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ORIGINAL ARTICLE

Three-port laparoscopic cholecystectomy is safe and efficient in the treatment of surgical biliary disease: a retrospective cohort study

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Abstract

Multiple studies have suggested that three-port laparoscopic cholecystectomy is both feasible and safe. However, this approach has failed to gain acceptance outside of clinical trials, leaving adopters of this approach vulnerable to medico-legal scrutiny. We hypothesized that the three-port approach to laparoscopic cholecystectomy (LC) is safe and efficient in experienced hands. All LC (including robotic) cases were performed on patients 18 years and older between November 2018 and March 2020. Operations utilizing three ports were compared to those performed using more than three ports. The primary outcomes measured were total operative time, conversion-to-open rate, and the complication rate. A two-sample test was performed to compare operative times, and a Fisher's exact test was used to compare conversion-to-open and complication rates. Linear regression models were used to account for the effect of confounders. 924 total LCs were performed by 30 surgeons in the study period (71 three-port, 853 four or more ports). The mean operative time was 10 min shorter in the three-port group in comparison (64.1 ± 1.4 min vs. 74.4 ± 1.8 min, $p < 0.01$), despite a threefold higher rate of intraoperative cholangiogram in these cases (23.0% vs. 7.9%, $p < 0.001$). There was no significant difference in either the conversion-to-open rate (1.6% vs. 5.1%, $p = 0.35$), or the overall complication rate (7.1% vs. 8.7%, $p = 0.82$). Operative time for LC performed through three ports was significantly less than those performed through the traditional four port approach, despite utilizing intraoperative cholangiogram nearly three times as often. There was no difference in the conversion-to open rate or complication rate. These results provide considerable evidence that three-port laparoscopic cholecystectomy is comparable to four-port laparoscopic cholecystectomy in operative duration, conversion-to-open rate, and complication rate.

Keywords Laparoscopic cholecystectomy · Surgical education · Minimal ports

Introduction

The first laparoscopic cholecystectomy (LC) was performed by Dr. Erich Muhe of Boblingen, Germany, on September 12, 1985 [1]. The operation completed by Dr. Muhe was markedly different from the most-recognizable modern version of LC, however, in that it was completed utilizing only three ports: one for the endoscope inserted at the umbilicus, and two separate "working" ports placed in the suprapubic region [2]. Dr. Muhe's success with this initial operation was repeated 2 years later by Dr. Phillipe Mouret of Lyon, France, who had made two modifications to the procedure: the use of a charge-coupled device (CCD) camera attached to the laparoscope, allowing the procedure to be viewed on a monitor, and the addition of a fourth port, permitting retraction of the gallbladder by an assistant.

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News of Dr. Mouret's success quickly disseminated throughout France, and soon thereafter surgeons at academic hospitals in Paris and Bordeaux had replicated his technique. Within a year, multiple American surgeons reported successful completion of LC, setting off a revolution that has seen widespread adoption of laparoscopy as the recognized standard of care not only in cholecystectomy, but in a vast array of other common general surgery procedures as well. Relevant here, the earliest peer-reviewed reports of LC feature four-trocar techniques, with the fourth port used either for application of a liver retractor [3], or for active retraction of the gallbladder fundus by an assistant [4]. The benefits of a fourth port in the four-trocar technique have not been formally demonstrated, however. The purpose of this study was to compare operations performed through a three-port technique with those done through a traditional four-port technique in an effort to compare the two techniques in terms of operative duration, as well as safety against a recognized benchmark. We also hypothesized that this technique is safe to teach in the setting of a general surgery residency program with sufficiently experienced attending staff.

Methods

Data collection

All patients 18 years of age and older who underwent cholecystectomy at either of two academic medical center-affiliated hospitals within the same healthcare system between November 1, 2018 and March 20, 2020 were identified and charts retrospectively reviewed. Patients were excluded if no attempt was made at laparoscopy, as determined by review of the operative report, or the cholecystectomy was performed incidental to a clear, alternative primary indication (e.g., gastric bypass). The primary outcomes measured included the duration of the operation in minutes, as recorded in the perioperative nursing notes, as well as the complication rate and conversion-to-open rate. Operative indication was determined by surgeon-specified postoperative diagnosis. Postoperative length of stay (POLOS) was measured from the date of surgery to the calendar date of discharge. The postgraduate year (PGY) of the involved resident, or alternative assistant (nurse practitioner, physician assistant, certified first assist, attending) was recorded. When multiple residents were involved, the senior-most resident was considered the operator. Postoperative length of stay (POLOS) was measured from the date of surgery to the calendar date of discharge; this study included any LC performed inpatient or outpatient. Complications were determined by chart review. Intraabdominal fluid collections were considered to be the result of a bile leak only if evidence of a leak was seen on postoperative MRCP or ERCP. Due to differences noted in operative indication between study groups, subset analysis was performed in which the primary outcomes were determined in those patients undergoing LC for biliary colic, and separately for those patients undergoing LC for acute cholecystitis. This study was approved by the University of Arizona Institutional Review Board, protocol number 2006717305.

