



# Comparative effectiveness of human scope assistant versus robotic scope holder in laparoscopic resection for colorectal cancer

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## Abstract

**Background** Several types of robotic scope holders have been developed to date, but there are only some experimental reports or the results of small clinical cases. The Soloassist® system is a unique robotic scope holder with which the surgeon can control the field of view by a joystick. We evaluated the efficacy of Soloassist in laparoscopic resection for colorectal cancer.

**Materials and methods** We investigated operative time, blood loss, setup time, length of hospital stay, and the number of participating surgeons in 273 laparoscopic colorectal resections, including 130 cases with human assistant (HA group) and 143 cases with Soloassist (SA group). Additionally, we also used logistic regression of the perioperative factors for the propensity score calculation to balance the bias.

**Results** The number of participating surgeons was apparently less in the SA group (HA group: 3.3 vs. SA group: 2.5,  $p < 0.01$ ). The average operative time was shorter in the SA group, but there was no statistical difference (HA group: 287.0 min vs. SA group: 268.5 min,  $p = 0.07$ ). No significant difference was found in setup time, conversion rate, perioperative complications, and length of hospital stay. There was no conversion case to human scope assistant and no system-specific adverse event. Similar results were observed between two groups after propensity score matching.

**Conclusion** Laparoscopic colorectal resection with Soloassist is safe and feasible. The present study demonstrated that Soloassist system provided the possibilities of saving human resources in laparoscopic colorectal resection without prolonged operative time or system-specific morbidity. Soloassist is an effective robot-assisted surgical instrument for colorectal surgery.

**Keywords** Laparoscopic surgery · Colorectal cancer · Robotic scope holder · Soloassist

Since Jacobs et al. [1] first reported a series of 20 laparoscopy-assisted colectomies, nearly 3 decades have passed, and now laparoscopic surgery has become widespread as a common approach for colorectal surgery all over the world as well as in Japan [2]. There are two major trends in progress of laparoscopic surgery. First, single-incision

laparoscopic surgery (SILS) and reduced port surgery (RPS) were performed to reduce total amount of skin incisions for further minimally invasive surgery [3, 4]. The other is due to the progress of mechanical supporting equipment, including robot-assisted surgery typified by da Vinci system (Intuitive Surgical, Sunnyvale, CA) [5, 6]. Advances in robot-assisted laparoscopic surgery have undergone various evolutionary stages in accordance with the progress of mechanical industry. The first commercial robotic scope holder was developed by Computer Motion Inc. and was a voice control scope holder called automatic endoscope system for optimal positioning (AESOP) [7, 8]. After that, ZEUS (Computer Motion, Sunnyvale, CA) was developed as a robot-support surgical system [9]. These mechanical developments have led to the appearance of da Vinci system, which is the most popular robot-assisted laparoscopic surgery (RALS) platform in the world today. Although there are some limited supportive reports, the clinical efficacy of robot use in colectomy is controversial because of huge costs and lack of data

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regarding outcomes on a national level data [10–12]. However, global attention has been drawn to da Vinci surgery in a short period. On the other hand, the previous reports on active scope holder that controls only laparoscope by robotic technology were sporadic and evaluation of its clinical efficacy was not sufficiently discussed [13–15].

The Soloassist® system (AKTORmed, Barbing, Germany), a unique robotic scope holder, is a joystick-guided endoscope remote control system with which the surgeon can control the field of view [15]. We introduced the Soloassist system from December 2014 and have applied it in all laparoscopic surgeries including emergency operation. We recently reported the feasibility and usefulness of Soloassist in laparoscopic cholecystectomy, regardless of elective or emergency cases [16]. In colorectal surgery, it is necessary to observe wider range of the abdominal cavity for a longer time compared with cholecystectomy, and more advanced skill is required for precise scope manipulation. Therefore, the skill of the scope assistant may affect the perioperative results of the patients. The purpose of this study was to evaluate the clinical efficacy of Soloassist system compared to human scope assistant in laparoscopic surgery for colorectal cancer.

