World J Surg (2017) 41:1246–1253
DOI 10.1007/s00268-016-3799-0

ORIGINAL SCIENTIFIC REPORT

A Comparative Study of Outcomes Between Single-Site Robotic and Multi-port Laparoscopic Cholecystectomy: An Experience from a Tertiary Care Center

Banujan Balachandran[1] · Theadore A. Hufford[2] · Taha Mustafa[1] · Kunal Kochar[1] · Suela Sulo[3] · Joubin Khorsand[4]

Published online: 5 January 2017

Abstract

Background The aim of this study was to compare the outcomes of single-site robotic cholecystectomy with multi-port laparoscopic cholecystectomy within a high-volume tertiary health care center.

Methods A retrospective analysis of prospectively maintained data was conducted on patients undergoing single-site robotic cholecystectomy or multi-port laparoscopic cholecystectomy between October 2011 and July 2014. A single surgeon performed all the surgeries included in the study.

Results A total of 678 cholecystectomies were performed. Of these, 415 (61%) were single-site robotic cholecystectomies and 263 (39%) were multi-port laparoscopic cholecystectomies. Laparoscopic patients had a greater mean BMI (30.5 vs. 29.0 kg/m^2; $p = 0.008$), were more likely to have undergone prior abdominal surgery (83.3 vs. 41.4%; $p < 0.001$) and had a higher incidence of preexisting comorbidities (76.1 vs. 67.2%; $p = 0.014$) as compared to the robotic group. There was no statistical difference in the total operative time, rate of conversion to open procedure and mean length of follow-up between the two groups. The mean length of hospital stay was shorter for patients within the robotic group (1.9 vs. 2.4 days; $p = 0.012$). Single-site robotic cholecystectomy was associated with a higher rate of wound infection (3.9 vs. 1.1%; $p = 0.037$) and incisional hernia (6.5 vs. 1.9%; $p = 0.006$).

Conclusion Multi-port laparoscopic cholecystectomy should remain the gold standard therapy for gallbladder disease. Single-site robotic cholecystectomy is an effective alternative procedure for uncomplicated benign gallbladder disease in properly selected patients. This must be carefully balanced against a high rate of surgical site infection and incisional hernia, and patients should be informed of these risks.

✉ Joubin Khorsand
sentinelnode1@yahoo.com

[1] Division of Colon and Rectal Surgery, Advocate Lutheran General Hospital, Park Ridge, IL, USA

[2] University of Illinois Metropolitan Group General Surgery Residency, Advocate Lutheran General Hospital, Park Ridge, IL, USA

[3] Russell Institute for Research and Innovation, Advocate Lutheran General Hospital, Park Ridge, IL, USA

[4] Division of General Surgery, Advocate Lutheran General Hospital, 1775 Dempster Street, Park Ridge, IL, USA

Introduction

When first introduced in 1985 as a viable replacement for open cholecystectomy [1], multi-port laparoscopic cholecystectomy (LC) was met with questions of technical feasibility and effectiveness. With improving skill set and comfort of use by surgeons, the technique soon evolved to become the gold standard for the treatment of symptomatic gallbladder disease. Now those same questions and concerns plague the introduction of a newer technology, single-site robotic cholecystectomy (SSRC), the premise of

