Original Article

Retrospective Non-Inferiority Analysis of Comparative of Performance on Single Incision Laparoscopic Cholecystectomy (SILC) between Using a Conventional Equipment and a Commercially Available Equipment

Weerayut Thowprasert MD[1], Saritphat Orrapin MD[1]

[1] Department of Surgery, Faculty of Medicine, Thammasat University, Thammasat University Hospital, Pathum Thani, Thailand

Background: Single incision laparoscopic cholecystectomy (SILC) is a modern technique for cholecystectomy via a single transumbilical incision. Original surgical equipment including an articulated minimally invasive surgical instrument was necessary for SILC procedures. However, the articulated long length with flexible rotatable tip instrument is expensive and could not be reimbursed by the Thai National Health Insurance. The present study used conventional laparoscopic equipment that is a non-articulated, shorter, and rigid tip to perform SILC.

Objective: To compare the effectiveness between conventional and original equipment for the SILC procedure by evaluating the difficulty of SILC indicated by the length of operative time.

Materials and Methods: The patients that underwent SILC in Thammasat University Hospital between October 2014 and December 2020 were reviewed from the electronic medical database. The primary outcome was the difficulty of the SILC procedure, determined from the operative time, to evaluate the performance of the SILC procedure between using the conventional or the original equipment in a non-inferiority trial. The secondary outcome was intraoperative and post-operative complications.

Results: The eligibility criteria included 592 SILC procedure that was categorized as conventional equipment group with 351 (59.29%) patients and original equipment group with 241 (40.71%) patients. The multivariate analysis reported the number of difficult SILC procedures was less frequent in SILC using conventional equipment when compared with original equipment, significantly with 37 (10.54%) versus 43 (17.84%) relative risk (RR) (1.75, 95% CI 1.081 to 2.822, p=0.023). The intraoperative bile leakage, cystic artery injury, wound infection and 3-months follow-up of incisional hernia were not different in SILC procedures using eithers equipment.

Conclusion: The application of conventional equipment that is used in multiple-port LC procedure to perform in SILC procedure was safe and not related to difficulty of SILC. This can reduce the cost of surgery, especially for articulated instrument that cannot be reimbursed from the National Health Insurance in Thailand.

Keywords: Laparoscopic cholecystectomy; Single-incision laparoscopic cholecystectomy; Articulated minimally invasive surgical instrument; Difficult laparoscopic cholecystectomy.

Received 6 May 2021 | Revised 16 June 2021 | Accepted 17 June 2021

J Med Assoc Thai 2021;104(8):1326-38

Website: http://www.jmatonline.com

The practice of minimally invasive surgery spread quickly around the world after a laparoscopic cholecystectomy (LC) became the standard treatment of benign gallbladder disease. Additionally, there was a rapid evolution of medical instrument and technology[1-3]. Conventional LC that uses multiple small incisions or multiple-port LC, has demonstrated to lower post-operative pain, shorter patient's length of hospital stay, and shorter convalescent phase when compared with open cholecystectomy[1]. Currently, the novel technique, namely, single incision laparoscopic cholecystectomy (SILC) or single-port LC has been developed to reduce the number of incisions from 3 or 4-port LC to 1-port LC by using original equipment[2-5]. The reduction of the number of incisions can decrease post-operative pain with good cosmetic result[6,7]. Recent studies report the good outcome and safety of SILC procedures with the same rate of overall complications such as major biliovascular structure injury, bile leakage, retained common bile duct (CBD) stones, and wound infection[3,4,7-11].

Correspondence to:

Orrapin S.

Department of Surgery, Faculty of Medicine, Thammasat University, Thammasat university Hospital, 99/209 Paholyotin Road, Klongluang, Pathum Thani 12120, Thailand.

Phone: +66-2-9269523, **Fax**: +66-2-9269530

Email: sam3_orra@hotmail.com

How to cite this article:

Thowprasert W, Orrapin S. Retrospective Non-Inferiority Analysis of Comparative of Performance on Single Incision Laparoscopic Cholecystectomy (SILC) between Using a Conventional Equipment and a Commercially Available Equipment. J Med Assoc Thai 2021;104:1326-38.

doi.org/10.35755/jmedassocthai.2021.08.12826

However, original surgical equipment was necessary for SILC procedures, which are disposable and more expensive than the conventional multiple-port LC equipment, including the articulated type of surgical devices[6,7,12-14]. The articulated minimal invasive surgical instruments was specially designed for dissecting the surrounding tissue to remove the gallbladder through the single-port and had a video camera. Original commercially available equipment including Endo SILS® Maryland dissector, laparoscopic scissors, hook, Endo Grasper, and Cambridge Endo® articulating instruments are rotatable, have a flexible tip, and are long to help the surgeon move and manipulate the instrument freely and get more space for gallbladder manipulation. In addition, the original commercially available equipment facilitated the surgeon to dissect tissue in normal view similar to that of multiple-port LC[13,14].

In Thailand, SILC could not be reimbursed or get support from the Thai National Health Insurance. Thus, very low-income, and low-income patients who had problems with benign gallbladder have always been performed open cholecystectomy or multiple-port LC. Therefore, the authors used conventional laparoscopic equipment, which were inexpensive and easily available in Thailand, to perform SILC. The stiff point and short length of the conventional Maryland dissector, Endo Grasper, were used in the LC through a single transumbilical incision. The aim of the present study was to compare the effectiveness between the conventional equipment and the commercially original equipment on SILC procedure by determining the non-inferiority of the outcome by using operative time and adverse outcomes. The result of the operation time was categorized as difficult SILC and non-difficult SILC[15-18].

Materials and Methods

Study design and participants

Data from a retrospective cohort of benign gallbladder disease patients being performed SILC procedure in Thammasat University Hospital between October 2014 and December 2020 were retrieved from the electronic medical database. The certificate of approval was given by the Human Research Ethics Committee of Thammasat University (Medicine), number MTU-EC-SU-0-070/64. The inclusion criteria were the patients who had indication of cholecystectomy included 1) symptomatic gallstone (GS), 2) acute cholecystitis, 3) chronic cholecystitis[1], 4) gallbladder polyp size more than 1 centimeter or increasing of size during imaging surveillance[19], 5) porcelain or calcified gallbladder[20], and 6) biliary dyskinesia[21]. The exclusion criteria included 1) the patients with malignant gallbladder or suspected gallbladder malignancy by preoperative presentation and imaging, and 2) patients who loss to follow-up within the first three months after SILC procedure.

The patient's data included 1) pre-operative data, including patient's baseline characteristics and demographic data such as age, gender, body mass index, underlying disease, clinical presentation, and pre-operative ultrasound finding. 2) Intraoperative finding including operative time, major biliovascular injury such as cystic artery injury and bile duct injury. 3) Post-operative data, including early complication or wound infection and 3-months complication including incisional hernia were reviewed and analyzed. The potential source of bias is inherent to the retrospective nature of the design.

