

ArtiSential laparoscopic cholecystectomy: a comparative analysis with robotic single-port cholecystectomy

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Purpose: Laparoscopic cholecystectomy is the gold standard procedure for benign gallbladder disease. However, reducing ports still causes frustration when using various instruments. We investigated early perioperative outcomes of laparoscopic single site + 1 cholecystectomy using ArtiSential instruments (ArtiSential laparoscopic cholecystectomy [ALC], LIVSMED).

Methods: From July 2022 to December 2022, 116 patients underwent ALC in Severance Hospital and Yongin Severance Hospital. From May 2019 to December 2022, 210 patients underwent robotic single-port cholecystectomy (RSPC). We compared clinical characteristics, perioperative outcomes, and postoperative pain scores between the ALC and RSPC groups.

Results: Patients in the ALC group were significantly older than those in the RSPC group (51.9 years vs. 43.9 years, $P < 0.001$), and the ALC group had a larger proportion of male patients (50.9% vs. 24.8%, $P < 0.001$) and cases of acute cholecystitis with stones (21.6% vs. 0.5%, $P < 0.001$) than the RSPC group. The groups did not differ in their estimated blood loss, postoperative complications, or hospital stays. The mean operation time of the ALC group was shorter than that of the RSPC group (56.5 minutes vs. 94.8 minutes, $P < 0.001$). Although the pain scores reported on discharge day did not differ, the ALC group reported significantly lower immediate postoperative pain scores than the RSPC group (2.7 vs. 5.4, $P < 0.001$).

Conclusions: ALC is a safe and feasible procedure. ALC patients reported markedly lower immediate postoperative pain scores than RSPC patients, with comparable operative outcomes for estimated blood loss, hospital stay, and postoperative complication rates.

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INTRODUCTION

Laparoscopic cholecystectomy is the gold standard procedure for treating benign gallbladder disease. Since the inception of cholecystectomy, surgeons have been working to advance minimally invasive surgical techniques [1,2]. Conventional laparoscopic cholecystectomy, initially performed with 3 to 4 ports plus a camera port, has been reduced to single-port cholecystectomy. However, the narrow field of operation and limited maneuverability of a single port have constrained its applicability [3].

To address those limitations, single-port cholecystectomy is being performed using robotic platforms. The da Vinci system (Intuitive Surgical, Inc.) introduced robotic single-site cholecystectomy, but it was restricted by its rigid instruments [4]. Our medical center was the first in Korea to perform both robotic single-site cholecystectomy and robotic single-port cholecystectomy (RSPC), beginning with multiport robotic cholecystectomy using the da Vinci system [4-6]. Additionally, the Revo-i cholecystectomy, a Korean robotic surgery system, was conducted for the first time in Korea [7]. In a context in which new approaches and research for robotic cholecystectomy are underway, a laparoscopic alternative to RSPC that uses an articulating instrument was developed in Korea.

In many countries, national insurance does not cover robotic platform surgeries, and their high cost is a barrier to entry. Therefore, the ArtiSential instrument (LIVSMED), which capitalizes on the robotic system's articulating capabilities, is being developed as a cost-effective alternative. Since the early 2000s, numerous laparoscopic instruments with articulating

freedom have been developed, and although some have been marketed, many manufacturers have discontinued their products or had their usage restricted in certain countries [8].

Various uses of ArtiSential instruments, characterized by 7 degrees of freedom and a lower cost than robotic platforms, are being explored in different surgical disciplines. This study compares the initial perioperative outcomes of ArtiSential laparoscopic cholecystectomy (ALC) with those of RSPC to contribute to the advancement of reduced-port cholecystectomy techniques.

METHODS

Ethics statements

The Institutional Review Board of Yongin Severance Hospital approved this study (No. 9-2023-0120). This study was performed in accordance with the Declaration of Helsinki and written informed consent was waived due to its retrospective nature.