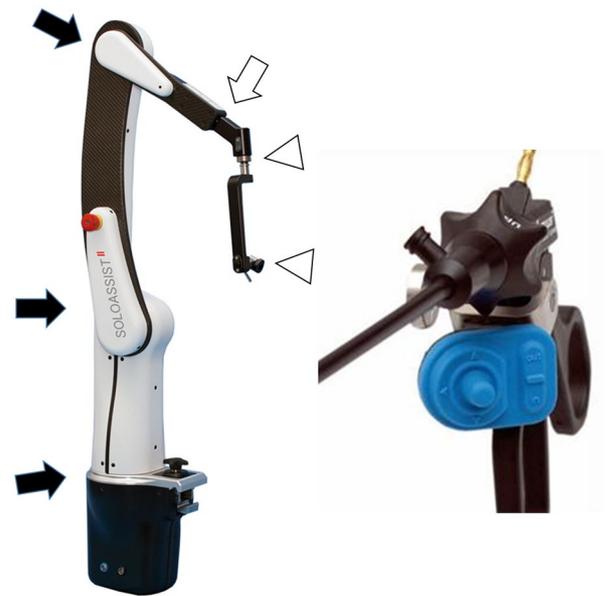
## Materials and methods

### Soloassist II® robotic camera control system

Soloassist is an endoscope holder with computer-controlled electric motors, and Soloassist II is a newly evolved model. It has six joints, three of which are computer-controlled, one can be adjusted manually, and two act as gimbal joints (Fig. 1). The only parts that require sterilization are the universal joint, camera clamp, and joystick. Soloassist can be installed on any part of the side rail of the operation table, and the main body is covered by a dedicated single-use drape. The Joystick is attached to the left-hand forceps with a small screw. Scope movement can be controlled by the surgeon via a joystick after adjusting the “trocar point” that defines the axis of motion. The joystick moves the scope intuitively 360° by tipping. Two small buttons next to the joystick are used to move the laparoscope forward and backward. While fine movements are adjusted by joystick, and dynamic movement can be enabled manually with pushing the unlock button by single hand.

### Patient’s position and location of Soloassist

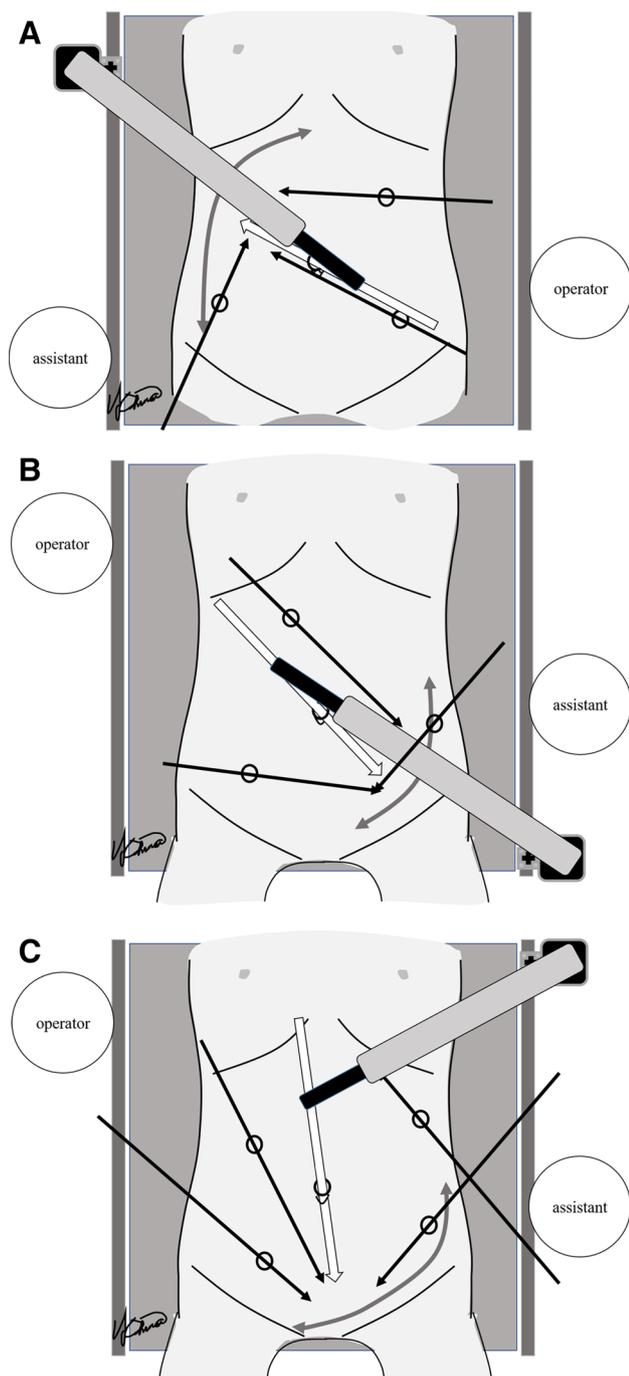
All the patients underwent surgery under general anesthesia with or without epidural anesthesia. We use a standard operation table (MAQUET, Rastatt, Germany) and 3D flexible laparoscope (ENDO EYE FLEX 3D: Olympus, Tokyo,



**Fig. 1** Soloassist II® system has six joints: computer controlled (black arrows), manual controlled (white arrow), a gimbal joint (white arrow head). The joystick can be operated 360° intuitively with the finger. Next to the joystick are two small buttons for in-and-out movement

