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Transumbilical single-incision laparoscopic cholecystectomy: long-term review from a single center

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Abstract

Background Currently, researches about single-incision laparoscopic cholecystectomy (SILC) are various, but long-term reviews assessing relevant complications after SILC with considerable amount of case series are rare.

Study design We retrospectively reviewed a large series of 529 patients undergoing SILC to assess the long-term postoperative recovery, including postoperative complications, retained symptoms, and quality of life. Finally, we assessed its associated risk factors related to SILC patients' recovery in the long term.

Results During a mean follow-up period of 36.8 ± 8.8 months after SILC, 402 (76.0 %) patients underwent complete resolution. Frequent diarrhea (12.1 %) and recurrent omphalitis (5.9 %) were most commonly seen among other complications and retained symptoms within overall the patients. We identified 1 (0.3 %) incision hernia and 1 (0.3 %) intra-abdominal abscess among overall the patients, while 3 (0.8 %) common bile duct stones and 1 (0.3 %) biliary pancreatitis among the patients with symptomatic cholelithiasis during long-term review period. No significant differences were identified between patients with symptomatic cholelithiasis and gallbladder polyps when considering other incidences (all $p > 0.05$). Patients undergoing SILC with older age ($p = 0.023$) or female gender ($p = 0.020$) contributed to complete resolution.

Conclusions SILC via traditional devices is feasible and safe with acceptable postoperative incidence rate in the long run. Patients with older age or female gender, who have no severe systemic diseases, tend to benefit more from the surgical intervention.

Keywords Single-incision laparoscopic cholecystectomy (SILC) · Long-term review · Traditional devices

Abbreviations

SILC	Single-incision laparoscopic cholecystectomy
TMLC	Traditional multiport laparoscopic cholecystectomy
SF-36	Short-Form-36 Health Survey questionnaire
CBDS	Common bile duct stones
ERCP	Endoscopic retrograde cholangiopancreatography
BMI	Body mass index
ASA	American Society of Anesthesiology
QoL	Quality of life
SD	Standard deviation
IQR	Interquartile range
CI	Confidence interval

Single-incision laparoscopic cholecystectomy (SILC) is an alternative to natural orifice transluminal endoscopic surgery. The overall surgical procedures are performed through only one incision within the umbilicus, which remains an invisible scar postoperatively. Since SILC was first reported by Navarra [1] in 1997, several transumbilical devices have been created to benefit the operation [2–12]. However, one of the most cost-effective methods to establish transumbilical access is the multiport approach, which is performed by multiple fascial punctures through

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one transumbilical skin incision with traditional trocars. The theoretical advantage of SILC is better in cosmesis [13] with equally fast recovery and light intra-abdominal adhesion [14], comparing with traditional multiport laparoscopic cholecystectomy (TMLC), but no gain of postoperative pain and complications [13, 15]. It is also convenient to convert to TMLC when needed [16]. However, the retained abdominal symptoms, complications and cosmetic satisfaction after SILC have not been fully assessed in the long run [14, 17]. Thus, the primary aim was to obtain the exact complication rate and profile of SILC performed by an experienced professional in the long-term review. Secondarily, we investigated the factors predicting patients' recovery.

Materials and methods

Study design and setting

This is a retrospective study including all patients who underwent SILC in the Shengjing Hospital of China Medical University over a 3-year period between January 2010 and December 2012. After approved by the research ethics committee of our hospital, a telephonic survey was developed to ascertain long-term review data until September 2014, with a minimum 22-month follow-up period after SILC. It was intended to investigate the long-term postoperative incidence, recovery, and satisfaction after SILC. Participants gave written consent after receiving verbal and written information.

Participants

The survey was performed among patients after SILC with an indication for elective cholecystectomy, including symptomatic cholelithiasis, and gallbladder polyps (over 1 cm in diameter). The patients would be excluded, if they complicated with acute cholecystitis (according to TG13 diagnostic criteria [18]), prior upper abdominal surgery, common bile duct stones (CBDS), or severe systemic diseases before surgery. The patients who underwent endoscopic retrograde cholangiopancreatography (ERCP) previously, common bile duct exploration, or subsequent abdominal operations unrelated to SILC were not involved. We also excluded the patients who had severe complications (such as intraoperative biliary duct injury, severe blood loss), which would result in converting to multiport laparoscopic surgery or open surgery. All above exclusions were established in avoiding to influence the accuracy of relevant long-term complication rate.