Surgical techniques

ArtiSential laparoscopic cholecystectomy

ALC, laparoscopic single-site plus 1 cholecystectomy using ArtiSential instruments, is a form of reduced-port cholecystectomy. To overcome the drawbacks of laparoscopic single-site cholecystectomy, we adapted articulating instruments to dissect Calot's triangle. The most critical disadvantage of conventional laparoscopic single-site cholecystectomy is the narrow view that restricts the operation field for dissecting Calot's triangle [9].

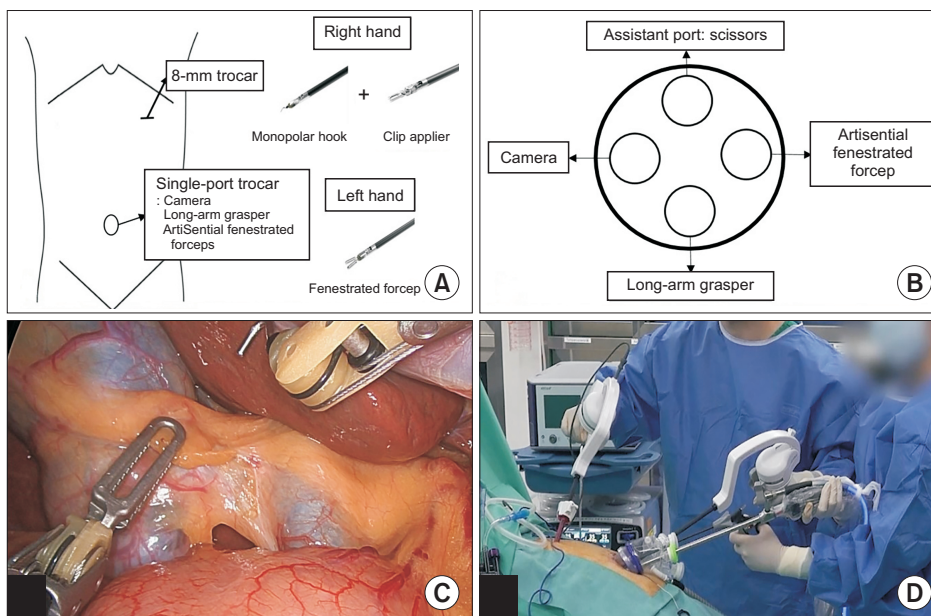


Fig. 1. Scheme for ArtiSential laparoscopic cholecystectomy (LIVSMED). (A) Port placement site and instruments. (B) Single-port schematic figure. (C) Surgical procedure of ArtiSential laparoscopic cholecystectomy. (D) Configuration of procedure using ArtiSential instruments.

ALC is performed with 2 ports (Fig. 1A). A camera, long-arm grasper, and ArtiSential fenestrated forceps are placed through a transumbilical incision about 2 cm in size. In the coronal view, the positional correlation of each instrument through the single port is as shown in Fig. 1B. While retracting the fundus of the gallbladder to the superolateral side with a long-arm grasper, a critical view of safety must be secured before dissecting the Calot's triangle by manipulating the infundibulum with ArtiSential fenestrated forceps. It is useful to make the Calot's triangle as wide as possible by crossing the camera and fenestrated forceps (Fig. 1C). An 8-mm trocar is placed in the epigastric area. Due to the articulating action of the ArtiSential instruments, they can be positioned more laterally than in a conventional laparoscopic cholecystectomy. The surgeon uses a monopolar hook or clip applier in the right hand to dissect tissue and ligate the cystic duct and artery and holds the fenestrated forceps in the left hand (Fig. 1D, Supplementary Video 1).

Robotic single-port cholecystectomy

RSPC was performed using da Vinci SP, the most recent da Vinci system for single-site surgery. We conduct RSPC as follows: The patient is placed in the supine position, cleansed, and draped. The robotic acting arm (patient side cart) is placed at the patient's head. A 2.5-cm transumbilical vertical incision is made for the main single-port system. Because the assistant surgeon has no access port, gauze and an endo-bag are inserted before docking the SP system.