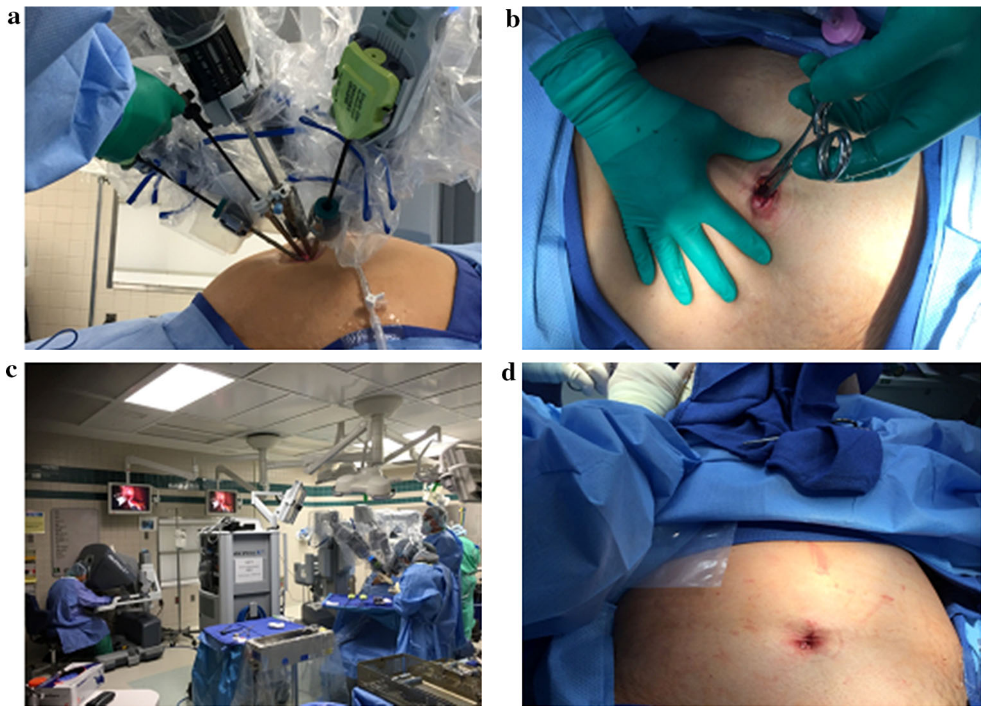

Fig. 1 Single-site robotic cholecystectomy. **a** Multichannel single port with assistant port (*green*) in the middle. **b** Showing fascial defect. **c** Surgeon sitting on the console and performing the operation. **d** Wound after skin closure

which is to further improve upon the advantages of minimally invasive surgery of the gallbladder [2].

While laparoscopic surgery can be done via a single site, multiple problems including instrument clashing within the port, reduced triangulation and poor surgical ergonomics have negated its prevalent use in teaching hospitals [3, 4]. SSRC offers a way to offset the limitations of single-site laparoscopic cholecystectomy (SSLC) by reducing tremor, restoring good hand–eye coordination and the ability to perform very small movements [5–8], while also maintaining the benefits of single-port operations which include improved cosmesis and quicker healing times for the patient [9]. SSRC has also been shown to decrease pain, blood loss, minimize scarring, provide greater patient satisfaction, while allowing the surgeon to work in a more ergonomically advantageous workstation [10].

Very few studies have looked at the perioperative and postoperative outcomes of this procedure in comparison with the LC. In addition, even fewer studies have looked at long-term postoperative outcomes of patients undergoing these procedures or have small sample sizes. Our study aims to investigate the outcomes of SSRC as compared to LC, all evaluated through a single surgeon's experience at a high-volume tertiary health care center.

Patients and methods

A retrospective analysis of a prospectively maintained data at a tertiary care center was performed on cases performed between October 2011 and July 2014. All cases undergoing SSRC or LC for symptomatic gallbladder disease were included. Open cholecystectomies, cholecystectomies terminated for anesthesia complications, and patients who underwent surgery simultaneously for other indications (i.e., appendicitis) were excluded from this study. Data collected include patient demographics [age, gender, body mass index (BMI)], necessity of surgery (elective vs. urgent), preoperative diagnosis, American Society of Anesthesiologists (ASA) classification and any history of prior abdominal surgeries. A comprehensive list of all operative data including intraoperative complications (i.e., bile duct injury or spillage), conversion rate to laparoscopic or open surgery, requirement for the utilization of additional ports, total surgery time (incision to skin closure), robotic console time and docking time was also documented. Finally, postoperative information including length of stay, follow-up, visits to the emergency department (ED) within 30 days, any immediate postoperative complications as defined as those recognized within 30 days, and long-term complications were recorded.