Data sources

We used administrative and surgical records as basic information. Data from postoperative questionnaires were also recorded, involving patients' complications, retained symptoms, and surgical satisfaction during the long-term follow-up period. Long-term complications were collected as recurrent omphalitis (defined as long-term infection of the umbilicus after SILC, complicating with the symptoms of periumbilical pain, suppuration, and inflammation, etc.), incision hernia (defined as a palpable or CT scan-verified fascial defect with potential protrusion of intra-abdominal content [19]), intra-abdominal abscess, CBDS, reflux gastritis, and biliary pancreatitis. All these complications were confirmed by physical or chemical examinations during follow-up period. Postoperatively retained symptoms were collected as right upper quadrant pain, diarrhea, nausea/vomiting, periumbilical pain, all of which were classified into three degrees of agreement with the symptoms, not agree [1], relatively agree [2], and very agree [3]. The scores of surgical satisfaction and cosmetic satisfaction were determined by a 10-point scale (from 1 to 10), respectively, which represented the degree of agreement with the surgical outcomes of recovery and umbilical incision cosmesis. The validated Short-Form-36 Health Survey questionnaire (SF-36) [20] was used to assess general health perception and well-being before surgical intervention, and long-term benefits from SILC.

Surgical procedure

The operations were performed by an experienced biliary surgeon who majored in laparoscopic surgery. The operations were assisted by resident doctors who had experience in handling the laparoscope. Before January 1, 2010, we had completed over 30 cases via traditional trocar devices [6] to overcome the learning curve of SILC [21]. Following the induction of general endotracheal anesthesia, the abdomen was prepped and draped in the usual sterile fashion. The umbilicus was carefully cleaned. The transumbilical route was established with traditional trocars (TRINOX trocar system, 1×10 mm, and 2×5 mm, XION GmbH, Berlin, Germany) to create three fascial punctures through one transumbilical skin incision, which were placed in a reverse triangular configuration within the umbilicus, leaving a small bridge of fascia between each trocar. Then, the patient was placed in a reverse Trendelenburg position with a 15° left tilt. All the operative procedures were completed as previously reported [6], which were retrograde dissection. This approach is most convenient to form optimal exposure by grasping the fundus of gallbladder and could successfully avoid the triangulation difficulty of instruments through a single

umbilical incision. The gallbladder was dissected to the cystic duct with Harmonic ACE (Ethicon, USA), which was then ligated using two clips after careful identification of the cystic duct and artery. The gallbladder was free, followed by thorough examination of bleeding, and visceral injury, especially biliary injury. The gallbladder was extracted through the umbilical incision together with the three trocars. The fascial incision was firstly closed in a Fig. 8 fashion, and then, running suture was applied to umbilical reconstruction. All layers of the umbilical incision were closed with subcutaneous absorbable stitches (Synthetic absorbable suture, 3–0, Ethicon Inc., New Jersey, USA). Then, adhesive surgical dressing (10 cm × 10 cm) was used to protect the umbilical wound. Routine nursing of incisional wound was carried out among all patients during the postoperative period.

Statistical analysis

Continuous variables were presented as mean, median, standard deviation (SD), and interquartile range (IQR). Categorical variables were presented as absolute numbers and percentages. Comparative analyses of continuous variables were performed using Student's *t* tests. Chi-square test was used for comparing categorical variables (Fisher's exact tests were used as needed). Multivariate linear regression was performed to assess the factors influencing SILC patients' satisfaction to the surgery and cosmesis during long-term follow-up period. Multivariate logistic regression was performed to assess the risk factors associated with SILC patients' complete resolution. Meanwhile, it was also performed to assess the risk factors associated with recurrent omphalitis and frequent diarrhea, both of which were more commonly encountered among all the postoperative complications and retained symptoms (incidence rate >5 %). Odds ratios or β-coefficient was presented with 95 % confidence interval (CI). All analyses were carried out with SPSS Statistics for Windows, version 17.0. Statistical analyses with $p < 0.05$ (two-tailed) were considered as significant. The risk factors in univariate analyses with $p < 0.10$ were further considered to undergo multivariate analyses.