The camera is placed in the middle lower hole, fenestrated bipolar forceps in the left (arm 1), Cadiere forceps in the upper-middle hole (arm 2), and a hook in the right hole (arm 3). Arm 1 is controlled by the left hand, arm 3 by the right hand, and arm 2 by both hands interchangeably. During the procedure, the Cadiere forceps on arm 2 pull the gallbladder's fundus to the superolateral side. Dissection begins at the cystic plate using the left-hand grasper and right-hand hook for diathermy. After ensuring a critical view of safety, the cystic duct and artery are double-clipped using Hem-o-lok (Teleflex Incorp.) and then divided. The gallbladder is placed in the endo-bag and removed from the peritoneum after detachment from its bed.

Study cohort and statistical analysis

From July 2022 to December 2022, 116 patients underwent ALC in the Division of Hepatobiliary and Pancreas Surgery at Severance Hospital and Yonsei Severance Hospital, Yonsei University; and from May 2019 to December 2022, 210 patients underwent RSPC in Severance Hospital. A total of 4 hepatobiliary and pancreas (HBP) surgeons participated from 2 different hospitals with a hierarchical relationship, including 1 senior and 1 junior HBP surgeon from each hospital. We retrospectively reviewed their medical records and

compared the groups in terms of their clinical characteristics, perioperative outcomes, and postoperative pain scores.

Descriptive analyses of clinical characteristics were conducted using the Student t-test, Pearson chi-square test, and Fisher exact test. A 1:1 propensity score matching analysis was performed using covariates including age, sex, body mass index (BMI), diagnosis, history of abdominal surgery, and American Society of Anesthesiologists (ASA) physical status classification system. Statistical significance was set as $P < 0.05$. All statistical analyses were performed using IBM SPSS Statistics for Windows ver. 22.0 (IBM Corp.) and R software ver. 3.3.1.

RESULTS

Clinical characteristics of patients

The mean ages of the RSPC and ALC groups were 43.9 and 51.9 years, respectively. Most patients in the RSPC group (75.2%) were female, but only 49.1% of ALC patients were female. Regarding ASA classification, 33.4% of RSPC patients were classified as ASA I, compared to only 13.8% of ALC patients. In the RSPC and ALC groups, 47.6% and 37.1% of patients, respectively, underwent surgery for disease discovered at a medical check-up without any previous symptoms, and 0.5% and 21.6%, respectively, were treated for acute cholecystitis. All of those clinical characteristics differed significantly between the groups ($P < 0.05$). The only other characteristic to differ was BMI, which was 23.3 kg/m² in the RSPC group and 24.1 kg/m² in the ALC group, which had marginal significance ($P = 0.060$) (Table 1).

Perioperative outcomes

The mean total operation time was 94.8 minutes in the RSPC group and 56.5 minutes in the ALC group, which was a statistically significant difference. Estimated blood loss, hospital stay, and intra/postoperative complications did not differ significantly between the groups. No intraoperative open conversions or additional trocar ports were needed. In the numeric pain scores immediately after surgery, the ALC group reported lower pain scores than the RSPC group (2.7 vs. 5.4), which was a statistically significant difference ($P < 0.001$). However, the pain scores prior to discharge did not differ significantly between groups (Table 2).

Comparisons of pain score in subgroup analyses

In the subgroup analyses, both female and male patients in the ALC group reported numeric pain scores significantly lower than those reported in the RSPC group. The ALC group reported significantly lower pain scores regardless of BMI, dichotomized as below or above 25 kg/m². In the subgroup analysis by operation time, the ALC group reported lower postoperative pain scores no matter how long the operation lasted. Similar

