



Comparative study of three-port vs four-port laparoscopic cholecystectomy in a cohort study: a surgical task load survey

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Abstract

The three-port laparoscopic cholecystectomy (LC) approach is gaining attention for its perceived benefits, although it is not widely accepted outside of clinical trials. The present investigation aims to compare the outcomes of three-port LC (3PLC) and four-port LC (4PLC) methods, focusing on their safety, efficacy, and workload. This multicenter investigation was performed between March 2021 and April 2022. Demographic data, procedural outcomes, visual analog scale regarding postoperative pain, and the level of satisfaction were collected and compared. In addition, the Surgery-TLX and Borg's CR10 tools were utilized to assess the surgeon's workload. Of 169 patients who enrolled in the study, 84 individuals underwent 3PLC, and 85 cases had 4PLC. The three-port LC indicated a significantly shorter duration of operation compared to the four-port (63.55 vs. 69.08 min respectively, $p=0.001$). The hospital length of stay and the mean pain score on day 1 were also lower in the 3PLC (1.14 days vs. 1.79 days, $p<0.001$ and 1.85 vs. 2.52, $p=0.004$, respectively). The mean level of satisfaction on day 7 was higher in the 3PLC. The Borg's CR10 scale showed that surgeons experienced more physical discomfort and pain in the left shoulder, left forearm, and trunk after 4PLC. The surgery-TLX scale in our study indicated increased mental demands and distraction, but less situational awareness in the surgeons after 4PLC. The 3PLC technique could serve as a safe and feasible laparoscopic technique and does not cause more complications than the conventional 4PLC.

Keywords Laparoscopic cholecystectomy · Three-port laparoscopic cholecystectomy · Four-port laparoscopic cholecystectomy · Surgery-TLX

Introduction

Laparoscopic cholecystectomy (LC) is the most common approach to remove the gallbladder due to various indications. Its surgical technique may differ in the number of incisions, including single-incision (SILC), three-port, and four-port LC [1]. The four-port method with two 5-mm and two 10-mm entries is commonly used because it provides a better anatomical view and is easier to learn for trainees [2–4]. As a result, it is currently considered the gold standard method for performing LC [5, 6]. Recently, the use of a fourth port has been under question, and many surgeons believe that an appropriate view of Calot's triangle is achievable even in the absence of the fourth port [7]. The logic behind the three-port approach is that it offers an acceptable perspective of Calot's triangle even without fundal retraction [3]. Although numerous studies claim that 3PLC is feasible and comparable to 4PLC in terms of postoperative and intraoperative complications, some authors have reported that 4PLC

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is associated with complications, such as wound infections [3, 8, 9]. Therefore, this question remains debatable among surgeons as prior investigations often had small sample sizes, were conducted in a single center, and did not comprehensively assess the burden on surgeons, and advocates of 3PLC may face medicolegal scrutiny because it has not been accepted outside of the clinical trials [10]. A meta-analysis done by Sun et al. suggested that there were no significant differences in operating time, success rate, and postoperative hospital stay. However, regardless of the heterogeneity of the included studies, they did not assess the burden on surgeons or compare complications between the two methods [7]. Noticeably, during the operation, there should be a perfect connection between the surgeon and assistants to maneuver appropriately, which can be exhausting. Thus, many modifications have been made to reduce the number and size of ports and to provide optimal coordination for the surgeon by minimizing the number of staff in the operating room who may interrupt the surgeon's concentration. Several investigations suggested 3PLC as a safe alternative procedure to 4PLC [8, 10–12]. However, this debate should be considered from both the surgeons' and the patients' views.

Hence, it seems that due to higher postoperative pain (POP), longer hospital length of stay (HLS), and additional surgical scar, unnecessary assistant involvement, better intraoperative communication, and reduced interpersonal distractions, the 3PLC approach should gain more attention in the surgical world [6, 13, 14]. Therefore, this research aims to compare three-port vs. four-port elective LC in a multicenter setting from both patient and surgeon perspectives.

