1.96 (1.43–2.69)	<0.01
Hemorrhagic complications	1.07 (0.87–1.31)	0.51	1.89 (1.49–2.41)	<0.01	1.84 (1.35–2.49)	<0.01
Deep incisional SSI	0.90 (0.55–1.49)	0.69	3.20 (1.63–6.29)	<0.01	2.35 (1.02–5.41)	0.04
Wound disruption	1.52 (0.91–2.54)	0.10	2.52 (1.34–4.72)	<0.01	2.31 (1.03–5.15)	0.04
Organ space SSI	1.05 (0.80–1.38)	0.70	1.88 (1.36–2.60)	<0.01	1.37 (0.93–2)	0.10
Anastomosis leakage	0.89 (0.63–1.25)	0.52	1.49 (1.02–2.18)	0.03	1.25 (0.79–1.96)	0.33
Sepsis	1.02 (0.74–1.40)	0.88	1.62 (1.11–2.37)	0.01	1.06 (0.68–1.65)	0.77
Unplanned intubation	0.68 (0.40–1.14)	0.15	0.93 (0.51–1.69)	0.81	1.94 (0.82–4.58)	0.12
Hospitalization >30 days	0.73 (0.46–1.17)	0.19	1.23 (0.66–2.29)	0.51	1.53 (0.66–3.53)	0.32
Return to operation room	0.91 (0.67–1.22)	0.53	1.09 (0.78–1.52)	0.59	1.31 (0.86–1.99)	0.19
Pneumonia	1.05 (0.68–1.64)	0.80	1.47 (0.87–2.50)	0.14	1.45 (0.74–2.84)	0.27
Myocardial infarction	0.92 (0.41–2.06)	0.85	1.86 (0.74–4.70)	0.18	0.91 (0.30–2.80)	0.87
Deep vein thrombosis	1.17 (0.71–1.94)	0.52	1.53 (0.85–2.75)	0.15	1.20 (0.59–2.43)	0.60
Central vascular accident	0.67 (0.14–3.21)	0.61	0.57 (0.11–2.82)	0.49	0.46 (0.05–7.05)	0.71
Urinary tract infection	0.75 (0.50–1.13)	0.17	1.28 (0.80–2.04)	0.29	1.21 (0.68–2.12)	0.50
Progressive renal insufficiency	0.40 (0.16–0.97)	0.04	1.35 (0.42–4.33)	0.61	0.62 (0.16–2.27)	0.47
Pulmonary embolism	0.89 (0.44–1.80)	0.74	1.36 (0.62–2.99)	0.43	2.43 (0.83–7.12)	0.10
Cardiac arrest	1.02 (0.44–2.37)	0.94	1.19 (0.44–3.17)	0.72	2.67 (0.64–11.18)	0.17
Ventilator dependency	0.89 (0.52–1.52)	0.68	1.22 (0.64–2.33)	0.52	1.97 (0.82–4.75)	0.12
Septic shock	0.75 (0.42–1.34)	0.33	1.03 (0.52–2.06)	0.92	1.53 (0.62–3.76)	0.35

SSI Surgical Site Infection

[a] Includes prolonged ileus, hospitalization more than 30 days, pneumonia, superficial surgical site infection, cardiac arrest, myocardial infarction, organ space surgical site infection, deep incisional surgical site infection, unplanned intubation, ventilator dependency, hemorrhagic complications, wound disruption, deep vein thrombosis, central vascular accident, pulmonary embolism, sepsis, return to operation room, anastomosis leakage, urinary tract infection, progressive renal insufficiency, and septic shock