Results

In all, 689 patients with gallbladder diseases were identified as having attempted SILC during our defined research period. There were 21 patients who underwent converting to TMLC, due to 20 severe adhesions (including 1 patient complicated with biliary injury as type D, representing lateral injury to extrahepatic bile ducts according to the Strasberg Bile Duct Injury Classification System [22]) and 1 accessory bile duct injury (categorized as type A, representing bile leak from a minor duct still in continuity with the common bile duct according to the Strasberg Bile Duct Injury Classification System [22]), which increased the surgical difficulty in SILC; 28 patients underwent prior ERCP; and 111 patients were lost to follow-up due to absence of available contact information, dead from other diseases, or refusing to answer the questionnaire. Ultimately, 529 patients joined for further analysis with a mean follow-up period of 36.8 ± 8.8 months after SILC, including 392 patients with symptomatic cholelithiasis, and 137 patients with gallbladder polyps.

Basic patient characteristics

The basic information for 529 SILC patients was presented in Table 1. There were 172 males (32.5 %) and 357 females (67.5 %) aged 48.1 ± 12.8 years, and 392 patients (74.1 %) were with symptomatic cholelithiasis; 137 patients (25.9 %) were with gallbladder polyps. The mean body mass index (BMI) was 23.8 ± 3.2 kg/m^2. The American Society of Anesthesiologists (ASA) score was ≤2 in 493 patients (93.2 %) and ≥3 in 36 patients (6.8 %). There were 213 patients (40.3 %) with education level below basic, 217 patients (41.0 %) with secondary level, and 99 patients (18.7 %) above tertiary level. There were 95 patients (18.0 %) complicated with comorbid diseases (including hypertension, ischemic heart disease, asthma, peptic ulcer, and others), 34 patients (6.4 %) with diabetes mellitus, 73 patients (13.8 %) with prior lower abdominal surgery (including traditional appendectomy, gynecologic surgery). There were 107 patients (20.2 %) with long-term smoking history.

Perioperative variables

All the 529 patients underwent SILC via the transumbilical route with three traditional trocars. The surgical procedures were performed by an experienced biliary surgeon who majored in minimally invasive surgery. He was assisted by residents who were experienced in handling the laparoscope. Overall, the mean operative time was 47.2 ± 18.5 min. The mean intraoperative blood loss was 33.1 ± 35.0 mL. However, the mean postoperative hospital stay was 3.1 ± 1.3 days, which was longer than reported in western countries since day-surgery was not carried out in our hospital, even most hospitals in China, due to different civilization and custom.

Follow-up information

During a mean follow-up period of 36.8 ± 8.8 months, there were 402 patients (76.0 %) who underwent complete

Table 1 Basic patient characteristics, morbid history, surgical and follow-up information

Variable	Overall patients ($n = 529$)
Basic patient characteristics	
Age, mean (SD, median, IQR), years	48.1 (12.8, 49, 39–58)
Male	172 (32.5 %)
BMI(kg/m^2), mean (SD, median, IQR)	23.8 (3.2, 23.7, 21.4–26.0)
ASA grade	
≤2	493 (93.2 %)
≥3	36 (6.8 %)
Diagnostic classification	
Symptomatic cholelithiasis	392 (74.1 %)
Gallbladder polyps	137 (25.9 %)
Education level	
Below basic	213 (40.3 %)
Secondary	217 (41.0 %)
Above tertiary	99 (18.7 %)
Smoker	107 (20.2 %)
Comorbid diseases	95 (18.0 %)
Diabetes mellitus	34 (6.4 %)
Prior abdominal surgery	73 (13.8 %)
Surgical information	
Operative time, mean (SD, median, IQR), min	47.2 (18.5, 45, 35–55)
Intraoperative blood loss, mean (SD, median, IQR), mL	33.1 (35.0, 20, 10–50)
Postoperative hospital stay, mean (SD, median, IQR), days	3.1 (1.3, 3, 2–4)
Follow-up information	
Follow-up period, mean (SD, median, IQR), mon	36.8 (8.8, 37, 29–44)
Avoid fatty food	366 (69.2 %)
Complete resolution	402 (76.0 %)
Satisfaction scores, mean (SD, median, IQR)	9.6 (1.0, 10, 10–10)
Cosmetic scores, mean (SD, median, IQR)	9.7 (0.8, 10, 10–10)

SD indicates standard deviation, *IQR* interquartile range, *BMI* body mass index, *ASA* American Society of Anesthesiology; operative time, defined as time from incision to closure

resolution. There were 366 patients (69.2 %) intended to avoid fatty food, due to eating habits or abdominal discomfort conditions. It scored 9.6 ± 1.0 in surgical satisfaction and scored 9.7 ± 0.8 in cosmetic satisfaction in the long-term.