Table 1. Clinical characteristics of patients

Characteristic	RSPC group	ALC group	P-value
No. of patients	210	116	
Age (yr)	43.9 ± 10.0	51.9 ± 12.7	<0.001
Sex			<0.001
Female	158 (75.2)	57 (49.1)	
Male	52 (24.8)	59 (50.9)	
Body mass index (kg/m ²)	23.3 ± 3.3	24.1 ± 3.4	0.060
Previous symptom			<0.001
Medical check-up	100 (47.6)	43 (37.1)	
Abdominal pain/discomfort	65 (31.0)	61 (52.6)	
Back pain	5 (2.4)	2 (1.7)	
Indigestion	40 (19.0)	10 (8.6)	
Preoperative diagnosis			<0.001
Chronic cholecystitis with stone	147 (70.0)	63 (54.3)	
Acute cholecystitis with stone	1 (0.5)	25 (21.6)	
Polyp	41 (19.5)	15 (12.9)	
Adenomyomatosis	21 (10.0)	13 (11.2)	
Previous abdominal operation history			0.587
No	171 (81.4)	98 (84.5)	
Yes	39 (18.6)	18 (15.5)	
ASA PS classification			0.001
I	70 (33.4)	16 (13.8)	
II	125 (59.5)	88 (75.9)	
III	15 (7.1)	12 (10.3)	

Values are presented as number only, mean ± standard deviation, or number (%).

RSPC, robotic single-port cholecystectomy; ALC, ArtiSential laparoscopic cholecystectomy (LIVSMED); ASA, American Society of Anesthesiologists; PS, physical status.

Table 2. Perioperative outcomes

Variable	RSPC group (n = 210)	ALC group (n = 116)	P-value
Total operative time (min)	94.8 ± 22.4	56.5 ± 20.7	<0.001
Estimated blood loss (mL)			0.216
<30	207 (98.6)	111 (95.7)	
≥30	3 (1.4)	5 (4.3)	
Intraoperative conversion, no	210 (100)	116 (100)	NA
Gallbladder rupture during operation			0.157
No	198 (94.3)	114 (98.3)	
Yes	12 (5.7)	2 (1.7)	
Indwelling drainage tube			0.763
No	210 (100)	115 (99.1)	
Yes	0 (0)	1 (0.9)	
Numeric pain score			
Immediately postoperative	5.4 ± 1.6	2.7 ± 1.8	<0.001
Prior to discharge	1.6 ± 0.9	1.4 ± 1.2	0.195
Hospital stay (day)	1.5 ± 0.8	1.5 ± 0.7	0.530
Intraoperative/postoperative complication			0.079
No	202 (96.2)	116 (100)	
Yes	8 (3.8)	0 (0)	
Complications			
Bowel injury during surgery	3 (1.4)	0 (0)	
Wound seroma	5 (2.4)	0 (0)	

Values are presented as mean ± standard deviation or number (%).

RSPC, robotic single-port cholecystectomy; ALC, ArtiSential laparoscopic cholecystectomy (LIVSMED); NA, not available.

Table 3. Comparison of pain scores

Variable	Operation type	Numeric pain score	
		Immediately postoperative	Prior to discharge
Sex			
Female (n = 215)	RSPC (n = 158)	5.5 ± 1.5	1.6 ± 0.9
	ALC (n = 57)	3.1 ± 1.9	1.2 ± 0.9
	P-value	<0.001	0.018
Male (n = 111)	RSPC (n = 52)	5.1 ± 1.8	1.5 ± 0.8
	ALC (n = 59)	2.4 ± 1.5	1.5 ± 1.4
	P-value	<0.001	0.847
Obesity, BMI (kg/m ²)			
<25 (n = 221)	RSPC (n = 147)	5.5 ± 1.5	1.5 ± 0.9
	ALC (n = 74)	3.1 ± 1.9	1.4 ± 1.0
	P-value	<0.001	0.26
≥25 (n = 105)	RSPC (n = 63)	5.1 ± 1.4	1.6 ± 0.9
	ALC (n = 42)	2.5 ± 1.7	1.4 ± 1.5
	P-value	<0.001	0.419
Operation time (min)			
Short, <60 (n = 90)	RSPC (n = 13)	4.6 ± 1.7	1.3 ± 0.9
	ALC (n = 77)	2.7 ± 1.7	1.3 ± 1.2
	P-value	0.001	0.932
Long, ≥60 (n = 236)	RSPC (n = 197)	5.4 ± 1.6	1.6 ± 0.9
	ALC (n = 39)	2.7 ± 1.8	1.5 ± 1.2
	P-value	<0.001	0.745
Preoperative symptoms			
No (n = 143)	RSPC (n = 100)	5.3 ± 1.6	1.5 ± 0.8
	ALC (n = 43)	2.8 ± 1.9	1.3 ± 0.9
	P-value	<0.001	0.259
Yes (n = 183)	RSPC (n = 110)	5.4 ± 1.6	1.6 ± 1.0
	ALC (n = 73)	2.7 ± 1.7	1.4 ± 1.3
	P-value	<0.001	0.327
Gallbladder stone with cholecystitis			
No (n = 90)	RSPC (n = 62)	5.7 ± 1.4	1.6 ± 0.9
	ALC (n = 28)	3.1 ± 1.9	1.2 ± 0.6
	P-value	<0.001	0.061
Yes (n = 236)	RSPC (n = 148)	5.3 ± 1.7	1.5 ± 0.9
	ALC (n = 88)	2.6 ± 1.7	1.4 ± 1.3
	P-value	<0.001	0.542