Statistical analysis

Patient characteristics were summarized using mean ± standard deviation for continuous variables and using frequency and the associated percentage for categorical variables by number of ports (three vs. > three). Wilcoxon rank-sum and Fisher's exact tests were performed to compare the continuous and categorical patient characteristics, respectively, between three ports and more than three ports. Log-normal regression was performed to compare highly right skewed operative time and length of stay between three and more than three ports. Logistic regression was performed to compare conversion and complication rates between three and more than three ports. Patient characteristics were adjusted in both log-normal and logistic regression. Subset analyses were also performed on those patients undergoing LC for acute cholecystitis, and those undergoing LC for biliary colic. The significance level was set at a p value of 0.05. All analyses were performed using SAS 9.4 (SAS, Cary, North Carolina).

Results

There were 924 total laparoscopic cholecystectomies performed over the study period. 71 were performed using three ports, and 853 were completed through more than 3 ports (traditional). Overall, there were 284 men (31%) and 634 women (69%), with no significant differences between the two groups (Table 1). The mean age was 45.4 + 17.1 years, again with no significant differences between the two groups. Body mass index (BMI), American Society of Anesthesiologists (ASA) classification, and smoking status were likewise similar between the two groups.

Abdominal access was gained with the use of a Veress needle in all but one of the three-port operations (99%), while in the comparison group access was evenly split between a Hasson and Veress approach (51% vs. 47%, Table 2). Intraoperative cholangiogram (IOC) was performed in 83 cases, 16 (23.0%) in the three-port group, and 67 (7.9%) in the traditional group. All but 1 of the three-port operations had resident participation (99.0%), whereas 793 (93.0%) of the traditional operations involved residents. The most common level of the involved resident in the three-port group was postgraduate year 3 (PGY-3,

Table 1 Demographic comparison of the three-port versus four-port study groups

	Overall, $N=924$	Three ports, $N=71$	> Three ports, $N=853$	p value
Gender				0.92
Male	284 (31.0%)	23 (32.0%)	261 (31.0%)	
Female	635 (69.0%)	48 (65.0%)	587 (69.0%)	
Age	45.4 ± 17.1	44.6 ± 15.3	45.4 ± 17.3	0.79
BMI	32.4 ± 8.1	32.2 ± 6.9	32.4 ± 8.2	0.84
ASA class				0.50
1	150 (16.0%)	13 (18.0%)	137 (16.0%)	
2	553 (60.0%)	48 (68.0%)	505 (59.0%)	
3	205 (22.0%)	10 (14.0%)	195 (23.0%)	
4	15 (1.6%)	0 (0.0%)	15 (1.8%)	
Smoker	178/924 (19.0%)	18/71 (25.0%)	160/853 (19.0%)	0.21

Table 2 Comparison of intraoperative characteristics of the three-port versus four-port study groups