Long-term complications postoperatively

Overall, there were 58 patients (11.0 %) suffering complications in the long term, including recurrent omphalitis (31 patients, 5.9 % overall), reflux gastritis (21 patients, 4.0 % overall), incision hernia (1 patient, 0.2 % overall), intra-abdominal abscess (1 patient, 0.2 % overall), CBDS (3 patients, 0.8 % in symptomatic cholelithiasis group), and biliary pancreatitis (1 patient, 0.3 % in symptomatic cholelithiasis group). Details for the long-term complications among patients with symptomatic cholelithiasis and gallbladder polyps are listed in Table 2. The three patients with CBDS were further treated with ERCP. The patient with incision hernia did not undergo further operation. Other complications were treated conservatively.

Long-term retained symptoms postoperatively

Overall, there were 14 patients (2.6 %) complaining about frequent occurrence of right upper quadrant pain, 64 patients (12.1 %) complaining about frequent diarrhea, 3 patients (0.6 %) complaining about frequent nausea/vomiting, and 4 patients (0.8 %) complaining about frequent periumbilical pain. Details for the long-term retained symptoms among patients with symptomatic cholelithiasis and gallbladder polyps are listed in Table 3. No significant differences were identified between patient with symptomatic cholelithiasis and gallbladder polyps referring to these retained symptoms (all $p > 0.05$).

Table 2 Long-term complications during follow-up period

Variables	Symptomatic cholelithiasis ($n = 392$)	Gallbladder polyps ($n = 137$)	p value
Recurrent omphalitis	24 (6.1 %)	7 (5.1 %)	0.83
Reflux gastritis	14 (3.6 %)	7 (5.1 %)	0.45
Incision hernia	1 (0.3 %)	0	–
Intra-abdominal abscess	1 (0.3 %)	0	–
Common bile duct stones	3 (0.8 %)	–	–
Biliary pancreatitis	1 (0.3 %)	–	–

SD indicates standard deviation, *IQR* interquartile range

Table 3 Long-term retained symptoms which patients commonly complained about during follow-up period

Symptom	Degree	Symptomatic cholelithiasis ($n = 392$)	Gallbladder polyps ($n = 137$)	p value
Right upper quadrant pain				
	1	339 (86.5 %)	120 (87.6 %)	0.87
	2	43 (11.0 %)	13 (9.5 %)	
	3	10 (2.6 %)	4 (2.9 %)	
Diarrhea				
	1	271 (69.1 %)	86 (62.8 %)	0.14
	2	80 (20.4 %)	28 (20.4 %)	
	3	41 (10.5 %)	23 (16.8 %)	
Nausea/vomiting				
	1	377 (96.2 %)	133 (97.1 %)	0.59
	2	12 (3.1 %)	4 (2.9 %)	
	3	3 (0.8 %)	0 (0.0 %)	
Periumbilical pain				
	1	370 (94.4 %)	132 (96.4 %)	0.63
	2	19 (4.8 %)	4 (2.9 %)	
	3	3 (0.8 %)	1 (0.7 %)	

Degree of agreement with above symptoms: 1, not agree; 2, relatively agree; 3, very agree

QoL assessed by SF-36

Figure 1 shows the mean scores for 8 health attributes measured by the SF-36 questionnaire given to patients during their preoperative clinic visit and postoperative long-term follow-up period. These 8 domains of health status include: physical functioning, role limitations—physical, role limitations—emotional, bodily pain, general health, vitality, social functioning, and mental health. Significant improvements in the 8 domains of functional health status were revealed among symptomatic cholelithiasis patients and gallbladder polyps patients after SILC during the long-term follow-up period (all $p < 0.05$), and patients with symptomatic cholelithiasis seemed to benefit more from this surgical intervention, especially in reduced bodily pain, physical limitation, and emotional limitations.

Identification of factors associated with patients' satisfaction and recovery outcomes

In the univariate analysis, complete resolution was associated with older age ($p = 0.069$), female gender ($p = 0.005$), higher BMI ($p = 0.008$), education level above tertiary ($p = 0.043$), and longer operative time ($p = 0.022$). Recurrent omphalitis was more common with increased intraoperative blood loss ($p = 0.20$), and longer follow-up periods ($p = 0.077$), whereas frequent diarrhea was more common in B group ($p = 0.019$), younger age ($p = 0.003$), non-smoker ($p = 0.024$), shorter operative time ($p = 0.002$), fewer intraoperative blood loss ($p = 0.061$), and shorter follow-up periods ($p = 0.021$).