Methods and materials

This study, based on a retrospective analysis of prospectively collected data, was conducted at three university-affiliated teaching hospitals between March 2021 and April 2022. The inclusion criteria were patients who were candidates for elective LC without acute cholecystitis and with a BMI < 35 kg/m². The patients were divided into two groups consecutively using convenience simple, non-random allocation without any presumption or matching. The same surgical team (right-hand dominant), anesthesiologists, and their assistants conducted all operations throughout the study following a uniform perioperative protocol. In their career, surgeons had similar training protocols and curricula, and an experienced general surgeon performs an average of 20 3PLCs and 100 4PLCs annually.

Age, gender, BMI, duration of operation, rupture of the gallbladder during surgery, conversion rate from 3 to 4PLC, surgical site infection, and HLS were extracted from medical records. The level of postoperative pain 24 h after the surgery and the patient's level of satisfaction 7 days post-surgery were measured

using a 10-point Likert visual analog scale (VAS). Patients were discharged when they were able to walk and tolerate oral intake. Discharge was postponed in case of unbearable pain unresponsive to acetaminophen (500 mg every 6 h till 1 g every 8 h), oral regimen intolerance, or serious red flags such as fever, altered mental status, abnormal vital signs, or suspected bile leakage.

Surgical procedures description

The position of trocars used in both techniques by our surgeons is illustrated in Fig. 1. During the four-port procedure, the epigastric (A) and mid-clavicular (C) trocars were held by the surgeon, and the umbilicus (B) and anterior axillary (D) ports were held by the cameraman and the surgical assistant, respectively. The three-port method was done in the absence of the 5 mm port in the anterior axillary line (D). Instead, in 3PLC, the mid-clavicular entry (C) was shifted downward from the costal margin (E) on the imaginary mid-clavicular line (Fig. 1).

Evaluation of surgeon workload

The current study compared the workload between the two groups employing the surgery task load index (Surg-TLX), which was developed from the National Aeronautics and Space Administration's Task Load Index (NASA-TLX) [15, 16]. Several studies support the validity of Surg-TLX

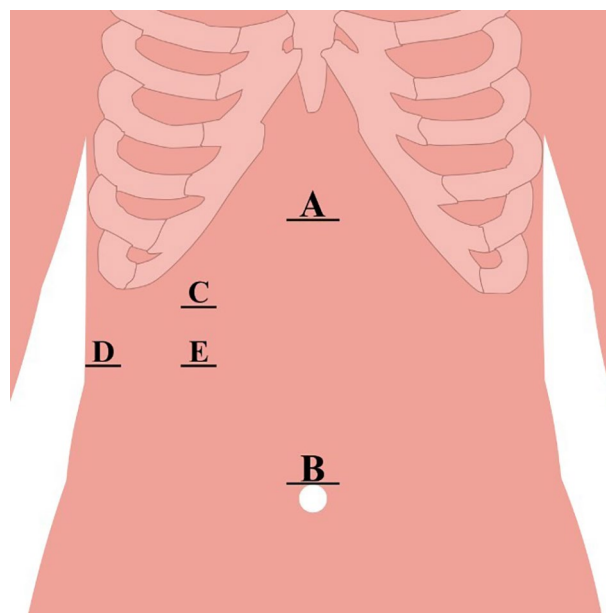


Fig. 1 Location of the trocars in four-port LC: (A) epigastric, (B) umbilical (for the camera), (C) mid-clavicular, (D) anterior axillary; in three-port method, the fourth trocar (D) is removed and the mid-clavicular (C) trocar is moved downward to create the third port (E), which is in the mid-clavicular line but approximately 10 cm below the costal margin

to evaluate surgeons' workload during different surgical settings [17, 18]. Surg-TLX utilizes six parameters that surgeons immediately rate following the procedure: mental demands, physical demands, temporal demands, task complexity, situational stress, and distractions [17]. Additionally, Borg's CR10 was used to measure the physical discomfort and pain throughout the procedure. The surgeons used a scale of 0 to 10 to assess seven regions of their body: the neck, the trunk, the shoulders, forearms, and legs (0: no exertion at all, 10: maximal effort) [19].

Statistical analysis

Numerical variables are presented as means with standard deviations, and nominal variables are presented as numbers with percentages. Kolmogorov–Smirnov test was applied to assess the normality of distribution, and only BMI was insignificant ($p=0.11$). The Mann–Whitney U test was used to assess numerical variables that did not have a normal distribution, meanwhile the T-test was used for normally distributed variables. Chi-square was applied to compare the nominal variables. IBM SPSS software (version 25.0, USA) was used for statistical analysis, and the p -values of <0.05 were considered statistically significant.