	Overall, $N=924$	Three ports, $N=71$	> Three ports, $N=853$	p value
Abdominal access				< 0.0001
Hasson	435 (47.0%)	1 (1.4%)	434 (51.0%)	
Optiview	17 (1.8%)	0 (0.0%)	17 (2.0%)	
Veress	472 (51.0%)	70 (98.6%)	160 (19.0%)	< 0.001
IOC	83 (9.0%)	16 (23.0%)	67 (7.9%)	
Resident level				< 0.0001
No assist	36 (3.9%)	0 (0%)	36 (4.2%)	
PGY-1	23 (2.5%)	9 (13.0%)	14 (1.6%)	
PGY-2	95 (10.0%)	6 (8.5%)	89 (10.0%)	
PGY-3	212 (23.0%)	26 (37.0%)	186 (22.0%)	
PGY-4	83 (9.0%)	2 (2.8%)	81 (9.5%)	
PGY-5	278 (30.0%)	23 (32.0%)	255 (30%)	
PGY-6	82 (8.9%)	4 (5.6%)	78 (9.2%)	
PGY-7	88 (9.5%)	0 (0.0%)	88 (10.0%)	
Attending	17 (1.8%)	1 (1.4%)	16 (1.9%)	
Certified first assist	4 (0.5%)	0 (0.0%)	4 (0.5%)	
Physician assistant	2 (0.2%)	0 (0.0%)	2 (0.2%)	
Nurse practitioner	2 (0.2%)	0 (0.0%)	2 (0.2%)	
Indication				< 0.0001
Acute cholecystitis	358 (39.0%)	18 (25.0%)	340 (40.0%)	
Biliary colic	260 (28.0%)	41 (58.0%)	219 (26.0%)	
Biliary dyskinesia	12 (1.3%)	0 (0.0%)	12 (1.4%)	
Biliary pancreatitis	76 (8.2%)	2 (2.8%)	74 (8.7%)	
Cholangitis	5 (0.5%)	0 (0.0%)	5 (0.6%)	
Choledocholithiasis	70 (7.6%)	1 (1.4%)	69 (8.1%)	
Cholelithiasis	1 (0.1%)	0 (0.0%)	1 (0.1%)	
Chronic cholecystitis	62 (6.7%)	5 (7.0%)	57 (6.7%)	
Gallbladder polyp	1 (0.1%)	0 (0.0%)	1 (0.1%)	
Gangrenous cholecystitis	39 (4.2%)	1 (1.4%)	38 (4.5%)	
Hydrops gallbladder	40 (4.3%)	3 (4.2%)	37 (4.3%)	
Mean operative time (min)		63.4 ± 1.4	73.7 ± 1.6	< 0.01
Complications	81 (8.8%)	5 (7.0%)	76 (8.9%)	< 0.001
Conversion to open	10 (1.1%)	1 (1.6%)	9 (1.1%)	0.83

$n=26$, 37.0%), followed by PGY-5 ($n=23$, 32.0%). This was in contrast to the traditional group, in which the most common level of the participating resident was PGY-5 ($n=255$, 30.0%), followed by PGY-3 ($n=186$, 22.0%). The most common indication for LC in those who underwent a three-port approach was biliary colic ($n=41$, 58.0%), with the second-most common indication being acute cholecystitis ($n=18$, 25.0%). In those who underwent the traditional approach, acute cholecystitis was the most frequent surgical indication ($n=340$, 40.0%), with biliary colic being the second most common indication ($n=219$, 26.0%).

Mean operative time was significantly lower in the three-port operations (63.4 ± 1.4 min vs. 73.7 ± 1.6 min, $p < 0.01$). Complication rates were not significantly different between the two techniques (7.0% vs. 8.9%, $p = 0.83$). There were two common bile duct injuries (CBDI) during the study period, both occurring in the traditional group. There was likewise no significant difference in the conversion-to-open rates (1.6% vs. 5.0%, $p = 0.36$).

To account for indication bias, subset analyses were performed on those patients undergoing LC for acute cholecystitis, and those undergoing LC for biliary colic. A comparison of the patient characteristics in the acute cholecystitis subset can be seen in Table 3. A total of 358 patients had LC in the setting of acute cholecystitis, of which, 18 underwent a three-port approach, and the remaining 340 had more than three ports utilized. There was no significant difference in the mix of male versus female patients between those undergoing LC with the use of three ports when compared to those in whom a traditional technique was used. Similarly, there was no difference in the mean age between the two groups (45.4 ± 18.3 years vs. 44.8 ± 16.5 years, $p > 0.9$), and BMI was likewise comparable (30.2 ± 6.3 kg/m^2 vs. 33.3 ± 8.4 kg/m^2, $p = 0.12$). Additionally, there were no differences in smoking status, the presence of major comorbidities, or ASA classification. Despite the comparability of the study groups, the difference in operative time persisted as shown in Table 4, with the three-port group demonstrating a mean operative time approximately 20 min less than that of the comparison group (67.3 ± 23.0 min vs. 87.6 ± 41.4 min, $p < 0.05$). Notably, three-port patients were seven times more likely to have intraoperative cholangiogram performed as compared to the traditional group (28.0% vs. 4.1%, $p < 0.001$). There were no differences in length of stay (1.33 ± 1.1 days vs. 1.21 ± 1.2 days, $p = 0.6$), complication rate (22% vs. 11%, $p = 0.3$), or conversion-to-open rate (0.0% vs. 4.1%, $p > 0.9$).