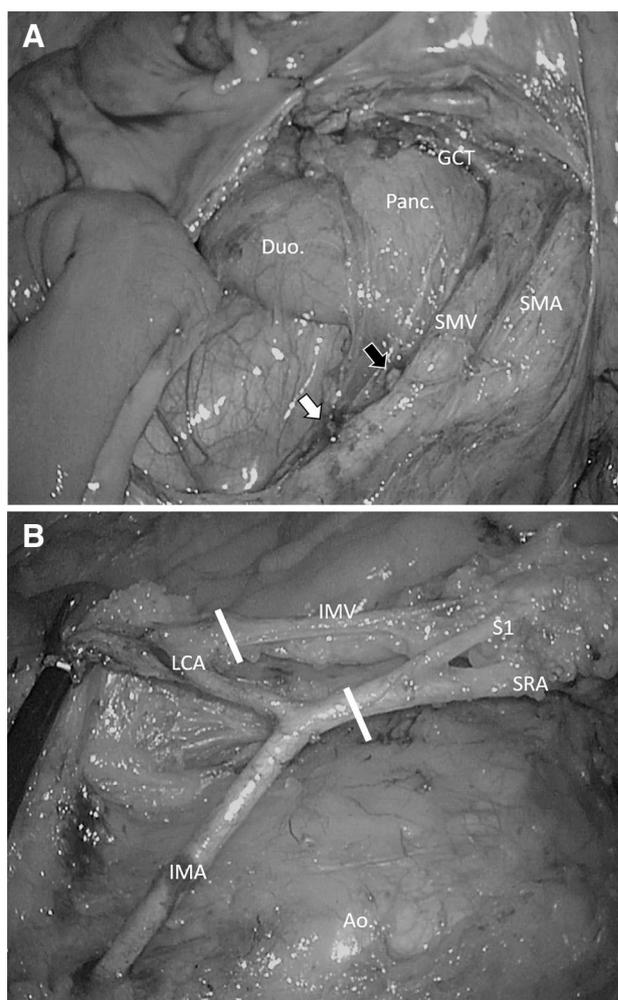
Japan). In our institution, 3 or 4 ports surgery is conducted in supine position for right-side colectomy. Laparoscope is always inserted from the umbilicus port, and Soloassist is attached at the nipple level on the right side of the patient (Fig. 2A). For medial approach, operation table is rotated to right lower angle with mild head down position. For lateral approach, operation table is tilted to the reverse angle which is with left lower rotation and head up position. The operator stands on the left side of the patient and completes all the procedures. In the case of transverse colectomy, the laparoscope is also inserted through the umbilicus port and the surgeon stand between the patient’s legs in lithotomy position. Soloassist is attached at the nipple level on the left side of the patient. The operator moves to the right side of the patient, if necessary, to dissect the splenic flexure and descending colon. When resecting sigmoid colon and rectum in lithotomy position, the surgeon stands on the right side of the patient and the assistant surgeon arranges operative field from the left side of the patient. The laparoscope is manipulated through the umbilical or right upper trocar. In the cases of 4 ports approach, we attach Soloassist on the lower left position (Fig. 2B). Otherwise, for 5 ports rectal resection in lithotomy position, Soloassist is attached to the upper left position to avoid forceps interferences with the scope holder (Fig. 2C).

In all cases, small midline laparotomy is made for hand-sewn anastomosis or anvil head insertion for double-stapling technique around the umbilicus. In the right-side D3



**Fig. 2** Setup position for laparoscopic right-side colectomy (A), left-side colectomy (B), and rectal resection (C). Operative field (curved arrow). Direction of the laparoscope (white arrow). Direction of the forceps (black arrows)

colectomy, the anterior and right-lateral walls of SMV were completely exposed and ileocolic vessels were divided at the root of the branches (Fig. 3A). For the left-side D3 colorectal resection, the root of inferior mesenteric artery was exposed and left colic artery (LCA) preserving D3 lymph



**Fig. 3** Laparoscopic view after right-side colectomy with D3 lymph node dissection (A). *Panc.* pancreas, *Duo.* duodenum, *GCT* gastrocolic trunk, *SMA* superior mesenteric artery, *SMV* superior mesenteric vein. Stump of ileocolic artery (black arrow) and vein (white arrow). Laparoscopic view after left-side colectomy with D3 lymph node dissection (B). *Ao.* aorta, *IMA* inferior mesenteric artery, *SRA* superior rectal artery, *S1* first branch of sigmoid artery, *LCA* left colic artery, *IMV* inferior mesenteric vein. Vessels are divided at the level of white bar

node dissection was performed. Superior rectal artery (SRA) and inferior mesenteric vein (IMV) were divided at the distal side of LCA (Fig. 3B).

### Patient evaluation

A total of 391 surgical resections for colorectal cancer was performed in our institution between January 2011 and March 2017. This study was approved by the institutional review board. All patients gave their informed consent for endoscopic procedures and for surgeries with robotic scope holder after introduction of Soloassist system. Emergency cases ( $n = 54$ ) were excluded, and among 337 elective

surgery patients, 53 patients underwent open surgery and 284 cases were operated by laparoscopic approach. Five cases simultaneously resected liver metastases and 6 multiple colorectal cancer cases were excluded and then 273 cases were enrolled to the retrospective analysis. Prior to introducing Soloassist system in December 2014, 130 cases were operated with human scope assistant (HA group), while 143 patients operated after introduction were all performed with Soloassist (SA group) (Fig. 4).