Results

A total of 169 patients underwent LC in this study; 84 underwent 3PLC (49.7%, Group A) and 85 underwent 4PLC (50.3%, Group B). The majority of patients in both groups were female ($p=0.567$). Age and BMI values are presented in Table 1 with no significant difference between the two groups ($p=0.841$ and $p=0.069$, respectively).

The mean skin-to-skin operative time was 63.55 and 69.08 min in Groups A and B, respectively, indicating significant differences between the two groups ($p=0.001$). Additionally, the mean HLS was 1.14 days in Group A and 1.79 days in Group B ($p<0.001$). The severity of POP in VAS score on day 1 was 1.85 in three-port and 2.52 in four-port LC ($p=0.004$). Furthermore, the patient satisfaction measured on day 7 using VAS was higher in the three-port group according to the VAS score (9.84 vs 9.46, respectively; $p=0.002$). However, postoperative wound infection, the occurrence of gallbladder rupture during surgery, and conversion to open cholecystectomy didn't show any significant differences between the two groups ($p=0.146$, 0.378, 0.482, respectively) (Table 1). Notably, three patients in the 3PLC group required conversion to the four-port method.

In terms of the surgeon's workload during the procedure, Borg's CR10 analysis showed significant differences between the two groups. Surgeons performing 4PLC reported more physical discomfort and pain in the left shoulder ($p=0.015$), left forearm ($p=0.042$), and trunk ($p=0.004$). Additionally, the Surg-TLX tool revealed significant differences between the two groups. In comparison to the 3PLC group, the 4PLC surgeons experienced greater distraction and mental demands, along with reduced situational awareness ($p=0.015$, 0.026, 0.009, respectively) (Table 2).

Discussion

In our study, both the operative duration and the HLS were significantly lower in the 3PLC group. Furthermore, patients reported less POP on day 1 and greater satisfaction on day 7 after 3PLC. Additionally, SSI, as one of the major postoperative complications, occurred in 4 patients, 3 of whom had undergone 4PLC, and fewer cases of gallbladder rupture in

Table 1 Preoperative, intraoperative, and postoperative variables are compared between 3 and 4PLC

Findings		3-port ($n=84$)	4-port ($n=85$)	p
Preoperative	Age	45.37 (15.51)	45.67 (14.38)	0.841
	Male sex	23 (27.4%)	19 (22.4%)	0.567
	BMI*	25.48 (4.25)	26.65 (3.97)	0.069
Intraoperative	DOP* (min)	63.55 (10.83)	69.08 (10.99)	0.001
	Rupture	1 (1.2%)	4 (4.7%)	0.378
	Conversion to open cholecystectomy	0 (0%)	2 (2.4%)	0.482
Postoperative	POP* at 24 h	1.85 (0.95)	2.52 (1.88)	0.004
	PS* at 7 days	9.84 (0.56)	9.46 (0.98)	0.002
	HLS*	1.14 (0.41)	1.79 (1.26)	<0.001
	SSI*	1 (1.19%)	3 (3.5%)	0.146

Bold values are statistically significant by considering the $p<0.05$ level

*BMI body mass index, DOP duration of operation, POP postoperative pain, PS patient satisfaction, HLS hospital length of stay, SSI surgical site infection

Table 2 Borg's CR10 and Surgery-TLX indices are compared between 3 and 4PLC

Variable		3-port (n = 84)	4-port (n = 85)	p
Borg's CR10*	Right shoulder	2.5 ± 1.3	2.7 ± 0.7	0.216
	Left shoulder	2.9 ± 1.2	3.3 ± 0.9	0.015
	Right forearm	3.1 ± 1.5	3.4 ± 1.1	0.141
	Left forearm	3.0 ± 0.8	3.4 ± 1.6	0.042
	Neck	2.9 ± 1.0	3.0 ± 1.2	0.557
	Trunk	3.3 ± 1.4	3.9 ± 1.3	0.004
	Legs	3.2 ± 1.1	3.4 ± 1.7	0.365
Surgery-TLX*	Mental demands	4.0 ± 1.4	4.5 ± 1.5	0.026
	Physical demands	3.6 ± 1.1	4.0 ± 1.6	0.06
	Temporal demands	3.9 ± 1.5	4.1 ± 1.4	0.372
	Task complexity	4.2 ± 1.1	4.5 ± 1.3	0.107
	Situational awareness	4.5 ± 2.0	3.8 ± 1.4	0.009
	Distraction	4.0 ± 1.8	4.7 ± 1.9	0.015