Values are presented as mean ± standard deviation.

RSPC, robotic single-port cholecystectomy; ALC, ArtiSential laparoscopic cholecystectomy (LIVSMED).

results were found in the analyses by preoperative symptoms and the presence of gallbladder stones (Table 3).

Chronological change in total operation time

The chronological change in total operation time for each group is analyzed in Fig. 2. The linear regression slope of the RSPC group is positive, and the slope of the ALC group is negative. The r^2 values were 0.1982 ($P < 0.001$) and 0.0322 ($P = 0.952$), respectively.

Comparisons of perioperative outcomes after propensity score matching

After 1:1 propensity score matching, 40 patients from each

group were analyzed. There were no significant differences between the 2 groups regarding preoperative characteristics, including age, sex, BMI, diagnosis, history of abdominal surgery, and ASA classification. Additionally, data from 20 RSPC cases and 20 ALC cases, all performed exclusively by senior surgeons at each hospital, were analyzed.

Comparison of perioperative outcomes showed no significant differences between the 2 groups in terms of estimated blood loss and gallbladder rupture. However, RSPC was associated with a longer total operation time and a shorter hospital stay, while ALC had a lower postoperative pain score (Table 4).

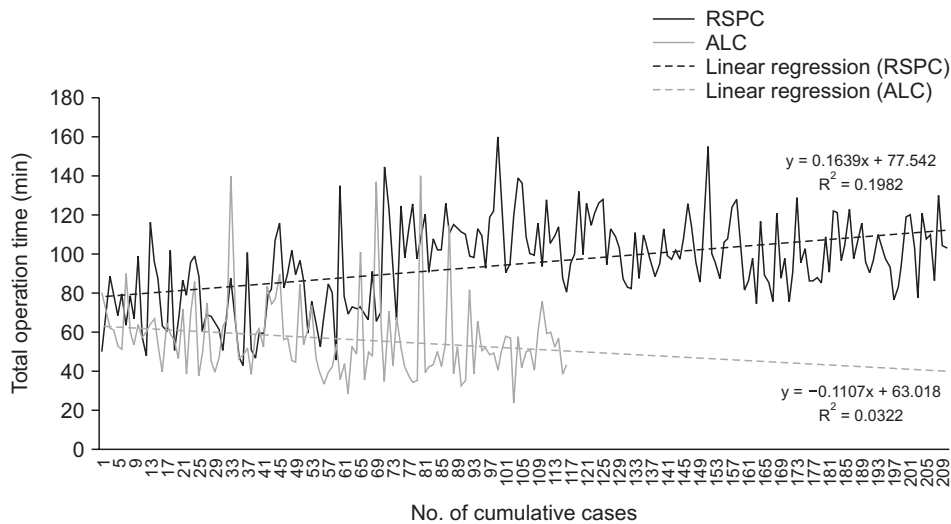


Fig. 2. Chronological analysis of total operation time. RSPC, robotic single-port cholecystectomy; ALC, ArtiSential laparoscopic cholecystectomy (LIVSMED).