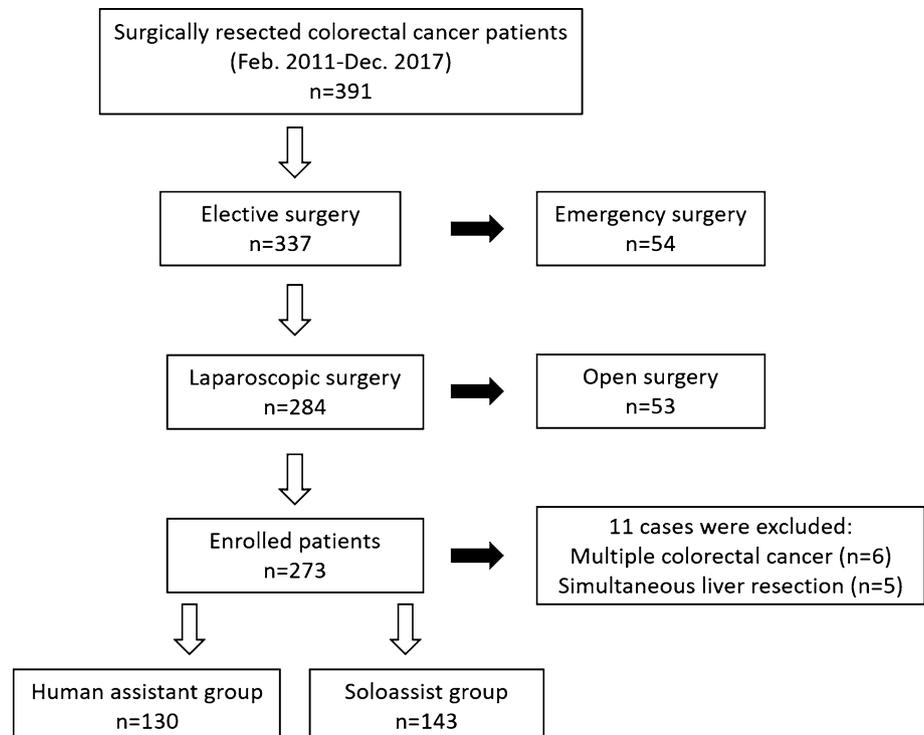
In order to evaluate the preoperative status of the patient, the data such as age, sex, BMI, tumor size, clinical stage, history of abdominal surgery, anticoagulant use, preoperative chemotherapy, preoperative decompression, and method of anesthesia were extracted. Then, we investigated operative duration, amount of intraoperative blood loss, length of hospital stay after surgery, the number of participating surgeons, conversion rate, and postoperative complication as perioperative data. For the purpose to objectively evaluate the setup time of the Soloassist, the time from room entry to initial skin incision was calculated and analyzed whether it affected occupation time of the operating room.

Additionally, we conducted similar analysis separately for each surgical procedure. In the cases with the tumor located at transverse colon, cases requiring dissection of the hepatic flexure were included in right-side colectomy group, while cases requiring the splenic flexure dissection were included in the left-side colectomy group.

## Statistical analysis

This was a retrospective study without randomization. Therefore, there were potential confounding biases among the two groups involved. To balance the bias, we used logistic regression of the following factors for the propensity score calculation: age, sex, BMI, anticoagulant usage, tumor size, clinical stage, and history of laparotomy. Additionally, epidural anesthesia application, operative procedure (right-side colectomy, left-side colectomy, and rectal resection), degree of lymph node dissection, and reconstruction method were also included for the propensity score calculation. Using calipers (0.01) with a width equal to 0.25 of the standard deviation of the logit of the propensity score, we performed propensity score analysis with 1:1 matching using the nearest neighbor matching method. After propensity score matching, we evaluated the two groups by using the absolute standardized differences (ASDs) before and after matching to confirm propensity scoring balance. Continuous data were analyzed with the Student's *t* test or Mann–Whitney *U* test. The Fisher's exact test or Chi-square test were used for comparison of categorical values. An open-source software, EZR version 1.37, was used for statistical analyses. All tests were two-sided, and a *p* value of <0.05 was considered statistically significant.

**Fig. 4** Flowchart for the current study detailing inclusion and exclusion criteria



## Results

Demographic characteristics and perioperative details of enrolled colorectal cancer patients are shown in Table 1. Due to the difference in treatment period, preoperative

chemotherapy and preoperative decompression were more frequently performed in the SA group. There was no statistical difference in the operative procedures, including the extent of lymph node dissection and anastomotic technique. The total number of dissected lymph nodes was higher in the SA group (HA group: 18.6 vs. SA group:

**Table 1** Demographic characteristics of colorectal cancer patients

Variables	Human assistant (n = 130)		Soloassist II (n = 143)		p value
<b>Backgrounds</b>					
Age, mean (SD), years	73.3 (11.4)	40–94	72.4 (9.73)	37–91	0.45
Sex (%)					
Male	68 (52.3)		74 (51.7)		0.93
Female	62 (47.7)		69 (48.3)		
BMI, mean (SD), kg/m <sup>2</sup>	21.3 (3.30)	13.7–31.0	21.7 (3.96)	14.2–37.8	0.30
Maximum tumor size (SD), mm	42.1(17.0)	8–95	42.9(17.5)	8–96	0.71
cStage (%)					
0	3 (2.3)		4 (2.8)		0.27
I	40 (30.8)		30 (21.0)		
II	31 (23.9)		40 (28.0)		
III	45 (34.6)		59 (41.3)		
IV	11 (8.5)		10 (7.0)		
Prior abdominal surgery (%)	39 (30.0)		55		0.14
Anticoagulant use (%)	27 (20.8)		18 (12.6)		0.07
Preoperative chemotherapy (%)	0 (0.0)		6 (4.2)		0.05
Preoperative decompression (%)	1 (0.8)		9 (6.3)		0.04
<b>Perioperative details</b>					
Epidural anesthesia (%)	95 (73.1)		111 (77.6)		0.38
Surgical procedure (%)					
Right colectomy	48 (36.9)		59 (41.3)		0.37
Left colectomy	58 (44.6)		52 (36.4)		
Rectal resection	24 (18.5)		32 (22.4)		
Lymph node dissection (%)					
D1	6 (4.6)		5 (3.5)		0.19
D2	39 (30.0)		34 (23.8)		
D3	85 (65.4)		104 (72.7)		
Lymph node yield, mean (SD)	18.6 (7.40)	4–35	21.0 (9.42)	3–64	0.02
Anastomosis fashion (%)					
Hand-sewn anastomosis	86 (66.2)		81 (54.6)		0.28
Double-stapling method	31 (23.8)		54 (37.8)		
Functional end to end anastomosis	2 (1.5)		0 (0.0)		
No (Ostomy)	11 (8.5)		7 (4.9)		
Concurrent cholecystectomy (%)	6 (4.6)		8 (5.6)		0.93
Participated surgeons, mean (SD)	3.3 (0.49)	3–5	2.5 (0.63)	2–5	<0.01
Setup time, mean (SD), min	47.8 (9.9)	25–70	49.8 (12.1)	22–72	0.14
Operative time, mean (SD), min	287.0 (86.3)	97–520	268.5 (77.5)	89–461	0.07
Blood loss, mean (SD), ml	31.3 (32.1)	5-150	41.0 (60.3)	3-350	0.09
Conversion to open surgery (%)	2 (1.5)		3 (2.1)		0.91
Complications, CD grade 2 < (%)	5 (3.8)		6 (4.9)		0.99
LOHS, mean (SD), days	14.1 (5.52)		13.0 (5.71)		0.11

*BMI* body mass index, *setup time* duration between room entry to skin incision. Clavien–Dindo classification, *LOHS* postoperative length of hospital stay

21.0,  $p = 0.02$ ). While there was no conversion case to human scope assistant, 2 cases (1.5%) in the HA group and 3 cases (2.1%) in the SA group were converted to open surgery due to severe adhesion. The number of participating surgeons was apparently less in the SA group (HA group: 3.3 vs. SA group: 2.5,  $p < 0.01$ ). The average operative time was shorter in the SA group, but there was no statistical difference (HA group: 287.0 min vs. SA group: 268.5 min,  $p = 0.07$ ). Setup time was similar in both groups. There was no grade 4 or higher perioperative complication of Clavien–Dindo classification, but 5 cases of the grade 3 were found in the HA group and 6 cases were in the SA group. These were anastomotic leakage, intestinal obstruction, and pelvic abscess, all of which were cured by surgical or radiological intervention. There was no system-specific complication regarding introduction of Soloassist.

Similar analysis was conducted separately for each operative procedure (Table 2). The numbers of right-side colectomy, left-side colectomy, and rectal resection were 97, 110, and 56 cases, respectively. In all procedures, the number of surgeons participating in surgery was significantly less in the SA group compared to the HA group ( $p < 0.01$ ). Operative time of the SA group was shorter in all procedures, but significant difference was demonstrated only in right-side colectomy ( $p = 0.01$ ).

After 1:1 propensity score analysis, a total of 273 patients with no missing data included 91 matched patients (Table 3). All matched patients were operated by the experienced surgeons with more than 100 laparoscopic surgeries. Distribution of propensity scores for the HA group and the SA group before and after propensity score matching is shown in Fig. 5. The propensity scores before matching were scattered (Fig. 5A), but it became similar distribution after matching (Fig. 5B). The backgrounds of the matched patients were well balanced. The results were similar to those before propensity score matching; the number of participating surgeons was significantly lower ( $p < 0.01$ ), and there was a tendency to shorten the operation time in the SA group, but no statistically significant difference was observed ( $p = 0.07$ ). There was no significant difference in other perioperative outcomes.

## Discussion

In the present report, we performed 143 cases of colorectal surgery with Soloassist and conducted retrospective analysis compared with 130 cases by human manual assistance, resulting in reduction in the number of participating surgeons without any adverse result. Similar results were obtained after propensity score matching. Shortening of operative time in right-side colectomy was observed in

the Soloassist group. When introducing surgery supporting devices, it may be expected that it takes an extra time for the setting, but as a result of our study, no additional time was required for using Soloassist.

Laparoscopic surgery has been widely practiced as minimally invasive surgery based on clinical evidence, especially in colorectal surgery, which contributes to postoperative pain relief and shortening of hospital stay [17–19]. Although SILS and RPS have been developed to reduce wounds and postoperative pain further, there are few reductions in the invasiveness in wounds of 5–10 mm. Therefore, compared to the benefits of laparoscopic surgery acquired as a difference from open surgery, it seems to be difficult to achieve significant reduction in invasiveness by SILS and RPS [3, 4]. Moreover, because the surgeon's forceps and laparoscope must be operated from close position, the available space for the surgeon and scope assistant is restricted. These circumstances complicate the surgical procedure and cause some difficulties in educating laparoscopic surgery for young surgeons compared with multi-port surgery. In laparoscopic surgery, we are basically pursuing an approach that allows to perform surgical procedures with coaxial position where there are eyes between both hands, that is, everyday situation for humans. But in coaxial position, the surgeon and the scope assistant are also placed in a somewhat cramped position, because the scope assistant needs to manipulate the laparoscope between the operator's arms.