In the multivariate logistic regression analysis (Table 4), patients who were of older age ($p = 0.023$) and female gender ($p = 0.020$) had more chance to undergo complete

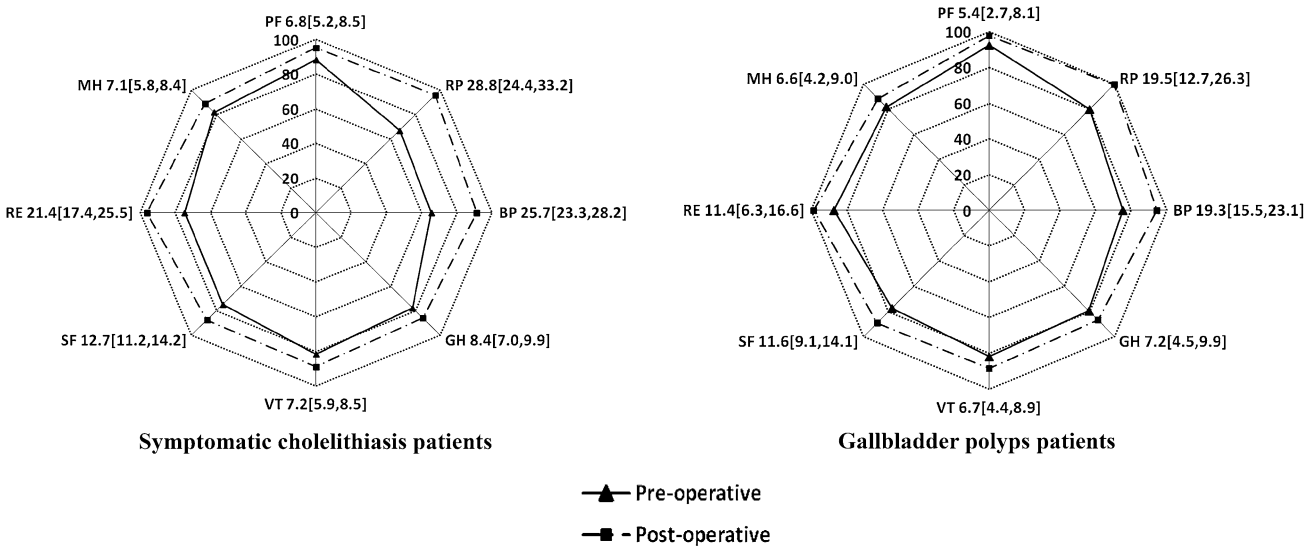

Fig. 1 Mean SF-36 profiles for patients undergoing SILC, preoperatively and postoperatively (variables were presented as mean difference and 95 % CI). Significantly increased 8 health status domains were revealed among patients with symptomatic cholelithiasis and gallbladder polyps during postoperative long-term follow-up period. PF indicates physical functioning; *RP* role limitations—physical, *BP* bodily pain, *GH* general health, *VT* vitality, *SF* social functioning, *RE* role limitations—emotional, and *MH* mental health

Table 4 Multivariate binary logistic regression analysis showing factors associated with patients' recovery outcomes or/and complications after SILC during long-term follow-up period

Factors	Odds ratio	95 % CI	*p*
Complete resolution			
Age (per year increment)	1.022	1.003, 1.040	0.023
Female	1.880	1.104, 3.202	0.020
The Hosmer–Lemeshow χ^2 of this model was 5.470 ($p = 0.706$)			
Recurrent omphalitis			
Intraoperative blood loss (per mL increment)	1.011	1.003, 1.020	0.008
Follow-up period (per month increment)	1.049	1.004, 1.097	0.033
The Hosmer–Lemeshow χ^2 of this model was 9.803 ($p = 0.279$)			
Frequent diarrhea			
Age (per year increment)	0.967	0.944, 0.991	0.008
Smoker (yes)	0.291	0.143, 0.591	0.001
Operative time (per minute increment)	0.973	0.953, 0.992	0.007
Follow-up period (per month increment)	0.967	0.937, 0.997	0.030
The Hosmer–Lemeshow χ^2 of this model was 3.415 ($p = 0.906$)			