Study outcome

The primary outcome was the performance of the SILC procedure by conventional and commercially original equipment by using the difficulty of the SILC procedure determined by the operative time. There were many reports about the difficult LC including operative time, intraoperative bile leakage, bile duct injury, cystic artery injury, open conversion[18]. The most common indicator to identify the difficulty of LC procedure was operative time[15-18]. Therefore, the present study classified patients into the difficult SILC group and the non-difficult SILC group according to the surgeon's individual operative time[15-18]. The SILC procedure that had an operative time greater than 1.5 times of the surgeon's individual operative time was classified as difficult SILC. Conversely, the non-difficult SILC was operative time less than 1.5 times of the surgeon's individual operative time[16]. All factors that affected the operative time of LC procedure were reviewed and included in data analyses, such as age, gender, body mass index (BMI) as kilograms per square meters (kg/m^2), and presenting symptom such as dyspepsia, abdominal pain, history of acute cholecystitis, CBD stone, history of endoscopic retrograde cholangiopancreatography (ERCP), GS pancreatitis, GS cholangitis, and acute cholecystitis. Preoperative ultrasound finding that could affect the difficulty of LC procedure including thickening of gallbladder wall, acute cholecystitis, chronic cholecystitis, gangrenous cholecystitis, adenomyosis, gallbladder polyps, contracted gallbladder, calcified gallbladder, CBD dilatation were collected and analyzed[15-18,22-34]. The secondary outcomes were early

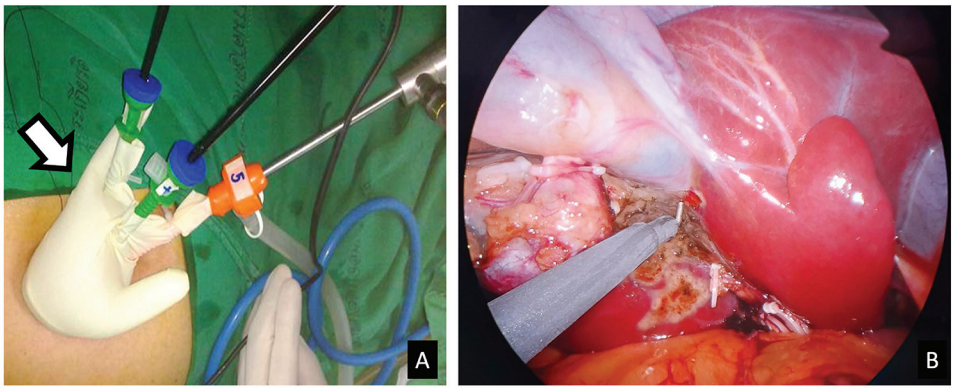

Figure 1. The laparoscope and equipment for SILC were inserted through the tip of fingers of medical sterile glove (No. 6) which cover on a small size Alexis® O Wound retractor/Protector (arrow) via transumbilical incision (A). The laparoscope view from SILC procedure during the dissection of gallbladder from the liver bed by a conventional diathermy hook after ligating of cystic duct and cystic artery by Hem-o-Lok clip (B).

and mid-term (3-months) complications including wound infection and incisional hernia, respectively[32].

Operative technique of SILC

Patient positioning and surgical incision: The single surgeon who had a high expertise in LC procedure with more than 1,000 cases including SILC procedure for 10 years at Thammasat University Hospital performed the SILC procedure. All patients underwent SILC under general anesthesia. The patient was placed in supine position, head up and left side down about 15 to 20 degrees[10,35,36]. The surgeon stood on the left side of the patient and assistant stood on the right side[35]. The incision was transumbilical incision, most of the cases were a transverse incision followed skin crease 1.5 to 2 centimeters (cm), meanwhile, 16 cases used a vertical incision and other six cases were adopted a curved incision around umbilicus due to the shape of an umbilicus and for a cosmetic result.

Placement of ports for laparoscopic surgery: After the transumbilical incision was made, skin was undermined, and fascia was exposed and opened longitudinally about 2 to 2.5 cm and the peritoneum was opened. A small size Alexis® O Wound retractor/Protector (Applied Medical Technology, Modesto, CA, USA) was installed and covered with medical sterile glove (No. 6). Then 4×5-mm ports were placed through the tip of a finger of the glove and the pneumoperitoneum was induced with 12 mmHg-CO_2 gas (Figure 1A). A standard 5-mm 30° laparoscope was used in all cases. After the abdominal cavity was explored by laparoscope and no contraindication for SILC was observed, the gallbladder and the hepatoduodenal ligament were identified.

Dissection of the Calot's triangle: The Calot's triangle was identified and dissected by the Maryland dissector for the exposed cystic duct and cystic artery and to obtain a critical view of safety. In most of the cases, cystic duct and cystic artery were clipped using Hem-o-Lok clip and some cases were clipped with metallic clip. After ligating of cystic duct and cystic artery, the gallbladder was dissected from the liver bed by a diathermy hook or Maryland dissector (Figure 1B).

Gallbladder extraction and closure of the incision: The gallbladder was removed through Alexis® retractor and the pneumoperitoneum was deflated, the glove and Alexis® refractor were removed. The fascia was closed by interrupting sutures with No. 2/0 polyglactin suture material. The skin was closed by subcuticular suture with No. 5/0 polyglactin suture material.

The commercially original equipment for SILC

The articulated minimal invasive surgical instruments (Endo SILS® Maryland dissector, Endo SILS® Hook, Endo SILS® laparoscopic scissor and Cambridge Endo® articulating instruments) which were commercially original equipment for SILC procedure were longer length than the instruments in conventional equipment[5,14]. The tip of the instrument was flexible and rotatable freely in all directions that were controlled from the handle of the instrument[13,14] (Figure 2A, B) The long instrument was designed for transumbilical single-port operation for facilitating the surgeon to move and manipulate the instrument freely without collision of hands because long instrument gave more space for manipulation. The flexible tip of

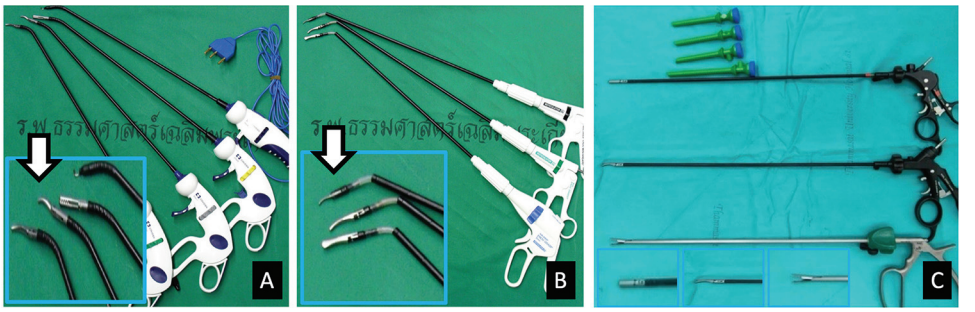

Figure 2. The articulated instruments in commercially available equipment group for SILC, the long length, flexible tip and rotatable properties of articulated instrument (arrow) (Maryland dissector, Endo Grasper, laparoscopic scissor, hook) (A, B). The non-articulated instrument in conventional equipment group for SILC, the short length with non-flexible and rigid tip (Maryland dissector, Endo Grasper, Endo Clip, laparoscopic scissor, hook) (C).

articulated instruments had more advantages in SILC due to the flexible tip in all directions could avoid the collision between the instrument and laparoscope. Furthermore, the surgeon could operate in normal view similar to multiple-port LC by adjusting direction of the flexible tip for dissection, cutting or cauterization in a difficult position (Figure 3A, B).