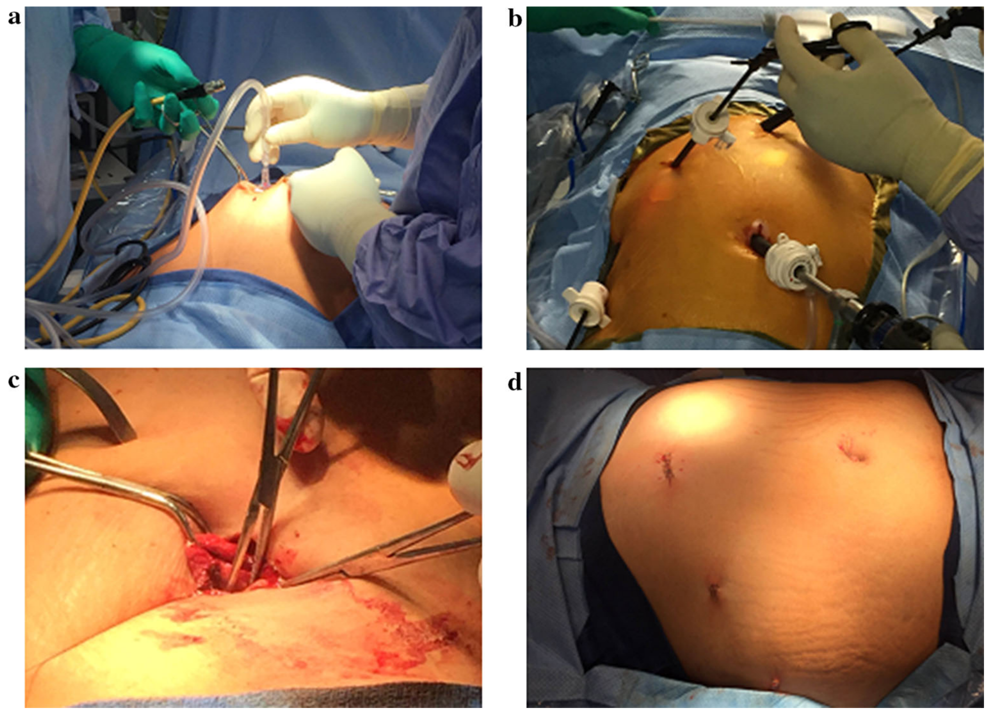

Fig. 2 Multi-port laparoscopic cholecystectomy. **a** Induction of pneumoperitoneum with Veress needle. **b** Standard four ports used. **c** Incision of the fascia for entry into the abdomen. **d** Wound after skin closure of all four ports

Postoperative complications included wound infection, incisional hernia, seroma formation, clear leakage, etc. Abdominal pain was defined as any complaint of continued pain that had not improved at the follow-up visit as documented by the primary surgeon in the EMR.

Surgical technique

Single-site robotic cholecystectomy

A 2-cm incision was made at the umbilicus followed by a 2-cm incision within the fascia. A multichannel silicon port was placed at the umbilicus. Pneumoperitoneum was established up to 14 mmHg. A diagnostic laparoscopy was performed. The robot was then docked starting with the camera port in the middle followed by 2 working arms 1 and 2 on the sides of the camera port through the same silicon port. Dissection was then carried out in Calot's triangle, and after obtaining, the critical view of safety the cystic artery and cystic duct was identified, clipped and divided. The gallbladder was then dissected from the gallbladder fossa by electrocautery. The gallbladder was then removed through the umbilical site using a specimen retrieval bag. The fascia of the umbilical site was then closed with 0-Vicryl suture in an interrupted figure of eight fashion. The skin was closed with a 4-0 Monocryl suture in a sub-cuticular fashion (Fig. 1).

Multi-port laparoscopic cholecystectomy (4 ports were used)

A 5-mm incision was made at the umbilicus, and pneumoperitoneum was established using a Veress needle. A 5-mm trocar was then placed using a Visiport, and diagnostic laparoscopy was performed. An 11-mm port was then placed at the sub-xiphoid region followed by two more 5 mm ports: one at the subcostal region and another in the anterior axillary line, in line with the umbilicus for retraction. Steps of dissection of Calot's triangle were the same as in robotic surgery. Specimen was then removed from the sub-xiphoid port in a specimen retrieval bag. Umbilical and sub-xiphoid ports were closed with size 1-Vicryl suture in a figure of eight fashion (Fig. 2).

Statistical analysis

All results were analyzed using SPSS software, version 23.0. The Chi-square test or Fisher's exact test was employed to compare both single-site robotic cholecystectomy and multi-port laparoscopic cholecystectomy groups for categorical data, while Student's *t* test was used