Scope holder is a surgery-assisting device that can provide high-quality intraperitoneal images without tremor, which is one of the important advantages of robotic surgery. The scope holders invented as the first generation was passive scope holder, which aimed only to fix the laparoscope and surgeons had to interrupt the procedure to move it with both hands. As a second generation, new products that facilitate single-handed repositioning were developed [20, 21]. And recently, robotic scope holders have been developed that allow the operator to control the laparoscope intuitively without removing hands from the forceps [7, 13–16]. Although there are only some experimental reports and the results of small clinical cases, the role of an active scope holder has not been discussed so much and they have not been widely used in clinical practice to date.

With a human assistant, the laparoscope is often not steady or centered to the surgeon's satisfaction due to the different performance level of the scope assistant. To perform less stressful surgery, participation of a skilled assistant is desirable to operate the laparoscope; otherwise, it is difficult to always have such personnel. The use of robotic scope holder controlled by well-trained laparoscopic surgeon could contribute to shortening of the operation time [13]. Moreover, according to the previous reports, scope cleaning and unnecessary scope movement causing contamination decreased by using robotic scope holders [8, 22–24].

**Table 2** Demographic characteristics, perioperative details according to operative procedures

Variables	Right-side colectomy			Left-side colectomy			Rectal resection		
	HA (n=44)	SA (n=53)	p value	HA (n=58)	SA (n=52)	p value	HA (n=24)	SA (n=32)	p value
<b>Backgrounds</b>									
Age, mean (SD), years	74.9 (10.9)	72.1 (13.1)	0.24	70.5 (13.1)	72.3 (10.6)	0.43	74.2 (9.6)	70.0 (8.3)	0.08
<b>Sex (%)</b>									
Male	16 (36.4)	28 (52.8)	0.16	39 (67.2)	25 (48.1)	0.04	13 (54.2)	20 (62.5)	0.53
Female	28 (63.6)	25 (47.2)		19 (32.8)	27 (51.9)		11 (45.8)	12 (37.5)	
BMI, mean (SD), kg/m <sup>2</sup>	20.8 (3.3)	21.8 (4.1)	0.20	21.5 (3.4)	21.7 (4.0)	0.77	21.4 (2.9)	22.0 (4.0)	0.45
Maximum tumor size (SD), mm	42.0 (18.6)	45.1 (16.7)	0.39	42.7 (14.4)	38.5 (17.1)	0.16	41.5 (21.3)	46.4 (17.6)	0.36
<b>cStage (%)</b>									
0	1 (2.3)	1 (1.9)	0.07	0	0	0.62	0	0	0.62
I	15 (34.1)	7 (13.2)		17 (29.3)	18 (34.6)		8 (33.3)	5 (15.6)	
II	11 (25.0)	18 (34.0)		12 (20.7)	9 (17.3)		3 (12.5)	9 (28.1)	
III	14 (31.8)	23 (43.4)		24 (41.4)	22 (42.3)		10 (41.7)	15 (46.9)	
IV	3 (6.8)	4 (7.5)		5 (8.6)	3 (5.8)		3 (12.5)	3 (9.4)	
Prior abdominal surgery (%)	15 (34.1)	20 (37.7)	0.71	19 (32.8)	20 (38.5)	0.53	8 (33.3)	13 (40.6)	0.58
Anticoagulant use (%)	11 (25.0)	3 (5.7)	0.01	10 (17.2)	9 (17.3)	0.99	6 (25.0)	5 (15.6)	0.38
Preoperative chemotherapy (%)	0	0	1.00	0	0		0	5 (15.6)	0.12
Preoperative decompression (%)	1 (2.3)	1 (1.9)	0.89	0	6 (11.5)	<0.01	0	2 (6.3)	0.60
<b>Perioperative details</b>									
Epidural anesthesia (%)	29 (65.9)	39 (73.4)	0.41	41 (70.7)	40 (76.9)	0.46	17 (70.8)	28 (87.5)	0.22
<b>Lymph node dissection (%)</b>									
D1	2 (4.5)	1 (1.9)	0.21	4 (6.9)	4 (7.7)	0.53	0	0	0.80
D2	12 (27.3)	10 (18.9)		20 (34.5)	14 (26.9)		6 (25.0)	9 (28.1)	
D3	30 (68.2)	42 (79.2)		34 (58.6)	34 (65.4)		18 (75.0)	23 (71.9)	
Lymph node yield, mean (SD)	17.7 (7.5)	23.1 (9.6)	<0.01	17.3 (6.9)	20.5 (10.5)	0.06	17.8 (8.0)	18.8 (7.4)	0.62
<b>Anastomosis fashion (%)</b>									
Hand-sewn anastomosis	44 (100.0)	53 (100.0)		39 (67.2)	23 (44.2)		0	0	
Double-stapling method	0	0		14 (24.1)	29 (55.8)		17 (70.8)	25 (78.1)	
Functional end to end anastomosis	0	0		1 (1.7)	0		0	0	
No (Ostomy)	0	0		4 (6.9)	0		7 (29.2)	7 (21.9)	
Concurrent cholecystectomy (%)	1 (2.3)	3 (5.7)	0.77	0	4 (7.7)	0.10	0	2 (6.3)	0.60
Participated surgeons, mean (SD)	3.1 (0.3)	2.2 (0.4)	<0.01	3.3 (0.5)	2.4 (0.5)	<0.01	3.8 (0.5)	3.2 (0.6)	<0.01
Setup time, mean (SD), min	46.6 (8.7)	45.9 (12.1)	0.74	47.5 (9.9)	51.3 (11.5)	0.07	47.1 (10.8)	53.8 (10.9)	0.07
Operative time, mean (SD), min	285.2 (80.8)	246.2 (61.0)	0.01	295.1 (91.6)	265.9 (83.2)	0.09	276.5 (89.7)	314.8 (75.2)	0.09
Blood loss, mean (SD), ml	30.8 (34.6)	29.1 (35.3)	0.81	33.1 (30.6)	54.5 (78.3)	0.07	30.4 (33.3)	44.4 (60.9)	0.28
Conversion to open surgery (%)	0	0		2 (3.4)	3 (5.8)	0.56	0	2 (6.3)	0.60
Complications, CD grade 2 < (%)	0	0		3 (3.4)	3 (5.8)	0.89	2 (8.3)	3 (9.4)	0.89
LOHS, mean (SD), days	13.5 (3.8)	12.7 (5.3)	0.38	14.8 (4.7)	12.7 (6.1)	0.07	14.5 (8.8)	14.3 (6.2)	0.89