Bold values are statistically significant by considering the $p < 0.05$ level

*CR category–ratio, TLX task load index

the 3PLC group were also found. Regarding the physical and mental exertion and difficulty of the operation, the leading surgeon had a better experience and lower demands with the 3PLC technique, which was neither evaluated nor reported in any of the previous comparative investigations. Our study strongly indicates less distraction and mental demands and improved situational awareness during 3PLC.

A meta-analysis done by Hajibandeh et al. supports our outcomes regarding the shorter HLS in the 3PLC [14]. The patients' discharge during the present study was delayed due to unbearable pain unresponsive to painkillers. Therefore, the shorter HLS in the 3PLC group is likely attributable to reduced POP and analgesic requirements in this group. This finding has been indicated in a study conducted by Bari et al. [20]. Pain scores on postoperative day 1 were significantly lower after 3PLC. Various studies also addressed the same outcomes [8, 12]. Obviously, the absence of an extra trocar in the 3PLC method results in less tissue trauma. However, because the third trocar is moved 10 cm below the costal margin in this procedure, it is likely that reduced damage to the subcostal nerve, lower thoracic nerves, and caudal lower intercostal nerves is related to less POP [21]. Regarding gallbladder rupture and experiencing SSI, our results align with previous studies demonstrating the safety of 3PLC despite what has been proposed theoretically that 3PLC imposes a higher risk of gallbladder injury [3, 6, 11, 22]. However, due to inappropriate exposure of the gallbladder, three cases in our study experienced a conversion; therefore, surgeons should not hesitate to add an extra trocar or even convert the procedure to an open cholecystectomy in case of performing 3PLC.

Based on the previous evaluations, some studies proposed that the surgery lasted longer in the 4PLC [6]; however,

others had another experience [23]. Although the comparisons were statistically non-significant for this area in two meta-analyses [3, 14], the mean differences between the two procedures were not even clinically noteworthy; most of them were different in a matter of minutes, which is negligible. However, our study revealed a significantly shorter duration of operation in the 3PLC with a mean difference of approximately 6 min. Several studies claim that the rationale behind decreased operative time is the time spent for insertion and closure of the fourth port [6, 24], but we think it should be more complicated. During a 4PLC, the surgeon is assisted by two additional staff: a cameraman and an assistant who grasps the fourth port. Meanwhile, there is no assistant in the 3PLC and as a result, hand–eye coordination (the way one's hands and sight work together to be able to execute activities that require speed and precision) is improved with this method, which Surg-TLX assessed between our groups. Thus, we firmly believe that the shorter operating time in 3PLC is not related to the insertion and closure of the fourth port; rather, we propose that smoother operation flow in the 3PLC is a result of the surgeon's better hand–eye coordination and experiencing less burden (based on Surg-TLX and Borg's CR10) while using this approach. It should be noted that the duration of the procedure also depends on the surgeon's skills and experiences, which are related to the number of LCs performed, the volume of the centers, and the educational learning curve [25, 26].

Surg-TLX is the tool for appraising the surgeons' workload during surgery since it provides diagnostic data on how different stressors affect the demands that skilled surgical operators perceive [17]. To our knowledge, the current study is one of the first investigations comparing the surgeons' workload between the 3PLC vs. 4PLC.