Table 1 Preoperative data

Characteristics[a]	All cholecystectomies[b,c] ($n = 678$)	Single-site robotic ($n = 415$)	Multi-port laparoscopic[c] ($n = 263$)	p value
Age, mean (SD) [range]	54.8 (±18.6) [16.9–100.1]	54.1 (±18.7) [18.0–100.1]	55.8 (±18.4) [16.9–94.5]	0.234
Gender (%)				0.004
Male	209 (30.8)	111 (26.7)	98 (37.3)	
Female	469 (69.2)	304 (73.3)	165 (62.7)	
BMI (kg/m^2), mean (SD) [range]	29.6 (±6.9) [13.7–61.7]	29.0 (±6.1) [13.7–53.3]	30.5 (±7.8) [17.0–61.7]	0.008
ASA classification %				0.298
I	21.0	21.5	20.4	0.815
II	51.9	54.8	47.8	0.151
III	25.1	21.8	29.6	0.076
V	2.0	1.9	2.2	1.000
Comorbidities (%)	479 (70.6)	279 (67.2)	200 (76.1)	0.014
Hypertension	256 (37.8)	146 (35.2)	110 (41.8)	0.082
Hyperlipidemia	162 (23.4)	100 (24.1)	62 (23.6)	0.877
Diabetes mellitus	112 (16.5)	61 (14.9)	51 (19.4)	0.109
GERD	82 (12.1)	47 (11.3)	35 (13.3)	0.440
Hypothyroidism	54 (8.0)	35 (8.4)	19 (7.2)	0.571
Coronary artery disease	44 (6.5)	20 (4.9)	24 (9.1)	0.027
Asthma	27 (4.0)	20 (4.9)	7 (2.7)	0.162
COPD	16 (2.4)	6 (1.5)	10 (3.8)	0.049
Previous abdominal surgery (%)	391 (57.7)	172 (41.4)	219 (83.3)	<0.001
Diagnosis (%)				<0.001
Acute cholecystitis	173 (25.5)	76 (18.3)	97 (36.9)	
Chronic cholecystitis	505 (74.5)	339 (81.7)	166 (63.1)	

[a] Any missing data were not included in the calculations

[b] Not including 13 cases elected to proceed as open cholecystectomy prior to surgery

[c] Not including 1 case because patient could not tolerate anesthesia, and procedure was terminated before beginning

to compare continuous data. A p value of 0.05 was established as clinical significance.

Results

A total of 678 cholecystectomies were performed between October 2011 and July 2014, of which, 415 (61%) were SSRC and 263 (39%) were LC (Table 1). All were performed for symptomatic gallbladder disease. The age range of all patients was 16–100, but there was no difference in the mean age seen between the two groups (54.1 vs. 55.8 years; $p =$ NS). Both groups showed a higher percentage of females than males; however, this distinction was statistically different in the SSRC group ($p = 0.004$). LC patients had a greater mean BMI (30.5 vs. 29.0 kg/m^2; $p = 0.008$) and were more likely to have undergone prior abdominal surgery (83.3 vs. 41.4%; $p < 0.001$). There was no statistical difference in the American Society of Anesthesiologists (ASA) classification between the two groups (Table 1).

Overall, the percentage of patients with preexisting comorbidities was higher in the LC group (76.1 vs. 67.2%; $p = 0.014$). Further analysis revealed only coronary artery disease (9.1 vs. 4.9%; $p = 0.027$) and chronic obstructive pulmonary disease (3.8 vs. 1.5%; $p = 0.049$) to be statistically significant between the two groups. Pathology of biliary disease was also considered and investigated. Patients with acute cholecystitis were more likely to have undergone LC as compared to SSRC (36.9 vs. 18.3%; $p = 0.001$); however, this was based on intraoperative evaluation and postoperative pathology results and was not used in the decision-making process regarding which procedure each individual patient should undergo (Table 1).

The total operative times between the two groups did not vary significantly. The mean console time was 57 min,

Table 2 Perioperative data

Characteristics[a]	All cholecystectomies[b,c] ($n = 678$)	Single-site robotic ($n = 415$)	Multi-port laparoscopic[c] ($n = 263$)	p value
Total operative time (min), mean (SD) [range]	90.7 (±29.5) [36–265]	89.4 (±27.8) [36–265]	92.6 (±31.9) [41–257]	0.169
Robotic (console) time (min), mean (SD) [range]	57 (±14.7) [23–155]	57 (±14.7) [23–155]	–	
Docking time (min), mean (SD) [range]	6.8 (±5.2) [0–55]	6.8 (±5.2) [0–55]	–	
Mean estimated blood loss	Minimal	Minimal	Minimal	
Use of intraoperative cholangiogram (%)	1	0	1	
Use of additional ports (%)[d]	2	0	2	
Intraoperative complications (bile duct injury/spillage)	0	0	0	
Conversion (%)	38 (5.6)	25 (6.1)	13 (4.9)	0.551
To laparoscopic procedure	12 (1.8)	12 (2.9)	–	
To open procedure	26 (3.8)	13 (3.2)	13 (4.9)	0.232

[a] Any missing data were not included in the calculations

[b] Not including 13 cases elected to proceed as open cholecystectomy prior to surgery

[c] Not including 1 case because patient could not tolerate anesthesia, and procedure was terminated before beginning

[d] Not including cases where multiple ports were decided upon before beginning procedures

and the mean docking time was 6.8 min (Table 2). Estimated blood loss was reported as negligible in all cases with no cases requiring any blood transfusions. No intraoperative complications were reported. Twenty-five (6.1%) procedures in the SSRC group had to be converted for completion with twelve (2.9%) being converted to LC and thirteen (3.2%) converted to open procedures. The total rate of LC conversion or open conversion between the two groups was not statistically significant (6.1 vs. 4.9%; $p = 0.551$) (Table 2). Reasons for conversion included but were not limited to, body habitus limiting the use of robotic instrument length, adhesions, inability to define anatomy or achieve critical view, lack of plane or area for traction, inability to identify the gallbladder, inadequate visualization of vascular structures, or a general concern for patient safety as deemed necessary by the surgeon.