Overall, 260 patients underwent LC for an indication of biliary colic, 41 of whom via the three-port approach, and a traditional approach utilized in the remaining 219 patients. Table 5 shows a comparison of the patient characteristics between the two study groups in this subset. Again, there were no significant differences in the gender composition ($p = 0.9$), mean age (43.8 ± 14.0 years vs. 41.8 ± 15.8 years, $p = 0.3$), or mean BMI (33.3 ± 8.5 kg/m^2 vs. 32.1 ± 8.7 kg/m^2, $p = 0.3$). Likewise, there were no differences in smoking status, the presence of major comorbidities, ASA classification. Three-port patients were significantly more likely to undergo intraoperative cholangiogram (20.0% vs. 3.7%, $p < 0.001$), as well as a Veress-needle strategy for initial access (98.0% vs. 69.0%, $p < 0.001$). Table 6 shows the results of this subset analysis in terms of the primary outcomes considered. On average, the traditional approach was approximately three minutes faster than the three-port approach (65.0 ± 20.2 min vs. 62.0 ± 30.2 min, $p < 0.05$). As in the case of acute cholecystitis, there were no differences in length of stay (0.3 ± 0.7 days vs. 0.5 ± 1.1 days, $p = 0.09$), complication rate (2.4% vs. 6.4%, $p = 0.5$), or conversion-to-open rate (0.0% vs. 1.8%, $p > 0.9$).

Table 3 Comparison of the demographic characteristics of the subset of patients undergoing LC for acute cholecystitis

	Overall, $N = 357$	Three ports, $N = 18$	> Three ports, $N = 340$	p value
Gender				0.9
Male	119 (33.0%)	7 (39.0%)	112 (33.0%)	
Female	236 (66.0%)	11 (61.0%)	225 (67.0%)	
Age	44.9 ± 16.6	45.4 ± 18.3	44.8 ± 16.5	> 0.9
BMI	33.1 ± 8.3	30.2 ± 6.3	33.3 ± 8.4	0.12
ASA class				0.6
1	60 (17.0%)	5 (28.0%)	55 (16.0%)	
2	213 (60.0%)	9 (50.0%)	204 (60.0%)	
3	79 (22.0%)	4 (22.0%)	75 (22.0%)	
4	5 (1.4%)	0 (0.0%)	2 (0.6%)	
Smoker	86 (24.0%)	7 (39.0%)	79 (23.0%)	0.2

Table 4 Results of the subset analysis of patients undergoing LC for acute cholecystitis

	Overall, $N = 357$	Three ports, $N = 18$	> Three ports, $N = 340$	p value
Operative time (min)	86.6 ± 40.9	67.3 ± 23.0	87.6 ± 41.4	< 0.05
Length of stay (days)	1.2 ± 1.2	1.3 ± 1.1	1.2 ± 1.2	0.6
Any complication	40 (11.2%)	4 (22.2%)	36 (10.6%)	0.3
Converted to open	14 (3.9%)	0 (0.0%)	14 (4.1%)	> 0.9

Table 5 Comparison of the demographic characteristics of the subset of patients undergoing LC for biliary colic

	Overall, $N=260$	Three ports, $N=41$	> Three ports, $N=219$	p value
Gender				0.9
Male	58 (22.3%)	10 (24.4%)	48 (21.9%)	
Female	202 (77.7%)	31 (75.6%)	171 (78.1%)	
Age	42.1 ± 15.5	43.8 ± 14.0	41.8 ± 15.8	0.3
BMI	32.3 ± 8.5	33.3 ± 7.3	32.1 ± 8.7	0.3
ASA class	47 (18.1%)	8 (19.5%)	39 (17.8%)	0.7
1	163 (62.7%)	28 (68.3%)	135 (61.6%)	
2	49 (18.8%)	5 (12.2%)	44 (20.1%)	
3	1 (0.4%)	0 (0.0%)	1 (0.5%)	
4				

Table 6 Results of the subset analysis of patients undergoing LC for biliary colic

	Overall, $N=357$	Three ports, $N=18$	> Three ports, $N=340$	p value
Operative time (min)	62.5 ± 28.8	65.0 ± 20.2	62.0 ± 30.2	< 0.05
Postoperative Length of stay (days)	0.5 ± 1.0	0.3 ± 0.7	0.5 ± 1.1	0.09
Any complication	15 (5.8%)	1 (2.4%)	14 (6.4%)	0.5
Converted to open	4 (1.6%)	0 (0.0%)	4 (1.8%)	> 0.9

Discussion

Multiple groups have published guidelines for "safe" laparoscopic cholecystectomy in recent years [5, 6]. When confronting the question of the recommended number of ports, however, the guidance offered in the literature has been largely ambiguous. Perhaps the most ambitious effort to offer standardized recommendations for safe laparoscopic cholecystectomy was presented by the Prevention of Bile Duct Injury Consensus Workgroup (PBDICW) in 2020 [5]. This workgroup offered conflicting guidance on this issue: namely recommending "standard" (four-port) technique as the preferred approach based on a "moderate" certainty of evidence. In the panel's justification of this recommendation, it is clear that the comparative alternative being considered by the group is the single-incision technique. Even in this setting, however, the workgroup acknowledged that similar outcomes could be achieved in the hands of experts.