resolution. However, patients with increased intraoperative blood loss ($p = 0.008$) and longer follow-up periods ($p = 0.033$) had a relatively higher risk of recurrent omphalitis, whereas younger age ($p = 0.008$), non-smoker ($p = 0.001$), shorter operative time ($p = 0.007$) and shorter follow-up period ($p = 0.030$) were associated with a higher incidence rate of frequent diarrhea. In the multivariate linear regression analysis (Table 5), higher BMI ($p = 0.018$), shorter postoperative hospital stay ($p = 0.024$), shorter follow-up period ($p = 0.007$), no restriction of fatty foods ($p = 0.015$), more cosmetic satisfactions ($p < 0.001$), a lower degree of postoperative right upper quadrant pain ($p = 0.001$), diarrhea ($p < 0.001$), and nausea ($p < 0.001$) remained significantly associated with increased surgical satisfaction. Meanwhile, patients complicated with previous diabetes mellitus ($p = 0.048$), postoperative recurrent omphalitis ($p < 0.001$), and intra-abdominal abscess ($p = 0.039$) tended to score less in cosmesis satisfaction.

Table 5 Multivariate linear regression analysis showing factors related to patients' satisfaction with SILC during long-term follow-up period

Factor	β-coefficient	95 % CI	*p*
Surgical satisfaction			
BMI	0.027	0.005, 0.050	0.018
Postoperative hospital stay (day)	−0.060	−0.11, −0.008	0.024
Follow-up period (month)	−0.011	−0.018, −0.003	0.007
Avoid fatty food (yes)	−0.179	−0.324, −0.035	0.015
Cosmetic satisfaction	0.575	0.492, 0.657	< 0.001
Right upper quadrant pain (degree)	−0.274	−0.432, −0.116	0.001
Diarrhea (degree)	−0.234	−0.363, −0.105	< 0.001
Nausea (degree)	−0.534	−0.826, −0.242	< 0.001
The Anova F of this model was 11.965 ($p < 0.001$)			
Cosmetic satisfaction			
Diabetes mellitus (yes)	−0.281	−0.560, −0.002	0.048
Recurrent omphalitis (yes)	−1.398	−2.023, −0.773	< 0.001
Intra-abdominal abscess (yes)	−1.670	−3.259, −0.081	0.039
The Anova F of this model was 1.924 ($p = 0.004$)			

Discussion

SILC is an alternation of TMLC, which is performed through one single incision via one platform with multiple working channels or via multiple separate ports, and the incision is usually <2.5 cm [23]. SILC achieves a better surgical outcome with less parietal trauma and improved cosmesis, equally as well in decreased incisional pain, faster functional recovery, and shorter hospital stays, with no gain of postoperative complications when compared to TMLC [13, 15, 24, 25]. Ultimately, higher patient satisfaction was revealed, especially for young female individuals and those who cared more about cosmesis. However, the potential disadvantages of SILC are technical difficulty and the costs of instruments [24]. All the instruments enter through a single port, leading to clashing of instruments, which causes a loss of triangulation during operation. Additionally, limited exposure of the surgical field due to instruments in parallel also increases surgical difficulty [26]. But it is controllable with a relatively shorter learning curve for the performing surgeon [21, 27, 28]. Operative costs are higher for SILC procedures, mainly owing to single-port product cost, as related insurance is not provided domestically. A 10-mm trocar and two 5-mm trocars were placed through the same umbilical skin incision with separate fascial punctures; all were traditional and reusable trocars without placing a single-port product, which was cost-effective and feasible. No uncontrollable gas leakage occurred in our cases. It is also convenient in converting to a TMLC or open surgery if the surgeons felt it was unsafe to proceed with SILC.

Current reports about the patients who benefited a lot from SILC were mainly limited in perioperative outcomes; however, many long-term complications, indisposed symptoms, and rehabilitation conditions among most cases would remain undiagnosed. So far, this is the largest case series and first review to evaluate patients' recovery after SILC with the longest follow-up period. The patients had an apparent improvement in QoL assessed by SF-36 during the long-term follow-up period, and patients with symptomatic cholelithiasis seemed to benefit more from this surgical intervention, especially in reduced bodily pain, physical limitation, and emotional limitations.