BMI body mass index, setup time duration between room entry to skin incision. Clavien–Dindo classification, LOHS postoperative length of hospital stay

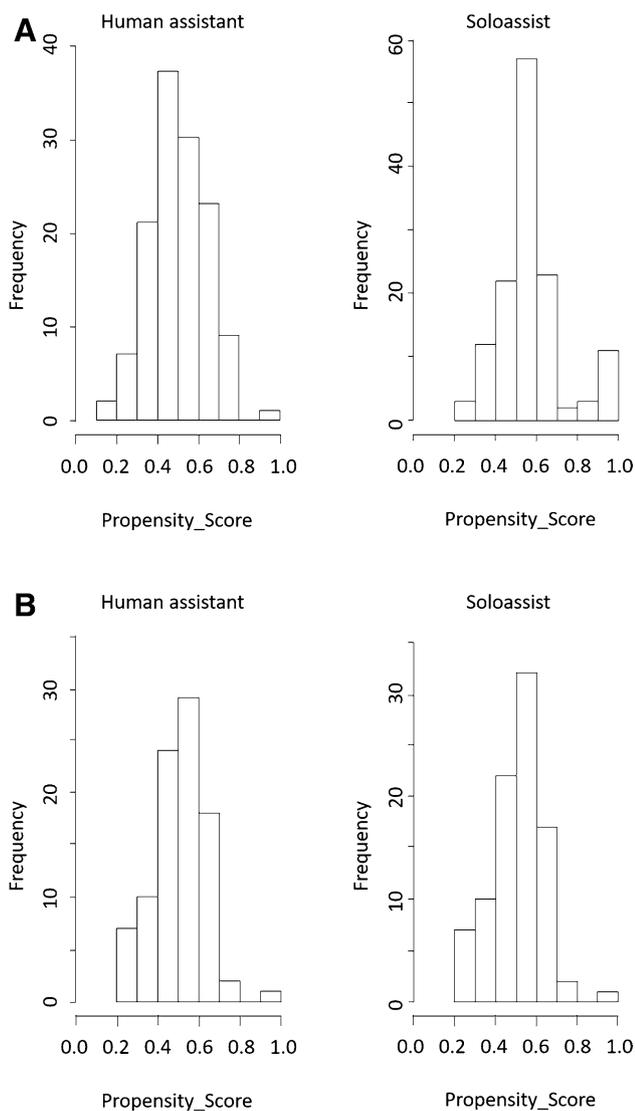
**Table 3** Demographic characteristics of colorectal cancer patients after propensity score matching