Our results corroborate the findings of Slim et. al., who reported on their experience with 710 LCs performed through three ports [7]. Their results supported the safety and efficacy of the three-trocar technique, although their work did not include a direct head-to-head comparison of the two approaches. The advantages of this technique, they argued, included decreased expense of the operation, decreased pain for the patient, and the ability of the surgeon to perform the operation without the need for an assistant. Some modern general surgeons have returned to a three-port technique as solution to a variety of concerns, including the lack of reliable assistance, minimization of operative expense, and mitigation of unnecessary postoperative discomfort. Numerous studies published in the past 15 years support the feasibility and safety of the three-port technique in both community-based and academic-affiliated hospital settings [7–16]. However, there appears to be little mainstream acceptance of the safety of the three-port approach within surgical societies at either the national or regional levels. This lack of acceptance potentially places practitioners of the technique at a disadvantage should medicolegal scrutiny arise out of a specific outcome.

In a 2014 Cochrane review on the issue of four ports versus less-than-four ports, Gurusamy et al. reported that their own analysis of the available literature showed no difference between the techniques in the rate of "serious" complications, patient quality of life between 10 and 30 days after surgery, conversion-to-open rate, or length of hospital stay [17]. The authors further reported that operative time was 15 min less in the fewer-than-four-ports population, and time to return to work was shorter by 2 days in those patients who underwent LC via a three-port approach. While we did not specifically evaluate time to return to work as an outcome of interest in this study, our results concur with the finding that operative time was significantly less in the patients who underwent the three-port technique.

We propose that the primary safety concern with respect to LC has little to do with the number of ports used, but rather the method of achieving recognition of biliary anatomy intraoperatively. There exists no controversy surrounding the importance of identifying the "critical view of safety" (CVS) in the prevention of CBDI. The surgeons

in this study all practice a CVS technique, which appears to be independent of the number of ports utilized. In referring to the "critical view of safety" we are here relying on the definition offered by Strasberg et. al., which has three requirements [18]. The first is that the triangle of Calot must be cleared of fat and fibrous tissue, the second is that the lowest part of the gallbladder must be separated from the cystic plate, and the third requirement is that two, and only two, structures should be seen entering the gallbladder. Yegiyants and Collins [19] reported a major bile duct injury rate of 0.03% (1 in 3042 operations) over a 5-year study period in which the predominant approach to LC was through identification of the CVS. Although the methodology of this report warrants some pause, this represents an injury rate at least fivefold lower than those reported elsewhere in the literature. More recent work by Stefanidis et al. published in 2016 has suggested that surgeons may be achieving the CVS in only a fraction of those cases in which it was believed to have been identified [20]. Nevertheless, there exists general agreement that demonstration of the CVS prior to ligation of the cystic duct is the most reliable method of reducing the incidence of CBDI. In a 2010 paper reinforcing the importance of the CVS, Strasberg and colleagues included multiple intraoperative photographs of this view, including one achieved through a single-incision laparoscopic surgery (SILS) approach [21]. We concur that fidelity to the CVS, not the number of ports utilized, is the most critical factor in the safe conduct of LC. Establishment of the critical view of safety as a crucial step of the operation can be accomplished with the three- or the four-port technique in experienced hands both during LC and RC.

We found it interesting that the rate of IOC in the present study was nearly three-fold higher in the three-port group. This is primarily attributable to differences in attending surgeon philosophies acquired in training, as the use of routine versus selective IOC remains a matter of some debate owing to uncertainty regarding the cost-effectiveness of the routine employment of the maneuver. This debate is relevant here in that IOC can be used to better delineate biliary anatomy in the setting of variant configurations, or when infection or other factors have rendered the CVS difficult to interpret. In a study published in 2011, Buddingh et al. compared the rate of bile duct injury (BDI) prior to the adoption of a "routine" IOC policy to that which was observed after implementation in a university-based hospital that was already adherent to a CVS strategy [22]. The authors found that routine IOC significantly decreased the rate of BDI (1.95% vs. 0.0%). Moreover, in a 2021 meta-analysis comparing routine to selective IOC, Rystedt and colleagues reported that a selective approach to IOC led to an increase in the risk of BDI of 43% compared to a strategy incorporating the routine use of cholangiography [23]. Of note, the decrease in operative time with the three-port technique was observed despite the increased utilization of IOC in these patients.