The conventional equipment for SILC

The non-articulated instruments of conventional equipment that is used in conventional LC including Maryland dissector, Endo Grasper, Endo Clip, laparoscopic scissor, and hook were shorter and no feasibility of flexion of the tip (Figure 2C). The application of conventional non-articulated instrument in SILC procedure was disadvantageous in the limiting and decreasing of the space of the surgeon's hand movement and working space in the operative field for tissue dissection and gallbladder manipulation. The additional technique that required to handle the non-articulated conventional instruments during the SILC procedure was the position of all instruments and the laparoscope. SILC using the conventional instruments could perform by the positioning of laparoscope had to place under all instruments and the tip was bending to medial, angle of view adjusts to lateral for avoiding instrument collision and increased the operative field for tissue dissection and manipulation. The technique of operation was the same as the articulated instrument of the commercially available equipment group, but the angle of view might need to be adjusted at all times during the operation (Figure 3C, D).

Postoperative care

After full recovery from general anesthesia, a soft diet was provided for the patients. The intravenous and oral analgesic drug, and anti-emetic drug were administered. Patients were allowed to ambulate and take regular diets within 12 hours of surgery and discharged within 24 to 48 hours. Most patients were discharged within 24 hours after surgery. Home medication was oral analgesics at discharge, but most of the patients did not require analgesics beyond the first postoperative day. The schedule for patient's follow-up were two weeks, six weeks, and three months postoperatively. The liver function test was examined at six weeks, postoperatively. The surgical complications including wound infection and incisional hernia were documented and analyzed as secondary outcome to identify the adverse outcomes associated with difficult SILC between the two types of equipment for SILC[32].

Sample size calculation

The comparative study of effectiveness on SILC between using the new technique by applied conventional equipment and the original technique with commercially original equipment were using non-inferiority test. The hypothesis was the SILC using conventional equipment did not make cholecystectomy become difficult surgery indicated by an operative time. Therefore, the sample size was calculated as non-inferiority trial with 15% of non-inferiority margin (δ)[37,38]. The retrospective data of SILC procedure of Thammasat University Hospital between October 2014 and December 2020 from electronic medical database system after excluding the patients who had incomplete data of the main outcomes due to loss to follow up and other reason demonstrated 592 SILC procedures for analyses. The ratio of conventional equipment and commercially original equipment was 1:5. From the non-inferiority two-sample of comparison of means with 1:5 ratio

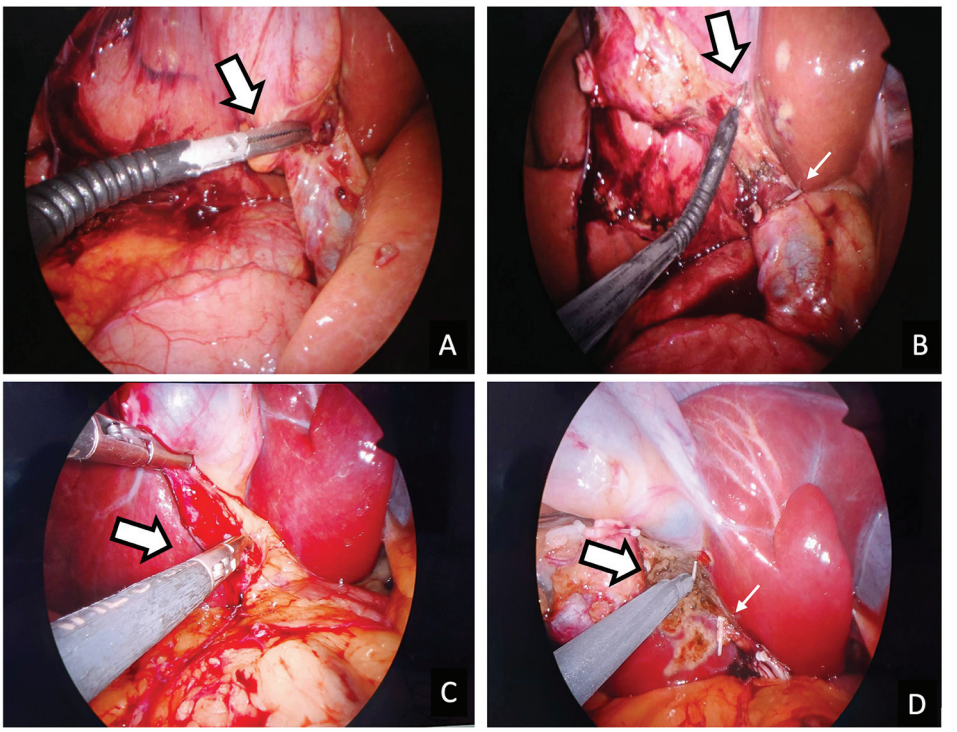

Figure 3. The laparoscope view from the SILC procedure during the dissection to identify the Calot's triangle by the articulated Maryland dissector (thick arrow) (A). The dissection of the gallbladder from the liver bed by the articulated diathermy hook (thick arrow) after ligating of cystic duct and cystic artery by Hem-o-Lok clip (thin arrow) (B). The laparoscope view from the SILC procedure during the dissection to identify the Calot's triangle by the conventional Endo Grasper and Maryland dissector (thick arrow) (C). The dissection of the gallbladder from the liver bed by the conventional diathermy hook (thick arrow) after ligating of cystic duct and cystic artery by Hem-o-Lok clip (thin arrow) (D).

between the two groups under the 0.05 of type I error (α) and 0.2 of type II error (β), 547 SILC procedures were required for analysis. Therefore, the number of SILC procedures between October 2014 and December 2020 were 592 procedures, including 351 procedures of conventional equipment group and 241 procedures of commercially original equipment group.

Statistical analysis

Patients undergoing SILC procedure were categorized into two groups of conventional equipment and commercially original equipment group. The performance of the SILC procedure used the difficulty of the SILC procedure as determined from the operative time. Non-difficult SILC was an operative time of less than 1.5 times the surgeon's individual base time and difficult SILC was an operative time of 1.5 times or longer of the surgeon's individual base time[16]. The associations between the baseline characteristic, demographic data, clinical presentation, and preoperative ultrasound finding were analyzed and reported in percentage or mean with standard deviation (SD). Student's t-test or the Mann Whitney's U test using for analysis of independent (continuous) variables and the chi-square test for dependent (categorized) variables.