Table 4. Clinical characteristics and postoperative outcome after propensity score matching

Characteristic	RSPC group (n = 40)	ALC group (n = 40)	P-value
Age (yr)	44.8 ± 10.0	46.9 ± 13.1	0.423
Sex			0.156
Female	23 (57.5)	30 (75.0)	
Male	17 (42.5)	10 (25.0)	
Body mass index (kg/m ²)	24.2 ± 3.6	23.4 ± 3.3	0.296
Preoperative diagnosis			0.062
Chronic cholecystitis with stone	28 (70.0)	21 (52.5)	
Acute cholecystitis with stone	0 (0)	7 (17.5)	
Polyp	7 (17.5)	8 (20.0)	
Adenomyomatosis	5 (12.5)	4 (10.0)	
Previous abdominal operation history			0.117
No	37 (92.5)	31 (77.5)	
Yes	3 (7.5)	9 (22.5)	
ASA PS classification			0.054
I	14 (35.0)	5 (12.5)	
II	24 (60.0)	29 (72.5)	
III	2 (5.0)	6 (15.0)	
Estimated blood loss (mL)			0.474
<30	40 (100)	38 (95.0)	
≥30	0 (0)	2 (5.0)	
Total operative time (min)	92.1 ± 25.1	61.4 ± 26.5	<0.001
Gallbladder rupture during operation			0.239
No	37 (92.5)	40 (100)	
Yes	3 (7.5)	0 (0)	
Hospital stay (day)	1.4 ± 0.6	1.8 ± 0.9	0.049
Numeric pain score			
Immediately postoperative	5.3 ± 1.7	2.7 ± 1.8	<0.001
Prior to discharge	1.7 ± 0.9	1.1 ± 0.9	0.004

Values are presented as mean ± standard deviation or number (%).

RSPC, robotic single-port cholecystectomy; ALC, ArtiSential laparoscopic cholecystectomy (LIVSMED); ASA, American Society of Anesthesiologists; PS, physical status.

DISCUSSION

Minimally invasive laparoscopic cholecystectomy has been

performed for decades, and its safety has been demonstrated by numerous latecomers. However, although the safety of laparoscopic cholecystectomy is clear, surgeons' research and

surgical method development toward the goal of minimal invasiveness are still in progress.

Efforts to reduce the number of ports required for instruments other than the camera have led to the development of single-incision laparoscopic cholecystectomy (SILC) [10]. Discussions about its safety and feasibility are ongoing, but studies indicate that SILC provides better short- and long-term cosmetic outcomes, body image satisfaction, postoperative pain relief, and overall quality of life scores than traditional 4-port laparoscopic cholecystectomy [11-14]. A notable drawback of SILC is the requirement for an experienced surgeon. Performing the surgical procedure through a single incision parallel to the camera view can be experienced as unnatural and uncomfortable, which is an inherent limitation of SILC because the dissection of Calot's triangle necessitates a perpendicular dissection vector rather than a straight view. To achieve a stable laparoscopic cholecystectomy, it is crucial to adequately secure the Calot's triangle by manipulating the gallbladder with a high degree of freedom using a freely moving instrument. Additionally, identifying the structures of the cystic duct and cystic artery is vital for a successful procedure.