This study captured all robotic cholecystectomies performed at this institution over the study period. It is not clear what effect the unique features of the robotic approach had on these results. Theoretically, the availability of the robotic wrist promotes optimization of retraction angles, making it more conducive to the three-port approach. Furthermore, the availability of indocyanine green (ICG) obviates the need for cholangiography for the purposes of delineating anatomy, which would be expected to further expedite these operations. With respect to operative duration, any gains observed due to the presence of the wrist and ICG might be lost in the docking process. Although we did not consider it a primary focus of the present study, future studies might randomize both platform and port number to further elucidate the effects of the robotic platform on the safety and duration of the three-port approach.

We also observed a significant difference in the indication for LC between the two groups in this study. The most common indication in the three-port group was biliary colic (41/71, 58%), and the most common indication in the traditional group was acute cholecystitis (340/853, 40%). Interestingly, the difference in operative duration was more pronounced on subset analysis of those patients undergoing LC for acute cholecystitis, with a mean operative time more than 20 min less in the three-port group. When considering only those patients undergoing LC for biliary colic, however, the mean operative duration was 3 min shorter in the traditional approach. This can be at least partially explained in two different ways. First, the IOC rate in those undergoing three-port LC for biliary colic was 20% as opposed to a rate of 3.7% in the traditional group. Second, we note that the mean operative time in the three-port group was 65.0 min in the setting of biliary colic, and 67.2 min when acute cholecystitis was the indication. This consistency in operative duration is almost certainly a product of these procedures having been performed under the supervision of a single surgeon.

Aside from the matter of the use of three or four ports in performing LC, there is a larger issue here, and that has to do with the role of innovation in surgical practice. Unchallenged dogma generally represents an obstacle to progress in any field, and this is also true in surgery. At a low level, this is exemplified by reluctance to accept laparoscopic procedures through fewer ports then traditional as safe. More perniciously, it leads to resistance to new and potentially better operations and platforms altogether. We believe that it is important to maintain an open mind and to embrace innovation in surgical practice while exercising discipline in subjecting such innovation to scientific scrutiny.

There are limitations to this study, and foremost among these is its retrospective design. As always, a blind,

randomized, controlled trial would be preferred, although it is difficult to imagine how one might blind the surgeon in such a study. Moreover, there was only one surgeon with at least 5 years of experience in the three-port technique, warranting the caveat that any findings in this study are applicable only to those surgeons with a similar experience profile. In a sense, resident involvement in these cases diminishes the power of this caveat somewhat, but that is difficult to quantify. Another limitation is that the study groups were not quite equivalent in terms of indication, a useful (albeit imperfect) proxy for the difficulty of any given case. The results of the subsequent subset analyses performed, however, would suggest that the limitations imposed by this observation are minor.

Another limitation is that this study is underpowered to declare noninferiority of three-port LC with respect to the most feared complication of this operation: CBDI. This is fundamentally a result of the rarity of this event in LC in general. As mentioned previously, rates of 0.03% to 0.4% for CBDI in LC have been reported elsewhere. Assuming a real rate of 0.4%, and that an observed rate of 0.8% would demonstrate non-inferiority, to detect such a rate at 80% power with a significance level of 5% in the setting of a ratio of three-port patients to four-port patients of 1:12 as observed in our data would require 822 three-port patients and 9,864 four-port patients. These numbers are difficult to achieve in surgical research, particularly in single-institution studies. Rather, we would propose that it is more useful to think of the 0.4% as a benchmark measure for surgeons to compare their outcomes to individually. In this study, the rate of CBDI in the three-port group was 0%.

Conclusion

We have shown that LC and RC performed through three ports is at least equivalent to the traditional approach in terms of operative duration irrespective of operative indication, with no increase in complication rate, or conversion-to-open rate. Additional studies, ideally prospective and multi-institutional in nature, are necessary to make more recommendations and advocate for the three-port technique, which allows for development of the CVS.

Declarations

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Conflict of interest None of the authors have any conflicts to disclose.

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