The differences of performance categorized by the difficulty of SILC between the conventional equipment group and the commercially original equipment group were analyzed using binary multivariate logistic regression. Relative risk (RR) and 95% confidence interval (CI) were reported. A p-value of less than 0.05 was considered significant. All the statistical analyses were performed with Stata/SE 16.0 for Mac (StataCorp LLC, College Station, TX, USA). The study process and report followed the strengthening of the reporting of observational studies in epidemiology (STROBE) statement in reports of cohort studies[39,40]. The authors planned to manage to the loss to follow-up patient and missing data by omitting those cases and analyzed the remaining data. However, after data collection, no loss to follow-up cases were detected initially.

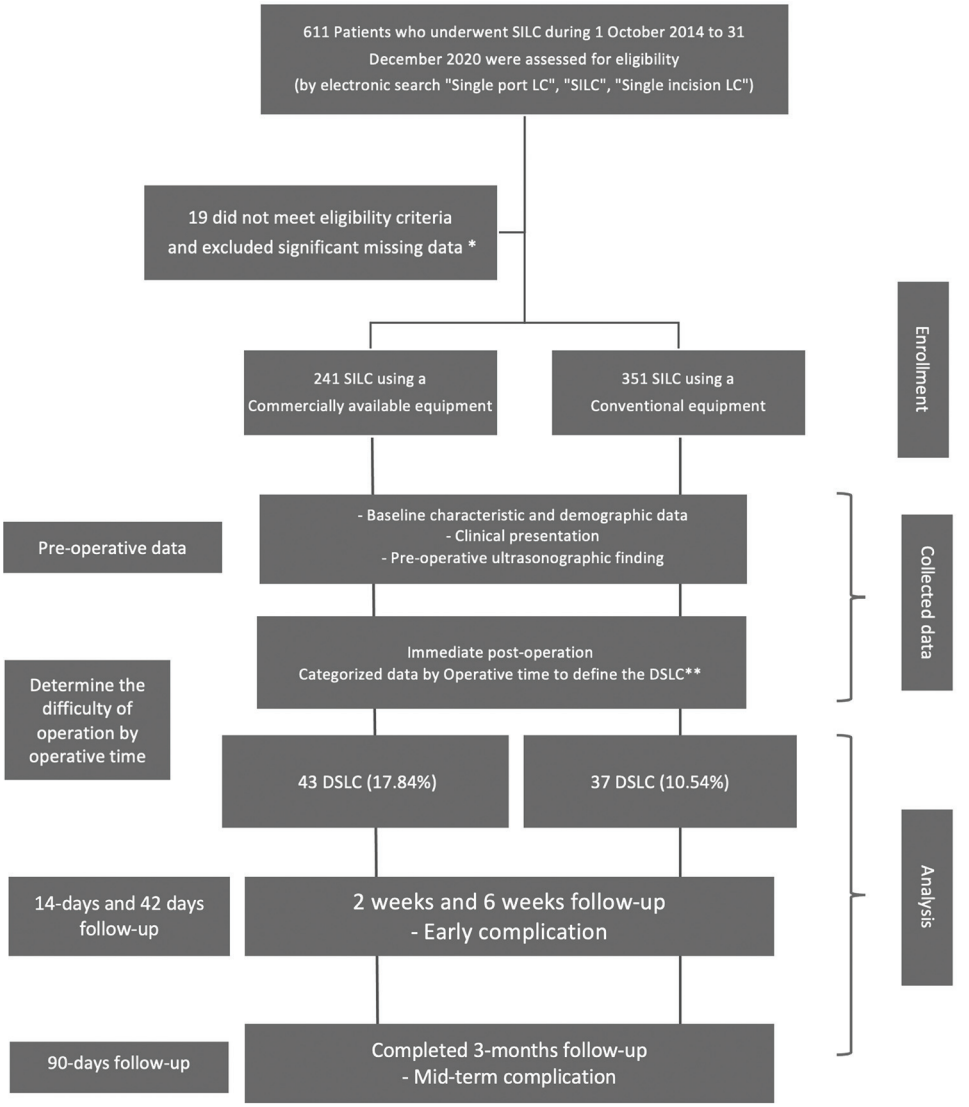

Figure 4. The study flow diagram of cohort study [STROBE Statement (2008)](39,40).

LC, laparoscopic cholecystectomy; SILC, single-incision laparoscopic cholecystectomy; DSLC, difficult single-incision laparoscopic cholecystectomy

* Important outcome data cannot assessed and missing data >80% in individual patients due to loss to follow up and other reason.

** The threshold time to define the DSLC is 1.5 × median operative time=72 minutes

Results

Between October 2014 and December 2020, the data of 611 patients that underwent SILC procedure were reviewed. Nineteen patients were excluded due to incomplete data of the main outcomes from missing the intraoperative time data, diagnoses, and loss to follow-up at three months (Figure 4). Therefore, 592 patients that underwent SILC procedure were included in the present study (Figure 4). The mean age at the time of SILC was 59±14 years, with the most advanced age at 93 years, and 183 (31.01%) patients were male. The most common underlying disease was dyslipidemia (DLP), (41.22%). The mean BMI was 25.64±4.69 kg/m², 295 (49.83%) patients were obese defined by a BMI greater than 25 kg/m². Dyspepsia was the most common symptom that led to perform investigation and treatment (96.96%). Three patients (0.51%) presented with acute cholecystitis. There were 38 (6.42%) patients who had a history of acute cholecystitis. Five hundred seventy-two (96.62%) of the preoperative ultrasound findings reported GSs.

Three hundred fifty-one (59.29%) patients

Table 1. Comparison of patient's demographic and clinical data between conventional equipment and a commercially available equipment groups

Variables	Conventional equipment (n1=351); n (%)	Commercially available equipment (n2=241); n (%)	Sum (n=592); n (%)	p-value
Age (years); mean±SD	57.85±13.87	60.67±14.86	59.00±14.33	0.019[a]
Sex: female	248 (70.66)	161 (66.8)	409 (69.09)	0.319
Weight (kg); mean±SD	66.39±14.41	64.90±12.78	65.78±13.78	0.199
Height (cm); mean±SD	159.85±8.16	159..96±8.78	159.89±8.41	0.867
BMI (kg/m^2); mean±SD	25.88±4.87	25.28±4.39	25.64±4.69	0.131
Underlying disease				
DM	77 (21.94)	42 (17.43)	119 (20.1)	0.179
HTN	146 (41.60)	93 (38.59)	239 (40.37)	0.464
DLP	151 (43.02)	93 (38.59)	244 (41.22)	0.282
CAD	10 (2.85)	7 (2.90)	17 (2.87)	0.968
Thalassemia	8 (2.28)	7 (2.90)	15 (2.53)	0.634
CKD	8 (2.28)	4 (1.66)	12 (2.03)	0.599
Asthma	5 (1.42)	5 (2.07)	10 (1.69)	0.546
Other	38 (10.83)	22 (9.13)	60 (10.14)	0.501
Blood thinner used				
Antiplatelet	36 (10.26)	30 (12.45)	66 (11.15)	0.405
Anticoagulant	3 (0.85)	1 (0.41)	4 (0.68)	0.521

SD=standard deviation; BMI=body mass index; DM=diabetes mellitus; HTN=hypertension; DLP=dyslipidemia; CAD=coronary artery disease; CKD=chronic kidney disease

[a] p<0.05, statistically significant

underwent SILC procedure with conventional equipment and 241 (40.71%) patients underwent SILC procedure with commercially original equipment. The distribution of patient's demographic and clinical data including underlying disease were not significantly different except the age of the patients (Table 1). The age in SILC in the commercially original equipment group was greater than in the conventional equipment group at 60.67±14.86 versus 57.85±13.87 (p=0.019). Most of the clinical diagnosis of patients that underwent SILC procedure were comparable between the two groups (Table 2). Dyspepsia, which was the most common clinical presentation, was more frequent in the commercially original equipment group than the conventional equipment group at 99.59% versus 95.16% (p=0.002).