To address those limitations, a robot-assisted single site cholecystectomy (RSSC) system was developed. RSSC uses a relatively flexible robotic instrument and a curved trocar at a single site to dissect Calot's triangle at an angle that is not completely parallel to the camera view. However, that system lacked sufficient force to dissect stiff fibrosis or firm tissue, which was a significant drawback. Additionally, it exhibited a tendency to revert to its original configuration, making angulation motion impossible [15]. In light of these facts, it is well known that while RSSC enables single-site cholecystectomy, ergonomic motion with angulation is not feasible. Therefore, it is more appropriate to analyze articulating instruments with the same ergonomic system. In addition, the RSSC system is no longer clinically relevant, as it has been discontinued by the manufacturer. Therefore, the most suitable and available robotic platform for reduced-port cholecystectomy is RSPC. Ultimately, comparing ALC and RSPC may provide valuable insights into alternative methods for medical centers where installing a robotic platform is not possible. For this reason, RSPC was compared with ALC rather than RSSC, despite the large number of RSSC cases performed in our center.

The da Vinci single-port system, released in 2019, addressed some of those limitations. Unlike RSSC, RSPC can use a pure single port with a single trocar, eliminating the need for additional devices such as a gel port or an individually curved trocar for instruments. Moreover, it offers advantages in terms of ergonomic configuration, angulation motion, and 3rd-arm swapping. It allows for 360° circumferential movement, and the camera is articulating. These advantages have led to its active application not only for cholecystectomy but also for procedures

such as prostatectomy, hysterectomy, oropharyngectomy, and hernia repair [16-19].

The primary barrier to the widespread adoption of robotic single-port systems remains their high cost. In an analysis of the cost-effectiveness of robotic cholecystectomy for benign gallbladder disease, traditional laparoscopic cholecystectomy emerged as the most practical and cost-effective treatment option [20-22]. Consequently, hepatobiliary pancreas surgeons have been working diligently to establish an optimal surgical environment that combines the cost-effectiveness and broad indication criteria of laparoscopic gallbladder surgery with the advantages of reduced-port cholecystectomy by using the articulating ergonomic instruments common with robotic systems for laparoscopy.

As a cost-effective alternative, many articulating laparoscopic instruments have been developed to provide the advantages of robotic surgery while being relatively inexpensive and easy to use. However, due to an un-ergonomic environment that was not suitable for surgeons, most of those products were discontinued after their market release. The latest U.S Food and Drug Administration-approved ArtiSential instrument is an advanced pistol-type articulating laparoscopic tool that has gained widespread use in various surgical fields [23-26].

The ArtiSential instrument offers articulation with 7 degrees of freedom. Similar to a robotic system, it provides an ergonomic environment for the surgeon and additional tactile feedback. Given these advantages and its cost-effectiveness, compared with robotic surgical systems, ArtiSential instruments are widely used, particularly in laparoscopic low anterior resections with total mesorectal excision. Furthermore, the ArtiSential instrument is finding applications in various fields, particularly reduced-port laparoscopic gastrectomy, because of its advantages for lymph node grabbing and retrieval around the pancreas.

This study was designed and conducted to offer a practical alternative to reduced-port cholecystectomy. To the best of our knowledge, this is the first large cohort study of ArtiSential instruments in laparoscopic cholecystectomy. It was proposed to address the narrow indication criteria and high cost associated with RSPC. In terms of patient demographics, there were significant differences between the RSPC and ALC groups, as the patient selection criteria for RSPC had been expanded compared to the initial criteria. Our institution has been striving to reduce the number of ports in minimally invasive cholecystectomy since the 2000s and reported the early surgical outcomes of RSSC in 2013. We then initiated RSPC with strict patient selection criteria in 2019. Following a stabilization period and the accumulation of experience with reduced-port cholecystectomy, we commenced ALC in July 2022. Initially, women without acute inflammation, who were relatively young and had a low BMI, were selected, with many patients classified

as ASA I during medical check-ups. As experience with reduced-port cholecystectomy increased, the patient selection criteria for ALC were subsequently expanded. Our aim was to expand the safe dissection range of Calot's triangle, minimize postoperative pain, and maximize cosmetic effects through port reduction. To overcome the limited gallbladder manipulation range with RSPC, the ALC approach uses ArtiSential fenestrated forceps to retract the infundibulum in the counter direction, requiring a camera port at the umbilicus and an additional port in the epigastric area to enable perpendicular dissection of Calot's triangle. This advantage is particularly beneficial for patients with a high BMI or severe acute inflammation, in whom RSPC can be challenging. Despite the expanded indication criteria, the groups did not differ significantly in terms of their operation time, estimated blood loss, postoperative complication rate, or open conversion rate.