Table 3 highlights the postoperative data from the two procedures. Mean length of follow-up was 2.5 months in the SSRC group and 3.3 months in the LC group ($p = 0.12$). Two cases of postoperative bile leak within the laparoscopic group and one in the robotic group were seen at follow-up. All cases were managed by ERCP and stenting. The average length of stay following the procedure was lower for patients undergoing SSRC (1.9 vs. 2.4 days; $p = 0.012$). Neither the frequency of 30-day postoperative visits to the emergency room or readmission rates in this time period varied significantly within the two groups. Major postoperative complications documented during follow-up at the surgeon's office or at the tertiary care center in the short term included abdominal pain, post-op ileus, urinary retention, wound infection/non-infectious complications, non-purulent or clear wound discharge, seroma formation, or bile leakages. Abdominal pain (8.4 vs. 4.2%; $p = 0.032$) and wound infections (3.9 vs. 1.1%; $p = 0.037$) were seen more commonly in SSRC group, while all others showed no significant differences. At the time of last follow-up, the rate of incisional hernias was higher in SSRC group as compared to LC group (6.5 vs 1.9%; $p = 0.006$).

Discussion

Gallbladder disease continues to be one of the most common medical problems leading to surgical intervention [11]. With over 0.5 million new cholecystectomies being performed within the US each year [11], gallbladder disorders have often been an ideal arena to test and compare new and innovative surgical techniques with current routine practices. All procedures included within this study period were performed by a single experienced surgeon.

Significant differences were noted in patient characteristics prior to undergoing their respective procedures. Both groups comprised of older adults, but the single-site robotic group did have a higher percentage of females. Reasons for this could be attributed to the better aesthetic appeal the robotic platform offers in terms of postoperative cosmesis compared to multi-port laparoscopic cholecystectomy [9]. Patients undergoing LC also typically had a higher BMI, which was not surprising as one of the reasons cited by the

Table 3 Postoperative data

Characteristics[a]	All cholecystectomies[b,c] ($n = 678$)	Single-site robotic ($n = 415$)	Multi-port laparoscopic[c] ($n = 263$)	p value
Length of stay (days), mean (SD) [range]	2.1 (±2.8) [0.2–33]	1.9 (±3.1) [0.24–33]	2.4 (±2.3) [0.2–13.2]	0.012
30-day post-op visits to ER (%)	52 (7.7)	38 (9.2)	14 (5.3)	0.068
Readmission (%)	17 (2.5)	13 (3.1)	4 (1.5)	0.191
Immediate post-op complications				
Abdominal pain (%)	46 (6.8)	35 (8.4)	11 (4.2)	0.032
Post-op ileus (%)	6 (0.9)	4 (1.0)	2 (0.8)	1.000
Urinary retention (%)	5 (0.7)	4 (1.0)	1 (0.4)	0.654
Wound infection (%)	19 (2.8)	16 (3.9)	3 (1.1)	0.037
Wound discharge (%)	11 (1.6)	7 (1.7)	4 (1.5)	0.868
Granuloma formation (%)	5 (0.7)	3 (0.7)	2 (0.8)	1.000
Seroma formation	3 (0.4)	3 (0.7)	0 (0)	0.287
Bile leakage	3 (0.4)	1 (0.2)	2 (0.8)	0.563
Delayed post-op complications				
Umbilical incisional hernias (%)	32 (4.7)	27 (6.5)	5 (1.9)	0.006
Follow-up (months), mean (SD) [range]	2.8 (±6.1) [0.1–44.0]	2.5 (±5.1) [0.16–35.77]	3.3 (±7.5) [0.1–44.0]	0.12

[a] Any missing data were not included in the calculations

[b] Not including 13 cases elected to proceed as open cholecystectomy prior to surgery

[c] Not including 1 case because patient could not tolerate anesthesia, and procedure was terminated before beginning

surgeon for conversions or the use of additional ports was due to the patient's body habitus and the limitation of the robotic instruments. Since ASA classification as a stand-alone has been shown as insufficient evidence to describe the physical condition of patients [12] and has a high degree of variability between observers [13–16], we further investigated specific comorbidities in both groups. This sub-analysis showed that a greater percentage of patients within the LC group had preexisting conditions and that both coronary artery disease and chronic obstructive pulmonary disease were significantly more common than within the SSRC group. Factors that have at times included morbid obesity, previous abdominal surgery, acute cholecystitis and a history of severe pulmonary or cardiac diseases were once considered relative contraindications to laparoscopic procedures [17–20].