Our study results show that HAL colectomy provides slightly more efficient segmental colectomy regarding operative time compared to laparoscopic colectomy. In addition, we found that the operative time of the hand-assisted approach and open colectomy have no significant differences. Previous studies have reported similar results.[14, 15, 21] Hand-assisted colectomy can be used to facilitate minimally invasive colectomy and speed up a certain laparoscopic step in difficult cases. Benefits of the hand-assisted approach should be balanced with its disadvantages such as higher risks of postoperative ileus and wound infection. In addition, long-term outcomes of HAL colectomy regarding the impact of creating a larger incision and inserting a hand into the abdomen as it relates to incisional hernia and small bowel obstruction needs more investigation. A recently published article reported HAL as an independent risk factor of incisional site hernia following abdominal surgery.[25] Closure of the hand port place with non-absorbable suture and limited activity for 4 to 6 weeks post procedure are suggested in the literature.[26]

The HAL approach in left-sided colectomies has the same outcomes as the laparoscopic approach. In the subset analysis of data, our study results show that patients with diverticular disease who underwent left colectomy benefit from both laparoscopic and HAL colectomy. However, we did not find any significant difference in postoperative complications of HAL and laparoscopic colectomy in diverticular disease patients. This is in line with previous reports.[15, 27] Considering the high conversion rate of laparoscopic colectomy to open for diverticulitis, such patients may benefit from the HAL approach before converting the procedure to open.[28]

Table 5 Risk-adjusted analysis for postoperative complications of patients with diverticulitis who underwent laparoscopic and hand-assisted laparoscopic colectomy compared to open colectomy

Complication	Open surgery	Laparoscopic approach			Hand-assisted laparoscopic approach		
		Rate	AOR and 95 % CI	*P* value	Rate	AOR and 95 % CI	*P* value
Mortality	1.2 %	0.2 %	0.25 (0.04–1.37)	0.11	0.2 %	0.34 (0.05–2.05)	0.24
Overall morbidity[a]	43.2 %	16.8 %	0.38 (0.31–0.47)	<0.01	19.8 %	0.39 (0.30–0.51)	<0.01
Hemorrhagic complications	10.2 %	2.8 %	0.66 (0.44–0.98)	0.04	2.5 %	0.37 (0.20–0.67)	<0.01
Unplanned intubation	2 %	0.2 %	0.19 (0.05–0.69)	0.01	0.2 %	0.11 (0.01–0.85)	0.03
Sepsis	5.9 %	2.1 %	0.61 (0.38–0.97)	0.03	2 %	0.33 (0.16–0.66)	<0.01
Prolonged ileus	18.1 %	5.2 %	0.40 (0.29–0.54)	<0.01	6.2 %	0.42 (0.29–0.61)	<0.01
Superficial SSI	10.2 %	4 %	0.33 (0.23–0.48)	<0.01	6 %	0.42 (0.27–0.66)	<0.01
Deep incisional SSI	1.6 %	0.5 %	0.29 (0.11–0.73)	<0.01	0.5 %	0.31 (0.10–0.98)	0.04
Hospitalization > 30 days	2.5 %	0.3 %	0.26 (0.08–0.79)	0.01	0.3 %	0.27 (0.06–1.18)	0.08
Return to operation room	6 %	3.9 %	0.83 (0.55–1.26)	0.38	3.7 %	0.46 (0.26–0.82)	<0.01
Anastomosis leakage	3.6 %	2.7 %	0.62 (0.37–1.04)	0.07	3 %	0.50 (0.26–0.99)	0.04
Wound disruption	1.9 %	0.5 %	0.38 (0.15–0.93)	0.03	0.6 %	0.37 (0.12–1.12)	0.08
Organ space SSI	6 %	3 %	0.75 (0.49–1.16)	0.21	3.1 %	0.48 (0.25–0.89)	0.02
Pneumonia	2 %	0.5 %	0.46 (0.20–1.09)	0.07	0.5 %	0.28 (0.08–1)	0.05
Progressive renal insufficiency	1 %	0.3 %	0.21 (0.04–1.06)	0.06	0.3 %	0.53 (0.10–2.66)	0.44
Urinary tract infection	3 %	1.6 %	0.62 (0.32–1.20)	0.16	2.1 %	1 (0.51–1.95)	0.99
Deep vein thrombosis	0.9 %	0.8 %	1.58 (0.53–4.72)	0.40	0.5 %	1.72 (0.52–5.71)	0.37
Central vascular accident	0.2 %	0 %	[b]	–	0.1 %	0.25 (0.01–7.47)	0.42
Myocardial infarction	0.6 %	0.2 %	0.84 (0.17–3.96)	0.82	0.2 %	0.36 (0.03–3.71)	0.39
Pulmonary embolism	0.8 %	0.3 %	0.45 (0.11–1.84)	0.26	0.3 %	0.53 (0.10–2.72)	0.45
Cardiac arrest	0.2 %	0 %	[b]	–	0 %	[b]	–
Ventilator dependency	2.1 %	0.5 %	0.62 (0.26–1.47)	0.28	0.4 %	0.24 (0.05–1.11)	0.06
Septic shock	1.5 %	0.6 %	1.03 (0.43–2.47)	0.93	0.5 %	0.69 (0.18–2.56)	0.58