However, it is well known that surgeon experience is a critical factor when adapting a new instrument or platform. A total of 4 HBP surgeons participated from 2 different hospitals with a hierarchical relationship, including 1 senior and 1 junior surgeon from each hospital. To adjust for the surgeon experience factor and the significant differences in clinical characteristics between the 2 groups due to the expansion of selection criteria, propensity score matching was performed. When 20 cases of RSPC and 20 cases of ALC performed by a senior surgeon at each medical center were analyzed, the total operation time for ALC was shorter, and the postoperative pain score was lower than for RSPC. ALC can be a good approach in situations in which the clinical expansion of RSPC is difficult due to its high price. Further research on this should be conducted in the future.

A noteworthy aspect of our results is that ALC showed statistically significant lower postoperative pain scores than RSPC. This tendency was consistent in the subgroup analyses, holding true regardless of sex, BMI, operation time, and the presence of gallbladder stones. This difference might be attributable to the continuous pressure exerted on the umbilicus by the robotic arm during surgery. In contrast, the camera port incision at the umbilicus in ALC is smaller than that in RSPC. Moreover, the broad range of articulating instruments suggests the possibility of trocar placement in the epigastric area with a left-sided deviation compared with conventional laparoscopic cholecystectomy, potentially reducing postoperative pain scores.

RSPC is not significantly affected by a learning curve, whereas ALC is influenced by a learning curve because it requires surgeons to adapt to a new type of instrument (Fig. 2). As the number of cases for RSPC and ALC increased, the operation time for ALC gradually decreased. In contrast, the total operation time for RSPC gradually increased. This trend is related to the fact that the study was conducted at a tertiary

medical center that trains HBP surgeons. After the successful implementation and stabilization of the RSPC, senior residents and fellows from the HBP department performed a significant portion of the procedures, which contributed to the increase in total operation time. In addition, the mean operation time for RSPC was longer because it included cases of acute cholecystitis with severe adhesions and bowel injuries that required intraoperative primary repair. In this regard, ALC is a valuable tool for training surgeons in advanced surgical approaches using ArtiSential instruments. Building on this experience, our institution is conducting research on pancreaticojejunostomy and choledochojejunostomy using ArtiSential instruments.

ArtiSential instruments are capable of articulation, but due to differences in angles and vectors compared to RSPC, a considerable amount of time is required to master their manipulation. However, for HBP surgeons with an understanding of the key structures and principles essential for performing laparoscopic cholecystectomy, proficiency with the operation technique can be achieved relatively quickly. Although cumulative sum analysis was not performed in the study, based on our experience, we believe that surgeons well acquainted with conventional cholecystectomy can overcome the learning curve in approximately 20 cases. In addition to the different angles and vectors, the surgeon must maintain the axis by controlling their own strength to manipulate the ArtiSential instrument precisely. However, this approach can enhance tactile feedback and enable rapid instrument exchange during surgery, thereby contributing to a reduction in overall operation time while maintaining surgical quality.

Despite our findings, cholecystectomy using an ArtiSential instrument does have a few limitations. Primarily, achieving the maximum cosmetic effect is challenging because it does not qualify as a perfect single-port solution. Furthermore, the price of the ArtiSential articulating instruments is higher than that of traditional laparoscopic instruments. Although future developments might introduce an instrument usable in a 5-mm trocar, the current requirement for an 8-mm trocar is a drawback.

In conclusion, ArtiSential cholecystectomy is safe and feasible and led to markedly lower pain scores immediately postoperatively than RSPC, with comparable operative outcomes for estimated blood loss, hospital stay, and postoperative complication rates.

SUPPLEMENTARY MATERIALS

Supplementary Video 1 can be found via <https://doi.org/10.4174/ast.2024.107.6.336>.

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Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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