Our data shows that 4PLC has more mental demands and distraction, and less situational awareness in comparison to 3PLC. Kim et al.'s study compared the workload of surgeons among robotic SILC and 3PLC via NASA-TLX. The results indicated a lower rate of workload in the 3PLC group in comparison to the SILC group [27]. Borg's CR10 scale was also employed to assess the level of physical discomfort and pain in different parts of the body during the procedures, and based on this scale, the 4PLC operators experienced greater levels of physical discomfort and suffering, particularly in the left upper limb and trunk. Complexity, difficulty of communication, hand–eye coordination, and prolongation of operation in 4PLC are possible explanations for these results. A higher workload in the long-term period may provoke physical and mental injuries to surgeons, and thus, a decrease in the number of practicing years may occur. Another aspect of the suitability of 3PLC is regarded to be more ergonomic for surgeons as one of the key factors for an effective operation. Positioning of trocars makes it difficult for one operator to handle both the camera and the fourth port.

One of the most obvious financial benefits of using 3PLC is the reduction in costs related to trocars. Single-use trocars can range from \$45 to \$70 each, depending on their size and brand [28]. Hospitals can save approximately this amount per procedure by reducing one trocar. When considering the volume of LC performed annually, the cumulative savings from this reduction can be substantial. In addition to the direct cost savings, the 3PLC can lead to a more streamlined workflow that requires fewer personnel. Surgeons can work more productively with fewer incisions, which may eliminate the need for extra personnel to help with patient monitoring and instrument handling. Furthermore, shorter HLS saves total healthcare expenditures associated with longer inpatient treatment. All these challenges demonstrate that removing one trocar will have significant cost savings without compromising safety or efficacy, which is particularly crucial in underdeveloped and developing countries where healthcare expenditure is a major concern.

Ultimately, according to our experiences with these two procedures, the difficulties do not grow as the number of ports decreases, and similar to previous investigations it can be said that this technique is as safe as the present standard method, the 4PLC, and that its application does not risk patient lives or impose increased postoperative burden. Nevertheless, patient selection is essential, since not all cases are suitable for 3PLC, and various patients require different settings. Moreover, the 3PLC is not officially accepted among all surgeons, and the pioneers of this strategy may face medicolegal scrutiny. Thus, a skilled approach is essential for 3PLC to avoid subsequent adverse consequences, and surgeons' training programs should be addressed as well [24].

The present study benefits from the multicentric manner and depicts a robust comparison between the two standardized laparoscopic methods. However, this survey is not without limitations that should be considered. We didn't assess the cosmetic outcomes and the need for strong painkiller administration or the rate of opium consumption for pain control. Furthermore, although the same surgical team performed all the operations, surgeons may have different interpretations of a specific surgery workload due to their inherent features and various amounts of experience. Furthermore, despite all surgeons receiving training through similar protocols, the comparison of results from separate surgical teams across different centers is considered a limitation, which should be addressed in future research. We used a standardized approach for placing the trocars of each 3PLC and 4PLC, and the comparison between other trocar locations should be evaluated in future studies. Although based on an observational hypothesis, 3PLC could be more cost-effective; we suggest more analytic studies on the financial aspect of these two techniques. Finally, due to ethical restrictions, the sample size, selection method, and non-random allocation process were among the biases, and we recommend larger multicentric trials evaluating the benefits and drawbacks of 3PLC vs. 4PLC from both patient and surgeon aspects, with additional focus on costs and financial burden.

Conclusion

LC through three ports is a safe alternative to 4PLC since complications such as gallbladder injury and surgical wound infection do not arise in this method. Additionally, this technique significantly decreases the severity of POP, the surgeons' operation workload, the duration of surgery, and the hospitalization course, making it a cost-effective approach. Furthermore, the patients were more satisfied with the three-port method. However, surgeons should not hesitate to add a fourth trocar if required.

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Data availability Data will be available for secondary analysis upon reasonable request and through email contact of the corresponding author.

Declarations

Competing interests Ali Javidi, Mohammad Eslamian, Erfan Sheikhabahaei, Ashkan Mortazavi, Farjam Khosravi, and Ali Mohammad Mokhtari have no conflicts of interest or financial ties to disclose. The authors declare that they have no conflicts of interest. Ali Javidi,

Mohammad Eslamian, Erfan Sheikhabahaei, Ashkan Mortazavi, Farjam Khosravi, and Ali Mohammad Mokhtari have no conflicts of interest or financial ties to disclose. The authors declare that they have no conflicts of interest.

Ethical approval Our institutional review board approved the ethical considerations and informed consent was obtained from all patients before surgery. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards

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