SSI surgical site infection

[a] Includes prolonged ileus, hospitalization more than 30 days, pneumonia, superficial surgical site infection, cardiac arrest, myocardial infarction, organ space surgical site infection, deep incisional surgical site infection, unplanned intubation, ventilator dependency, hemorrhagic complications, wound disruption, deep vein thrombosis, central vascular accident, pulmonary embolism, sepsis, return to operation room, anastomosis leakage, urinary tract infection, progressive renal insufficiency, and septic shock

[b] There was not any case at least in one group to run multivariate analysis

Study Limitations

The main weakness of the study was the retrospective nature of it, and causality cannot be inferred based only on our data. Our study is further limited by selection bias and coding inaccuracies as a result of the retrospective design and using discharge data. The

NSQIP database does not represent a national weighted distribution of cases, and we could not report the rates of open, laparoscopic, and HAL colectomy as the national rates. We investigated surgical approaches in elective colon resections; however, utilization of laparoscopic and HAL in emergent cases needs to be investigated. One of the purported advantages of HAL is a lower conversion rate compared to laparoscopic surgery, but NSQIP does not separate the conversion rate of laparoscopic surgery and HAL to open operation, and therefore, we cannot provide any data to answer that question, and also, we could not compare intention to treat laparoscopic colectomy with HAL colectomy.[18] The decision to use a hand port is sometimes made when it becomes clear that a laparoscopic approach alone is suboptimal. However, in the NSQIP database, no data was available to evaluate if patients undergoing LC were converted to HAL or the procedure was started with the HAL approach in the first place. We compared the three groups of open, laparoscopic, and HAL colectomy in this study. However, these three groups of patients were not three homogeneous groups of patients regarding demographic data and comorbidities. The NSQIP database does not provide any information on long-term oncologic outcomes, conversion rate to open, and intra-operative transfusion.[23] Despite these limitations, the present analysis can be used as a baseline in future strategies and studies of utilizing HAL surgery in colorectal surgery.

Conclusion

Hand-assisted laparoscopic colectomy is a safe approach with significant advantages compared to open colectomy. It is reasonable to utilize hand-assisted colectomy in complex cases which are not felt to be suitable for laparoscopic surgery. When comparing it with laparoscopic colectomy, HAL colectomy is associated with higher rates of prolonged ileus, sepsis, intra-abdominal infection, and superficial surgical site infection. However, hand-assisted approach to colectomy does modestly, but significantly, decrease the length of operation compared to laparoscopic colectomy. The advantages and disadvantages of HAL colectomy should be compared for each colon procedure. The possibility of conversion of a laparoscopic colon procedure to hand-assisted approach and long-term outcomes of the insertion of a hand into the abdomen regarding risk of incisional hernia and small bowel obstruction need more investigation.[25, 26]

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