The total operative time did not vary significantly between the two groups. Though we did not specifically compare pure surgical dissection times, the average console time was 57 min, in line with the high degree of precision achieved in tissue dissection with the robotic platform. This is quite comparable to a study recently published where console time was 52.8 min [21]. The conversion rates in our series are similar to reported conversion rates for LC [22, 23].

While a prior comparative study did not show any statistically significant difference in the length of postoperative stay [21], our study showed an increased length of stay in the LC group, explained by the presence of more emergent cases and patients with more comorbidities in this group. In our series, abdominal pain was more frequently reported in SSRC group which is in sharp contrast to some studies comparing single-port procedures to multi-port procedures [24–27]. Another study has actually shown increased postoperative pain following single-incision laparoscopic cholecystectomy when compared to multi-port laparoscopic cholecystectomy [28]. It is reasonable to assume that the larger incision, continuous movements of instruments within a confined space and higher pressure around the umbilical port may contribute to the increased intensity of postoperative pain in the SSRC group. Since postoperative pain after LC is already minimal and no objective pain measuring scale was used in our study, a potential reporting bias in the SSRC group can also not be excluded. While pain can often be a subjective measure [29], all patients in this study were discharged on a standard medication regimen for pain similar to that used in other settings from other studies.

Another finding of significance was the incidence of wound infections. Since operative characteristics were controlled with the same surgeon having performed the procedures in both groups, other risk factors for wound infection were examined including diabetes, cigarette smoking, obesity, or patient colonization [12]. None of these factors were found to be significant. Furthermore, among patients diagnosed with wound infections, no differences were seen in the mean BMI between the robotic or laparoscopic groups.

Finally, the most significant finding of this study was a high rate of incisional hernia in the SSRC group. Twenty-seven patients (6.5%) were diagnosed with umbilical incisional hernias after having undergone SSRC as opposed to five patients (1.9%) in the LC group. The surgical technique and suture used for port site closure were similar in all cases. On subgroup analysis, the rate of incisional hernia did not vary significantly between the first hundred, second hundred, third hundred and subsequent remaining cases (7, 7, 6, 7; $p = 0.984$). This would suggest that the learning curve and surgical technique were likely not the cause of incisional hernia. No statistically significant differences were seen in the mean BMI of patients diagnosed with hernia after undergoing robotic or laparoscopic procedures. Of the five hernia cases found within the laparoscopic group, one patient had undergone 4 abdominal surgical procedures prior to their laparoscopic cholecystectomy; another patient had a previous history of multiple ventral hernia repairs prior to their laparoscopic cholecystectomy; another patient was a case that had been converted to open procedure; and finally another one of the patients had undergone colon resection for myxoma of the appendix, which had been completed robotically via single-incision prior to the laparoscopic cholecystectomy. This then leaves only one patient (0.4%) who had been diagnosed with incisional hernia postoperation, where the procedure was the likely cause of the defect. While all hernias diagnosed within the robotic group were hernias occurring within the umbilicus, excluding cases with any form of previous abdominal surgery (even those not including the umbilicus in the surgical field, i.e., Pfannenstiel incision), the data still reflects a greater incidence of hernia in the SSRC group than in LC arm (2.9 vs. 0.4%; $p = 0.020$).

Previous studies looking at SSLC versus LC have reported higher rates of surgical site infection (4.0 vs. 1.6%) and incisional hernia (2.2–5.8 vs. 0.3–1.8%) in the SSLC group [30–34]. The higher rate of incisional hernia in SSLC has been ascribed to local ischemia induced by placement of a single large port or multiple ports at a single site, which could potentially weaken the fascia [30]. Similarly, potential ischemia combined with the fact that the fascial incision for SSRC represents a 400% increase in the length of incision as compared to LC (20 vs. 5 mm) could contribute to the higher incidence of wound infection and subsequent incisional hernia following SSRC.

The major limitation of this study is the fact it was nonrandomized and retrospective in nature. The preoperative data were also not exactly comparable between the two groups with BMI, comorbidities, prior abdominal surgery, and more urgent cases being skewed in a manner producing more unfavorable cases within the LC group.