The median time of forty-eight minutes was used as a cutoff point to determine the criteria for difficult SILC procedure because of the abnormal distribution pattern that was observed with the mean operative time. The mean operative time was 53.44±22.87 minutes (Table 3). The operative time of commercially original equipment group was greater than conventional equipment group at 56.76 minutes versus 51.17 minutes (95% CI 51.603 to 55.295, p=0.003). The threshold of median operative time to determine the DSLC was 72 minutes based on the formula 1.5×median operative time[16]. The number of non-difficult SILC procedures that had the operative time of less than 72 minutes was 512 (86.5%), and the number of difficult SILC procedures that had the operative time of 72 minutes or more was 80 (13.5%)(16). None of the SILC procedures required conversion to open cholecystectomy.

The multivariate analysis with an adjusted RR is reported in Table 3. The number of difficult SILC procedure was less frequent in SILC using conventional equipment when compared with commercially original equipment groups, significantly at 37 (10.54%) versus 43 (17.84%) (RR 1.75, 95% CI 1.081 to 2.822, p=0.023]. The SILC procedure was operated by the single surgeon who had experience in LC procedure, including SILC with more than 1,000 cases. The effect of the surgeon's learning curve was excluded by period analysis, which showed no relationship between period and operative time. Hence, both ordering and periods in years were not affected to the operative time and difficulty of SILC procedure.

The Table 4 demonstrates the intraoperative

Table 2. Clinical presentation, diagnosis and preoperative ultrasound finding between conventional equipment and a commercially available equipment groups

Variables	Conventional equipment (n1=351); n (%)	Commercially available equipment (n2=241); n (%)	Sum (n=592); n (%)	p-value
Clinical presentation				
Dyspepsia	334 (95.16)	240 (99.59)	574 (96.96)	0.002[a]
Abdominal pain	149 (42.45)	94 (39.00)	243 (41.05)	0.402
History of acute cholecystitis	22 (6.27)	16 (6.64)	38 (6.42)	0.856
CBD stone	18 (5.13)	9 (3.73)	27 (4.56)	0.425
History of ERCP	13 (3.70)	10 (4.15)	23 (3.89)	0.783
GS pancreatitis	6 (1.71)	4 (1.66)	10 (1.69)	0.963
GS cholangitis*	4 (1.14)	2 (0.83)	6 (1.01)	0.712
Acute cholecystitis**	1 (0.28)	2 (0.83)	3 (0.51)	0.359
Pre-operative ultrasound finding				
GS	341 (97.15)	231 (95.85)	572 (96.62)	0.390
Gallbladder wall thickening ≥4mm	45 (12.82)	27 (11.20)	72 (12.16)	0.554
Acute cholecystitis***	3 (0.85)	1 (0.41)	4 (0.68)	0.521
Gangrenous cholecystitis	1 (0.28)	0 (0.00)	1 (0.17)	0.407
Chronic cholecystitis****	21 (5.98)	12 (4.98)	33 (5.57)	0.601
Adenomyosis	23 (6.55)	13 (5.39)	36 (6.08)	0.562
Gallbladder polyp	29 (8.26)	21 (8.71)	50 (8.45)	0.846
Contracted gallbladder	9 (2.56)	13 (5.39)	22 (3.72)	0.074
Calcified gallbladder	4 (1.14)	3 (1.24)	7 (1.18)	0.907
CBD dilatation	7 (1.99)	9 (3.73)	16 (2.70)	0.200

CBD=common bile duct; ERCP=endoscopic retrograde cholangiopancreatography; GS=gallstones

[a] p<0.05, statistically significant

* Systemic inflammation (fever and/or chills or laboratory data) + cholestasis (Jaundice or Laboratory data) + imaging (biliary dilatation or evidence of the etiology on imaging)[34]

** Clinical diagnosis (local signs of inflammation (murphy's sign or right upper quadrant mass/pain/tenderness) + systemic signs of inflammation (fever or elevated C-reactive protein or elevated white blood cell count)

*** Ultrasound finding characteristic diagnosis

**** Gallbladder wall thickening ≥4mm with non-distended gallbladder[35]

Table 3. Operative time result and multivariate analysis of difficulty of SILC procedures between conventional equipment and a commercially available equipment groups

Variables	Missing data	DSLC**	NDSLC	Hazard ratio	CI	p-value
Conventional equipment vs. commercially available equipment*	None	10.54% vs. 17.84%	89.46% vs. 82.16%	1.75	1.081 to 2.822	0.023[a]

DSLC=difficult single-port laparoscopic cholecystectomy; NDSLC=non-difficult single-port laparoscopic cholecystectomy; CI=confidence interval

[a] p<0.05, statistically significant

* The multivariate analysis adjusted by age and dyspepsia.

** The SILC procedure which had an operative time greater than 1.5 times of the surgeon's individual operative time is classified as difficult DSLC (operative time ≥1.5 times the surgeon's individual base time). Conversely, the NDSLC is operative time less than 1.5 times of the surgeon's individual operative time. The threshold time to define the DSLC is 1.5 × median operative time=72 minutes[16].

and post-operative complications between the conventional equipment and the commercially original equipment group. The distribution of the complications between the two groups was comparable. The biliovascular injury, wound infection, and 3-months follow up of incisional hernia were not different in SILC procedure using the different equipment. The overall complication

Table 4. Complications between conventional equipment and a commercially available equipment groups

Variables	Conventional equipment (n1=351); n (%)	Commercially available equipment (n2=241); n (%)	Sum (n=592); n (%)	p-value
Intraoperative complication				
Intraoperative bile leakage	1 (0.28)	0 (0.00)	1 (0.17)	0.407
Cystic artery injury	1 (0.28)	0 (0.00)	1 (0.17)	0.407
Post-operative complication				
Wound infection	6 (1.71)	2 (0.83)	8 (1.35)	0.363
Incisional hernia	1 (0.28)	0 (0.00)	1 (0.17)	0.407

NDSLC=non-difficult single-port laparoscopic cholecystectomy; DSLC=difficult single-port laparoscopic cholecystectomy

occurred in 11 cases (1.86%). One incisional hernia occurred in conventional equipment, which was not associated with the difficulty of SILC procedure. The intraoperative bile leakage was not associated with wound infection in the present study.