The advantages of better cosmetic outcomes have been revealed in SILC compared with TMLC during the short-term follow-up [2, 24, 29–31]. Younger patients may tend to demand SILC because of cosmetic concerns [32]. However, it is skeptical when assessing the cosmetic advantages of SILC versus other minimally invasive cholecystectomy in the long-term follow-up, especially when considering the combination of multiple contributing factors, potential observer bias, and variations in patients' expectations, all of which contributes to difficulties in assessing cosmetic outcomes [33]. However, patients complicated with prior diabetic mellitus, postoperative omphalitis, and abdominal abscess may result in less cosmetic satisfaction, ultimately, which would affect patients' surgical satisfaction. It could be reasonably explained by the well-known effect of diabetes mellitus on tissue healing and discomfort condition related to omphalitis and abdominal abscess. Additionally, thin patients usually had difficulty in obscuring the umbilical scars, especially for the patients with a superficial umbilical fossa. It is no wonder higher BMI patients had better surgical satisfaction. A longer postoperative hospital stay might be related to older patients or poor vital signs. We had identified nearly 70 % postoperative patients intended to avoid fatty food, and a number of them were due to dietary habits;

others caused by dyspepsia, diarrhea, abdominal pain, or/and other indispositions after fatty food. Many of them complained about avoiding fatty foods, especially when encountering diarrhea or other indispositions. Male patients and those aged ≤45 years also tended to have low compliance in diet [34]. All these factors would contribute to patients' negative evaluations, in other words, less satisfaction scores to the surgical intervention.

In previously reported follow-up studies, post-cholecystectomy symptoms were present in 12–47 % of patients [35, 36]. We have identified 24.0 % of patients who did not undergo a complete resolution after SILC during the 37-month follow-up. Both morbidity rate of omphalitis (5.9 %) and frequent diarrhea (12.1 %) exceed 5 %, which were most commonly seen among other complications or indispositions (66.4 %). As a result, it was revealed that patients with older age or female gender, who have no systemic disease, might have more chance to recover with little or no postoperatively retained discomforts or complications, and benefited the most from SILC.

The reported rate of umbilical incision infection about SILC ranged from 1 to 14.3 % within the postoperative short-term follow-up [2–5, 10–12, 26, 27, 37–45]. However, we revealed that 5.9 % SILC patients had developed omphalitis due to long-term chronic inflammation in the umbilicus, which may be caused by residual bacterium in the surgical site, even though no apparent surgical site infection was revealed during perioperative period. The SILC patients who were complicated with omphalitis would suffer from wound pus, abscess, periumbilical pain, pruritus, and so on. Both the intraoperative blood loss and the follow-up period were identified as risk factors contributing to omphalitis. The main reason might be explained as the non-common use of protection bags when SILC was initially performed in our hospital. The other reason might be the high degree of gallbladder inflammation (which increased the surgical difficulties, especially in older patients who tended to endure long-term cholecystitis; ultimately, it might encounter with higher intraoperative blood loss). Both may result in pollution of the sterile incision, especially gallbladder ruptured while it was removed via the umbilical incision. The ability of natural defences to infection for the reconstructed umbilicus maybe also weaker than before, and long-time cumulative dirt in the umbilical fossa is a risk factor for omphalitis if no umbilical nursing was performed. As a matter of fact, deep umbilical fossa for high-BMI patients, especially in summer, may also increase surgical site infection. The common pathogens contributed to wound contamination are Escherichia coli, Klebsiell spp., and Streptococcus spp. [46]. However, the effects of a prophylactic antibiotic in prevention of surgical site infection are being questioned [47]. It is important for the doctors and nurses to take care in preoperative umbilical nursing, careful control of blood sugar, intraoperative protection of the umbilical incision using an end catch bag, and postoperative surgical site nursing.

Diarrhea in many post-cholecystectomy is multifactorial in origin [48]. The basic reasons for post-cholecystectomy diarrhea may be associated with, firstly, the malabsorption of bile acid [49–51], which would increase bile acid presenting to the large bowel [52], and secondly, shortening of the gut transit time by accelerating passage through the colon [53]. However, older age, smoking, longer operative time, and follow-up period were identified as protection factors in frequent diarrhea. Patients with gallbladder polyps also tended to complain more about frequent diarrhea. Fisher et al. [54] also pointed out that post-laparoscopic cholecystectomy diarrhea was independently associated with younger age, especially an age <50 years, and postoperative food intolerance, which might be explained as long-term disfunction of gallbladder in absorption and contraction, especially in older patients who complicated with longer term of severe cholelithiasis, whose bowel function might have gradually adapted malabsorption of bile acid, including increased ability of liquid recycling and alternation of transit time presenting to the large bowel. Meanwhile, male patients and those aged ≤45 years tended to have a low compliance [34] with low-fat foods, since cholecystectomy may decrease bowel tolerance toward fatty foods. What is more, nicotine receptors are abundantly present on colonic intrinsic and extrinsic nerves and in pre- and paravertebral ganglia. The lower risk rate of post-cholecystectomy diarrhea in smokers may be related to the effects of nicotine on colonic motility [55]. Smoking tobacco also suppresses appetite, which may be related to endogenous cholinergic control of hypothalamic circuits involved in food intake mediated by the nicotinic receptor [56]. It also benefits the bowel tolerance with less fatty food intake during the postoperative period. However, Fort et al. [53] found that cholecystectomy shortens the gut transit time by accelerating passage through the colon and that these sequelae develop early and persist for at least 4 years after cholecystectomy. In fact, the post-cholecystectomy diarrhea continued to decrease with time during long-term follow-up. Calculi and/or polyp removal with gallbladder preservation through minimally invasive surgery seemed to be an alternative choice for the patients if normal function of the gallbladder was diagnosed, which might greatly decrease the risk of diarrhea with the gallbladder function well preserved [57].