Decreased incisional hernia and wound infection incidence make it seem that LC should continue to remain the gold standard for treating gallbladder disease. If balanced against the higher rate of postoperative complications, SSRC is an effective alternative in uncomplicated benign gallbladder disease.

Acknowledgments The authors would like to acknowledge Dr. John J. Park MD, Associate Program Director of Minimally Invasive Colon and Rectal Surgery Fellowship at Advocate Lutheran General Hospital for editing the manuscript and his mentorship throughout the study. We would also like to thank the efforts of Mrs. Olympia Katsabanis for her logistical support throughout the data collection and manuscript preparation process.

Compliance with ethical standards

Conflict of interest Mr. Balachandran, Dr. Hufford, Dr. Mustafa, Dr. Kochar, Dr. Sulo and Dr. Khorsand have no conflicts of interest or financial ties to disclose.

References

1. Reynolds W Jr (2001) The first laparoscopic cholecystectomy. J Soc Laparoendosc Surg 5:89–94
2. Curcillo PG 2nd, Wu AS, Podolsky ER, Graybeal C, Katkhouda N, Saenz A, Dunham R, Fendley S, Neff M, Copper C, Bessler M, Gumbs AA, Norton M, Iannelli A, Mason R, Moazzez A, Cohen L, Mouhlas A, Poor A (2010) Single-port-access (SPA) cholecystectomy: a multi-institutional report of the first 297 cases. Surg Endosc 24:1854–1860
3. Mutter D, Callari C, Diana M, Dallemagne B, Leroy J, Marescaux J (2011) Single port laparoscopic cholecystectomy: which technique, which surgeon, for which patient? A study of the implementation in a teaching hospital. J Hepato-Biliary-Pancreat Sci 18:453–457
4. Prasad A, Mukherjee KA, Kaul S, Kaur M (2011) Postoperative pain after cholecystectomy: conventional laparoscopy versus single-incision laparoscopic surgery. J Minim Access Surg 7:24–27
5. Wren SM, Curet MJ (2011) Single-port robotic cholecystectomy: results from a first human use clinical study of the new da Vinci single-site surgical platform. Arch Surg 146:1122–1127
6. Allemann P, Leroy J, Asakuma M, Al Abeidi F, Dallemagne B, Marescaux J (2010) Robotics may overcome technical limitations of single-trocar surgery: an experimental prospective study of Nissen fundoplication. Arch Surg 145:267–271
7. Pietrabissa A, Sbrana F, Morelli L, Badessi F, Pugliese L, Vinci A, Klersy C, Spinoglio G (2012) Overcoming the challenges of single-incision cholecystectomy with robotic single-site technology. Arch Surg 147:709–714
8. Miller DW, Schlinkert RT, Schlinkert DK (2004) Robot-assisted laparoscopic cholecystectomy: initial Mayo clinic Scottsdale experience. Mayo Clin Proc 79:1132–1136
9. Ross SB, Sawangkum P, de La Vega KA, Teta A, Luberice K, Rosemurgy AS (2013) Single-site robotic cholecystectomy (SSRC): an initial review of safety and feasibility. Minerva Chir 68:435–443