Discussion

The first choice of surgical treatment in benign gallbladder disease is minimally invasive LC approach, which uses multiple ports to insert surgical instruments[41]. The SILC procedure that has evolved since 1997 is beneficial in cosmetic and post-operative pain result under minimally invasive surgery concept[8,12]. However, the limitation about SILC procedure is the requirement for specifically designed commercially original equipment including articulated instrument such as Endo SILS® Maryland dissector, Endo SILS® Hook, Endo SILS® laparoscopic scissor, and Cambridge Endo® articulating instruments. Those are expensive and are not reimbursed or supported by the National Health Insurance in Thailand[5,14]. The articulated instrument for SILC procedure has special properties including long length, all direction flexible, rotatable tip, which can increase the space of the operative field to perform LC via the single transumbilical incision[13,14]. Nevertheless, there is no clinical trial to perform SILC without articulated instrument, which can be performed by experienced LC surgeons. The present study used conventional laparoscopic equipment that is inexpensive and available in Thailand to perform SILC. The difficulty of LC and their complications between the conventional equipment and commercially original equipment on SILC procedure are analyzed under non-inferiority condition[15-18].

Same as the previous studies, the distribution of cholecystectomy procedure is dominant in female and obese patients. The present study reports the mean BMI of all patients that underwent SILC procedure as 25.6 kg/m². Most patients are female (69.09%), while fertile age is not frequent with a mean age 59 years[10,24,42,43]. The symptomatic GS, which presents with the dyspepsia (96.96%), is the most common presentation, and concurs with the majority of preoperative ultrasound finding reported as GSs (96.62%).

The age of the patients in SILC using the commercially original equipment group is greater than conventional equipment group in univariate analysis at 60 years versus 57 years (p=0.019). Previous studies have reported age-related difficult LC[24,44,45]. Vivek et al reported that the age greater than 65 years was identified as predictors of difficult LC[44]. Randhawa et al reported that the age greater than 50 years was associated with the same difficulties[18]. The old age has increased the difficulty LC by operative time and increasing the rate of open conversion surgery. This is because of the number of the acute cholecystitis episode and upper abdominal surgeries that produced the inflammation, adhesions, and fibrosis in the triangle of Calot, and the hepatic hilum are increasing with age. Therefore, there is increased incidence of difficult LC by age. The lysis of adhesion and dissection of the triangle of Calot are increasing the operative time of LC procedure[44].

However, several studies reported no relationship between patient's age and difficulty of LC[46-48]. Wakabayashi, et al and Japanese Society of Hepato-Biliary-Pancreatic Surgery reported the relationship between old age such as age older than 60 or 65 years and open conversion rate but no relationship between old age and operative time on Tokyo guideline 2018[32]. Agrawal et al described the difficulty of LC scoring method that included the age. However, the multivariate analysis found that the age is not related to the difficulty of LC[46]. Currently, the evolving of pre-operative ultrasound to evaluate the

predictive factors of difficult LC are reporting the sign of inflammation around Calot's triangle and hepatic hilum including thickening of the gallbladder wall, contracted gallbladder, calcified gallbladder, and size of the CBD. The preoperative ultrasound findings, which indicated the inflammation around the operative field are directly associated with the difficulty of LC and operative time more than patient's age and clinical presentation. There is no statistically significant difference in preoperative ultrasound finding that predicts the inflammation around the operative field between the commercially original equipment group and the conventional equipment group in the present study. Therefore, the age is not directly affecting the difficulty of SILC outcome between the commercially original equipment group and the conventional equipment group, as well as, less likely to confound the performance on SILC between using a conventional equipment or a commercially original equipment.

The most common clinical presentation in patients who underwent SILC procedure is dyspepsia, which is more frequent in the commercially original equipment group than in the conventional equipment group in univariate analysis. Several studies reported the association between sign and symptom of acute cholecystitis, number of attacks of cholecystitis, and difficulty of LC[24,44,46,47,49,50]. Nevertheless, no previous study report about the dyspepsia symptom associated with the difficulty of LC. The dyspepsia is not a symptom of acute cholecystitis but indicates the symptomatic uncomplicated cholecystolithiasis, which is caused by the distention and contraction of the gallbladder or GS impaction in the gallbladder neck without acute inflammation. Although symptomatic cholecystolithiasis typically presents with biliary colic, most patients have experience dyspepsia-like abdominal pain, bloating in the upper abdomen, especially after a large fatty meal[51,52]. Therefore, the dyspepsia symptom is not related to the operative time and difficulty of SILC outcome between the commercially original equipment and the conventional equipment group. In addition, other predictive factors that indicates the inflammation of Calot's triangle and operative field in the present study are compared between the commercially original equipment group and the conventional equipment group.

The number of difficult SILC using conventional equipment is less frequent than SILC using commercially original equipment in the multivariate analysis. However, the study is a non-inferiority trial model. So, the authors can conclude that the SILC using conventional equipment is not inferior to SILC using commercially original equipment on the operative time result. The SILC using conventional equipment is not increasing the risk of difficulty of SILC procedure. The intraoperative and post-operative complications between conventional equipment and a commercially original equipment group are comparable. There is no difference of the biliovascular injury, wound infection, and incisional hernia between the two groups using different equipment. Intraoperative management of cystic artery injury and bile leakage can manage via laparoscopic technique without open conversion. One case of the incisional hernia is treated by open surgical repair without mesh requirement due to a small defect of the abdominal sheath without any bowel involvement complication. Thus, the SILC without using articulated instrument can be performed with safety and satisfactory outcome of operative time.

The non-articulated and short length of the conventional Maryland dissector, Endo Grasper, are used in the SILC procedure under additional technique. Therefore, these can be performed by adjusting the angle of view during the operation by positioning of the laparoscope by placing it under all instruments and its tip is bending to medial, angle of view adjusts to lateral for avoiding instrument collision and increase the operative field for tissue handle. In addition, the surgeon who has expertise in conventional LC had a high experience in using of non-articulated instrument and can operate SILC procedure with conventional equipment without any additional skill required to handle the new articulated instrument.

The present study was a retrospective cohort with non-inferiority trial model. Although, the result of the multivariate analysis demonstrates the less frequent of difficult LC procedure in SILC using conventional equipment when compared with commercially original equipment groups with RR 1.75 ($p=0.023$), the limitations of the study include the limited sample size with non-inferiority margin (δ) and bias inherent to the retrospective nature of the design. To conclude that the conventional equipment may be superior to commercially original equipment as the present study result, further prospective equivalent trial is required. The surgeon who operated the SILC in the present study is a single surgeon who had high expertise in both conventional LC with non-articulated instrument and SILC procedure. The effect of the surgeon's learning curve is not accounted for in the present

study. The incidence of biliovascular injury (0.17%) and incisional hernia (0.17%) is low in both groups compared with previous studies[4,53-55]. In addition, the other criteria of difficult LC such as bile duct injury, cystic duct injury, and open conversion were not included in the present study. No open conversion was required in the present study. Therefore, the result of the present study may not be appropriate to apply in surgeons who has no experience in LC procedure. The skill to handle the conventional instrument and adjust the angle of view by positioning of laparoscope and instrument in SILC procedure are necessary.