Umbilical hernia was rare, but it might result in serious complications. Small bowel incarceration, obstruction, and ischemia may develop, which requires an urgent laparotomy and sometimes a small bowel resection [58]. A multivariate analysis revealed that fascial incision

enlargement, wound infection, diabetes mellitus, and obesity contributed to the risk of developing a trocar site incisional hernia [59]. Uslu et al. [58] also identified that an age >60 years was a significant risk factor since older people usually have weaker fascia and a less muscular abdominal wall. However, no fascial repairs of the umbilical trocar site were performed in this study, which might inevitably increase the hernia rate. This association is related to the weaker anatomic region of the midline of the abdomen combined with the larger diameter of the incision at that level, since frequently fascia dilations were needed to extract the specimen. So, prosthetic closure of the umbilical trocar site after laparoscopic surgery could become the standard method for preventing umbilical hernia in high-risk patients [60]. As reported, a larger transumbilical incision was more likely to increase the incidence of incisional hernias [16, 61–63]. The reported hernia rate ranged from 0.9 to 4.8 % for SILC, but higher incidence might be identified when performed through single-port product [2, 3, 26, 29, 38, 44, 45, 64] than SILC through three traditional ports [40, 65–67]. As a matter of fact, the umbilical hernia rate was 0.2 % in our long-term review, which was much lower than current reported rates. It is reasonable that the fascial incision was much shorter when SILC was performed via fascial puncture with traditional trocars in the umbilical incision, but an 1.5- to 2-cm fasciotomy would be created to insert the single-port product, which carries potential for hernia development and needs fascial suturing. Moreover, it is much easier for the surgeons to close all planes of an umbilical fascial incision within the enlarged skin wound in SILC. No wonder some authors had claimed that SILC bares the benefit of "lessening the risk of an incisional hernia" [26], and SILC performed via three traditional ports seemed to benefit the most.

The rate of retained bile duct stone identified during postoperative period ranged from 0 to 4.76 % among recent SILC studies [2, 26, 27, 31, 32, 38, 39, 65, 68], but with no long-term follow-up which might lead to under-reporting of unsuspected stones. Three patients were complicated with CBDS during our long-term review with an incidence rate of 0.8 % among the cholelithiasis patients, 2 were discovered 2 years later after surgery, and 1 was 1 year later. No definite association was identified for the CBDS originating from a retained stone in SILC patients. It also has not been proved that anterograde [27, 38, 39, 65, 68] procedure excels retrograde [31] procedure, in prevention of retained CBDS during a surgical procedure in SILC. It is still controversial if routine intraoperative cholangiography is necessary, since the incidence of retained CBDS is minimal [69].

Our follow-up results suggest that SILC, via fascial puncture with traditional trocars in the umbilical incision, is feasible and safe with acceptable incidence rate of postoperative complications in the long run. SILC provides an alternative to minimally invasive surgery, though not as profound as the application of TMLC which has transformed traditional open surgery to minimal invasion. Indeed, SILC favors the patients who take cosmetic result into account. However, not many surgeons believe that SILC can replace TMLC as the standard procedure for gallbladder surgery [70]. The main limitation for widespread promotion of SILC is technically challenging, such as limited triangulation and freedom of movements of instruments [71–73], and the critical view of the surgical field. The severity of intra-abdominal adhesions should be assessed at the time of surgery with regard to feasibility and safety of SILC [40]. In high-risk patients, surgical safety must be the primary concern rather than the cosmetic result, making TMLC more appropriate. Proper surgical devices may ease surgical performance in SILC, and long-term benefits are expected.

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Compliance with ethical standards

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