10. Lanfranco AR, Castellanos AE, Desai JP, Meyers WC (2004) Robotic surgery: a current perspective. Ann Surg 239:14–21
11. Schirmer BD, Winters KL, Edlich RF (2005) Cholelithiasis and cholecystitis. J Long Term Eff Med Implants 15:329–338
12. Owens WD, Felts JA, Spitznagel EL Jr (1978) ASA physical status classifications: a study of consistency of ratings. Anesthesiology 49:239–243
13. Mak PH, Campbell RC, Irwin MG, American Society of Anesthesiologists (2002) The ASA physical status classification: inter-observer consistency. Anaesth Intensive Care 30:633–640
14. Aronson WL, McAuliffe MS, Miller K (2003) Variability in the American Society of Anesthesiologists Physical Status Classification Scale. AANA J 71:265–274
15. Riley R, Holman C, Fletcher D (2014) Inter-rater reliability of the ASA physical status classification in a sample of anaesthetists in Western Australia. Anaesth Intensive Care 42:614–618
16. Haynes SR, Lawler PG (1995) An assessment of the consistency of ASA physical status classification allocation. Anaesthesia 50:195–199
17. Srivastava A, Niranjan A (2010) Secrets of safe laparoscopic surgery: anaesthetic and surgical considerations. J Minim Access Surg 6:91–94
18. Kama NA, Kologlu M, Doganay M, Reis E, Atli M, Dolapci M (2001) A risk score for conversion from laparoscopic to open cholecystectomy. Am J Surg 181:520–525
19. Frazee RC, Roberts JW, Symmonds R, Snyder SK, Hendricks J, Smith R, Custer MD (1992) What are the contraindications for laparoscopic cholecystectomy? Am J Surg 164:491–494 **(discussion 494–495)**
20. Alponat A, Kum CK, Koh BC, Rajnakova A, Goh PM (1997) Predictive factors for conversion of laparoscopic cholecystectomy. World J Surg 21:629–633. doi:10.1007/PL00012288
21. Chung PJ, Huang R, Policastro L, Lee R, Schwartzman A, Alfonso A, Sugiyama G (2015) Single-site robotic cholecystectomy at an inner-city academic center. J Soc Laparoendosc Surg 19(3):e2015.00033
22. Livingston EH, Rege RV (2004) A nationwide study of conversion from laparoscopic to open cholecystectomy. Am J Surg 188:205–211
23. Sakpal SV, Bindra SS, Chamberlain RS (2010) Laparoscopic cholecystectomy conversion rates two decades later. J Soc Laparoendosc Surg 14:476–483
24. Madureira FA, Manso JE, Madureira Fo D, Iglesias AC (2013) Randomized clinical study for assessment of incision characteristics and pain associated with LESS versus laparoscopic cholecystectomy. Surg Endosc 27:1009–1015
25. Asakuma M, Hayashi M, Komeda K, Shimizu T, Hirokawa F, Miyamoto Y, Okuda J, Tanigawa N (2011) Impact of single-port cholecystectomy on postoperative pain. Br J Surg 98:991–995
26. Tsimoyiannis EC, Tsimogiannis KE, Pappas-Gogos G, Farantos C, Benetatos N, Mavridou P, Manataki A (2010) Different pain scores in single transumbilical incision laparoscopic cholecystectomy versus classic laparoscopic cholecystectomy: a randomized controlled trial. Surg Endosc 24:1842–1848
27. Wong JS, Cheung YS, Fong KW, Chong CC, Lee KF, Wong J, Lai PB (2012) Comparison of postoperative pain between single-incision laparoscopic cholecystectomy and conventional laparoscopic cholecystectomy: prospective case-control study. Surg Laparosc Endosc Percutan Tech 22:25–28
28. Phillips MS, Marks JM, Roberts K, Tacchino R, Onders R, DeNoto G, Rivas H, Islam A, Soper N, Gecelter G, Rubach E, Paraskeva P, Shah S (2012) Intermediate results of a prospective randomized controlled trial of traditional four-port laparoscopic cholecystectomy versus single-incision laparoscopic cholecystectomy. Surg Endosc 26:1296–1303
29. Breivik H, Borchgrevink PC, Allen SM, Rosseland LA, Romundstad L, Hals EK, Kvarstein G, Stubhaug A (2008) Assessment of pain. Br J Anaesth 101:17–24
30. Pisanu A, Reccia I, Porceddu G, Uccheddu A (2012) Meta-analysis of prospective randomized studies comparing single-incision laparoscopic cholecystectomy (SILC) and conventional multiport laparoscopic cholecystectomy (CMLC). J Gastrointest Surg 16:1790–1801
31. Agaba EA, Rainville H, Ikedilo O, Vemulapali P (2014) Incidence of port-site incisional hernia after single-incision laparoscopic surgery. J Soc Laparoendosc Surg 18:204–210
32. Alptekin H, Yilmaz H, Acar F, Kafali ME, Sahin M (2012) Incisional hernia rate may increase after single-port cholecystectomy. J Laparoendosc Adv Surg Tech A 22:731–737
33. Bunting DM (2010) Port-site hernia following laparoscopic cholecystectomy. J Soc Laparoendosc Surg 14:490–497
34. Marks JM, Phillips MS, Tacchino R, Roberts K, Onders R, DeNoto G, Gecelter G, Rubach E, Rivas H, Islam A, Soper N, Paraskeva P, Rosemurgy A, Ross S, Shah S (2013) Single-incision laparoscopic cholecystectomy is associated with improved cosmesis scoring at the cost of significantly higher hernia rates: 1-year results of a prospective randomized, multicenter, single-blinded trial of traditional multiport laparoscopic cholecystectomy vs single-incision laparoscopic cholecystectomy. J Am Coll Surg 216:1037–1047 **(discussion 1047–1038)**