The non-inferiority trial model demonstrates the performance of the SILC using conventional equipment is not inferior to SILC using commercially original equipment. The operative time, the difficulty of SILC procedure, and their complications are comparable between the two different types of equipment.

Conclusion

The evolving of medical devices and novel technology in the minimally invasive surgery era created the SILC procedure that provide the least number of incisions in LC. The present study demonstrates the application of multiple-port LC procedure conventional equipment to perform SILC procedure. The authors report the comparable operative time and adverse outcome between these two groups. The use of conventional equipment can reduce the total cost of surgery, especially for special articulated instrument that could not be reimbursed by the National Health Insurance in Thailand.

What is already known on this topic?

The SILC procedures need to use the commercial original surgical equipment, which are disposable and more expensive than the conventional multiple-port LC equipment, including the articulated type of surgical devices.

What this study adds?

This study shows that application of the available conventional equipment in SILC procedure is safe and not difficult when use by experienced surgeons. The result of the operative time and complications of the conventional equipment are comparable to the commercially original equipment in SILC procedure.

Conflicts of interest

None of the authors have financial and non-financial conflict of interest to report.

References

1. Hendolin HI, Pääkönen ME, Alhava EM, Tarvainen R, Kemppinen T, Lahtinen P. Laparoscopic or open cholecystectomy: a prospective randomised trial to compare postoperative pain, pulmonary function, and stress response. Eur J Surg 2000;166:394-9.
2. van den Boezem PB, Velthuis S, Lourens HJ, Cuesta MA, Sietses C. Single-incision and NOTES cholecystectomy, are there clinical or cosmetic advantages when compared to conventional laparoscopic cholecystectomy? A case-control study comparing single-incision, transvaginal, and conventional laparoscopic technique for cholecystectomy. World J Surg 2014;38:25-32.
3. van der Linden YT, Bosscha K, Prins HA, Lips DJ. Single-port laparoscopic cholecystectomy vs standard laparoscopic cholecystectomy: A non-randomized, age-matched single center trial. World J Gastrointest Surg 2015;7:145-51.
4. Lyu Y, Cheng Y, Wang B, Zhao S, Chen L. Single-incision versus conventional multiport laparoscopic cholecystectomy: a current meta-analysis of randomized controlled trials. Surg Endosc 2020;34:4315-29.
5. Karakuş O, Ulusoy O. Evolution of laparoscopic cholecystectomy: From multiport to single port. J Minim Invasive Surg Sci 2016;5:e36366.
6. Qu JW, Xin C, Wang GY, Yuan ZQ, Li KW. Feasibility and safety of single-incision laparoscopic cholecystectomy versus conventional laparoscopic cholecystectomy in an ambulatory setting. Hepatobiliary Pancreat Dis Int 2019;18:273-7.
7. Omar MA, Redwan AA, Mahmoud AG. Single-incision versus 3-port laparoscopic cholecystectomy in symptomatic gallstones: A prospective randomized study. Surgery 2017;162:96-103.
8. Kumar M, Agrawal CS, Gupta RK. Three-port versus standard four-port laparoscopic cholecystectomy: a randomized controlled clinical trial in a community-based teaching hospital in eastern Nepal. JSLS 2007;11:358-62.
9. Akethanin T, Moungthard H, Techapongsatorn S, Tansawet A. Perception and attitude about laparotomy wound closure among Thai surgeons: A survey study: Fascia closure survey. J Assoc Gen Surg Thai 2021;5:3-11.
10. Casaccia M, Palombo D, Razzore A, Firpo E, Gallo F, Fornaro R. Laparoscopic single-port versus traditional multi-port laparoscopic cholecystectomy. JSLS 2019;23:e2018.00102.
11. Suraseang K. Laparoscopic cholecystectomy (LC): A comparison study between the single-incision and the three-port LC. Srinagarind Med J 2013;28:66-76.
12. Navarra G, Pozza E, Occhionorelli S, Carcoforo P, Donini I. One-wound laparoscopic cholecystectomy. Br J Surg 1997;84:695.
13. Al-Ameedee M. Articulated laparoscopic instruments:

A new technology to overcome challenging uro-laparoscopic surgery. Arab J Urol 2018;16:S40-1.
14. Arata J, Kogiso S, Sakaguchi M, Nakadate R, Oguri S, Uemura M, et al. Articulated minimally invasive surgical instrument based on compliant mechanism. Int J Comput Assist Radiol Surg 2015;10:1837-43.
15. Stanisic V, Milicevic M, Kocev N, Stanisic B. A prospective cohort study for prediction of difficult laparoscopic cholecystectomy. Ann Med Surg (Lond) 2020;60:728-33.
16. Bourgouin S, Mancini J, Monchal T, Calvary R, Bordes J, Balandraud P. How to predict difficult laparoscopic cholecystectomy? Proposal for a simple preoperative scoring system. Am J Surg 2016;212:873-81.
17. Wu T, Luo M, Guo Y, Bi J, Guo Y, Bao S. Role of procalcitonin as a predictor in difficult laparoscopic cholecystectomy for acute cholecystitis case: A retrospective study based on the TG18 criteria. Sci Rep 2019;9:10976.
18. Randhawa JS, Pujahari AK. Preoperative prediction of difficult lap chole: a scoring method. Indian J Surg 2009;71:198-201.
19. Joong Choi C, Roh YH, Kim MC, Choi HJ, Kim YH, Jung GJ. Single-Port Laparoscopic Cholecystectomy for Gall Bladder Polyps. JSLS 2015;19:e2014.00183.
20. Tomioka T, Tajima Y, Inoue K, Onizuka S, Ikematsu Y, Kanematsu T. Laparoscopic cholecystectomy is a safe procedure for the treatment of porcelain gallbladder. Endoscopy 1997;29:225.
21. Toouli J. Biliary dyskinesia. Curr Treat Options Gastroenterol 2002;5:285-91.
22. Nidoni R, Udachan TV, Sasnur P, Baloorkar R, Sindgikar V, Narasangi B. Predicting difficult laparoscopic cholecystectomy based on clinicoradiological assessment. J Clin Diagn Res 2015;9:PC09-12.
23. Chong JU, Lee JH, Yoon YC, Kwon KH, Cho JY, Kim SJ, et al. Influencing factors on postoperative hospital stay after laparoscopic cholecystectomy. Korean J Hepatobiliary Pancreat Surg 2016;20:12-6.
24. Seehawong U, Sumritpradit P, Krutsri C, Singhatat P, Thampongsa T, Tangtawee P. Risk factors of difficult laparoscopic cholecystectomy for acute cholecystitis in acute care surgery patients. J Med Assoc Thai 2019;102(Suppl 2):S56-60.
25. Poonkeaw T. Predicting factors of the difficult laparoscopic cholecystectomy in Phatthalung Hospital. Region 11 Med J 2019;30:251-60.
26. Hayama S, Ohtaka K, Shoji Y, Ichimura T, Fujita M, Senmaru N, et al. Risk factors for difficult laparoscopic cholecystectomy in acute cholecystitis. JSLS 2016;20:e2016.00065.
27. Inoue K, Ueno T, Douchi D, Shima K, Goto S, Takahashi M, et al. Risk factors for difficulty of laparoscopic cholecystectomy in grade II acute cholecystitis according to the Tokyo guidelines 2013. BMC Surg 2017;17:114.
28. Elgammal AS, Elmeligi MH, Koura MMA. Evaluation of preoperative predictive factors for difficult laparoscopic cholecystectomy. Int Surg J 2019;6:3052-6.
29. Yassein T, Iyoab I, Sallam A, Gomaa M, Sadek A, Osman M, et al. Predicting the risk factors of difficult laparoscopic cholecystectomy step by step. Egypt J Surg 2020;39:515-22.
30. Di Buono G, Romano G, Galia M, Amato G, Maienza E, Vernuccio F, et al. Difficult laparoscopic cholecystectomy and preoperative predictive factors. Sci Rep 2021;11:2559.
31. Saleem AA, Abdallah H. Evaluation of preoperative predictive factors for difficult laparoscopic cholecystectomy in comparison with intraoperative parameters. Egypt J Surg 2018;37:504-11.
32. Wakabayashi G, Iwashita Y, Hibi T, Takada T, Strasberg SM, Asbun HJ, et al. Tokyo Guidelines 2018: surgical management of acute cholecystitis: safe steps in laparoscopic cholecystectomy for acute cholecystitis (with videos). J Hepatobiliary Pancreat Sci 2018;25:73-86.
33. Kiriyama S, Kozaka K, Takada T, Strasberg SM, Pitt HA, Gabata T, et al. Tokyo Guidelines 2018: diagnostic criteria and severity grading of acute cholangitis (with videos). J Hepatobiliary Pancreat Sci 2018;25:17-30.
34. Yokoe M, Hata J, Takada T, Strasberg SM, Asbun HJ, Wakabayashi G, et al. Tokyo Guidelines 2018: diagnostic criteria and severity grading of acute cholecystitis (with videos). J Hepatobiliary Pancreat Sci 2018;25:41-54.
35. Bhandarkar D, Mittal G, Shah R, Katara A, Udwadia TE. Single-incision laparoscopic cholecystectomy: How I do it? J Minim Access Surg 2011;7:17-23.
36. MacDonald ER, Alkari B, Ahmed I. "Single-port" laparoscopic cholecystectomy--the Aberdeen technique. Surg Laparosc Endosc Percutan Tech 2010;20:e7-9.
37. Chow SC, Shao J, Wang H. Sample size calculations in clinical research. 2nd ed. New York: John Wiley & Sons; 2008.
38. Ngamjarus C, Chongsuvivatwong V, McNeil E. n4Studies: Sample size calculation for an epidemiological study on a smart device. The Thailand research fund & prince of Songkla university. Siriraj Med J 2016;68:160-70.
39. von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. J Clin Epidemiol 2008;61:344-9.
40. Vandenbroucke JP, von Elm E, Altman DG, Gøtzsche PC, Mulrow CD, Pocock SJ, et al. Strengthening the Reporting of Observational Studies in Epidemiology (STROBE): explanation and elaboration. Int J Surg 2014;12:1500-24.
41. Trichak S. Three-port vs standard four-port laparoscopic cholecystectomy. Surg Endosc 2003;17:1434-6.
42. Alves KR, Goulart AC, Ladeira RM, Oliveira IR, Benseñor IM. Frequency of cholecystectomy and

associated sociodemographic and clinical risk factors in the ELSA-Brasil study. Sao Paulo Med J 2016;134:240-50.
43. Malik AA, Wani ML, Tak SI, Irshad I, Ul-Hassan N. Association of dyslipidaemia with cholilithiasis and effect of cholecystectomy on the same. Int J Surg 2011;9:641-2.
44. Vivek MA, Augustine AJ, Rao R. A comprehensive predictive scoring method for difficult laparoscopic cholecystectomy. J Minim Access Surg 2014;10:62-7.
45. Abdeldayem M, Osgood L, Escofet X, Farag M. A new preoperative scoring system to predict difficulty of laparoscopic cholecystectomy and risk of conversion to open surgery. Indian J Surg 2019;82:501-6.
46. Agrawal N, Singh S, Khichy S. Preoperative prediction of difficult laparoscopic cholecystectomy: a scoring method. Niger J Surg 2015;21:130-3.
47. Gupta N, Ranjan G, Arora MP, Goswami B, Chaudhary P, Kapur A, et al. Validation of a scoring system to predict difficult laparoscopic cholecystectomy. Int J Surg 2013;11:1002-6.
48. Kanakala V, Borowski DW, Pellen MG, Dronamraju SS, Woodcock SA, Seymour K, et al. Risk factors in laparoscopic cholecystectomy: a multivariate analysis. Int J Surg 2011;9:318-23.
49. Jalil T, Adibi A, Mahmoudieh M, Keleidari B. Could preoperative sonographic criteria predict the difficulty of laparoscopic cholecystectomy? J Res Med Sci 2020;25:57.
50. Siddiqui MA, Rizvi SAA, Sartaj S, Ahmad I, Rizvi SWA. A Standardized ultrasound scoring system for preoperative prediction of difficult laparoscopic cholecystectomy. J Med Ultrasound 2017;25:227-31.
51. Portincasa P, Moschetta A, Petruzzelli M, Palasciano G, Di Ciaula A, Pezzolla A. Gallstone disease: Symptoms and diagnosis of gallbladder stones. Best Pract Res Clin Gastroenterol 2006;20:1017-29.
52. Latenstein CSS, de Jong JJ, Eppink JJ, Lantinga MA, van Laarhoven C, de Reuver PR, et al. Prevalence of dyspepsia in patients with cholecystolithiasis: a systematic review and meta-analysis. Eur J Gastroenterol Hepatol 2019;31:928-34.
53. Arezzo A, Passera R, Forcignanò E, Rapetti L, Cirocchi R, Morino M. Single-incision laparoscopic cholecystectomy is responsible for increased adverse events: results of a meta-analysis of randomized controlled trials. Surg Endosc 2018;32:3739-53.
54. Hoyuela C, Juvany M, Guillaumes S, Ardid J, Trias M, Bachero I, et al. Long-term incisional hernia rate after single-incision laparoscopic cholecystectomy is significantly higher than that after standard three-port laparoscopy: a cohort study. Hernia 2019;23:1205-13.
55. Rappaport WD, Gordon P, Warneke JA, Neal D, Hunter GC. Contraindications and complications of laparoscopic cholecystectomy. Am Fam Physician 1994;50:1707-11, 14.