Variables	Human assistant (n=91)		Soloassist II (n=91)		p value
<b>Backgrounds</b>					
Age, mean (SD), years	73.9 (11.3)	41–93	72.6 (9.8)		0.41
Sex (%)					
Male	51 (56.0)		47 (51.6)		0.55
Female	40 (44.0)		44 (48.4)		
BMI, mean (SD), kg/m <sup>2</sup>	21.3 (3.3)	15.4–31.0	22.1 (4.2)	14.2–37.8	0.16
Maximum tumor size (SD), mm	41.8 (17.0)	10–95	40.6 (17.6)	8–98	0.63
cStage (%)					
0	1 (1.1)		3 (3.3)		0.77
I	29 (31.9)		23 (25.3)		
II	22 (24.2)		22 (24.2)		
III	30 (33.0)		38 (41.8)		
IV	9 (9.9)		5 (5.5)		
Prior abdominal surgery (%)	30 (33.0)		33 (36.3)		0.76
Anticoagulant use (%)	17 (18.7)		11 (12.1)		0.30
Preoperative chemotherapy (%)	0		0		1.00
Preoperative decompression (%)	0		1 (1.1)		0.32
<b>Perioperative details</b>					
Epidural anesthesia (%)	60 (65.9)		63 (69.2)		0.63
Surgical procedure (%)					
Right colectomy	39 (42.9)		41 (45.1)		0.90
Left colectomy	40 (44.0)		37 (40.7)		
Rectal resection	12 (13.2)		13 (14.3)		
Lymph node dissection (%)					
D1	2 (2.2)		1 (1.1)		0.24
D2	26 (28.6)		20 (22.0)		
D3	63 (69.2)		70 (76.9)		
Lymph node yield, mean (SD)	17.9 (7.8)	4–35	19.9 (8.1)	6–64	0.08
Anastomosis fashion (%)					
Hand-sewn anastomosis	72 (79.1)		65 (71.4)		0.46
Double-stapling method	17 (18.7)		24 (26.4)		
Functional end to end anastomosis	0		0		
No (Ostomy)	2 (2.2)		2 (2.2)		
Concurrent cholecystectomy (%)	3 (3.3)		4 (4.4)		0.70
Participated surgeons, mean (SD)	3.3 (0.48)	3–5	2.4 (0.61)	2–5	<0.01
Setup time, mean (SD), min	46.6 (9.7)	25–70	49.5 (12.0)	22–72	0.17
Operative time, mean (SD), min	289.1 (86.2)	125–520	267.2 (76.5)	140–461	0.07
Blood loss, mean (SD), ml	29.7 (32.0)	5–150	38.2 (49.1)	3–300	0.16
Conversion to open surgery (%)	2 (2.2)		2 (2.2)		1.00
Complications, CD grade 2 < (%)	2 (2.2)		3 (3.3)		0.65
LOHS, mean (SD), days	13.4 (4.5)	5–27	12.5 (5.2)	4–36	0.10

BMI body mass index, *setup time* duration between room entry to skin incision. Clavien–Dindo classification, *LOHS* postoperative length of hospital stay

A prospective randomized study comparing the infrared-guided EndoAssist (Armstrong Healthcare, High Wycombe, UK) robotic camera holder to human camera control found it a suitable substitute, with shorter operative time in laparoscopic cholecystectomy [13]. Omote et al. reported that using the robot instead of a human camera assistant

significantly reduced both the frequency of the camera correction, 2.2 per hour compared with 15.3 per hour, and frequency of the lens cleaning, 1.0 per hour compared with 6.8 per hour in laparoscopic cholecystectomy [22]. Tran et al. underwent single-port total extraperitoneal inguinal hernia repair with FreeHand® (Prosurge Ltd, Bracknell,



**Fig. 5** Distribution of propensity scores for the human assistant group and the Soloassist group before and after propensity score matching. **A** Before matching. **B** After matching

UK) camera controller in consecutive 16 cases compared with conventional single-port procedure and reported that the time wasted for scope cleaning was 8.5 min for conventional compared with 1.5 min for robotic scope holder-assisted surgery [23]. Stolzenburg JU et al. also reported that significant differences in favor of the FreeHand camera holder were observed in case of horizontal and zooming camera movement, camera cleaning, and inadvertent movements of the laparoscope by prospective randomized study in endoscopic extraperitoneal radical prostatectomy [24]. We recently reported the results of a similar retrospective study in laparoscopic cholecystectomy counting the frequency of scope cleaning due to intraoperative contamination and found significantly decreased number of scope cleaning

(human assistant group: 3.2, Soloassist group: 0.9 times) and significantly shortened operative time in the Soloassist group compared to the human assistant group [16]. In the current study analyzed retrospectively, shortening of the operation time was observed only in the case of the right-side colectomy, and no significant difference was shown after the propensity score matching. However, we believe that clinical application of Soloassist is safe and feasible, at least without prolongation of the operative time.

We recognize the Soloassist has some notable features compared with other robotic scope holders. Prior robotic scope holders are controlled by voice, foot-pedal, or infrared-guided head motion signals. The joystick of Soloassist is a reliable interface operated by fingers that human can use most dexterously, and we can freely control both moving direction and distance. Most of prior robotic scope holder require large scope-mounting parts in the surgical field to control the movement of the laparoscope; therefore, the movement of the forceps is sometimes restricted. As the feature of Soloassist, the angle of rotation is determined indirectly by using draw-wire sensors, which are installed at the bottom of the main body which is located underneath the operating table. Therefore, the shape of the arm is really slim. Additionally, Soloassist has a unique arm, named “universal joint” and we can avoid the interference between the forceps by rotating it. For self-standing robotic scope holders which must be installed on the floor, tilting the operation table does not allowed while inserting the laparoscope into peritoneal cavity [13]. In laparoscopic surgery, we need to change the inclination of the operation table to create an appropriate surgical field, particularly in colorectal surgery. Thus, before tilting the operation table, it is necessary to pull out the laparoscope from the peritoneal cavity once for safety in self-standing robotic scope holders. Moreover, it is necessary to readjust the axis of scope motion and the total procedure will be longer. As Soloassist can be attached to the operation table directly, it is possible to tilt the operation table with the laparoscope inserted into abdominal cavity and readjustment is not necessary. Therefore, Soloassist permits easy position change. Additionally, our result demonstrated that the time taken to install Soloassist did not affect the occupation time of the operating room.

In recent years, robotic surgery represented by da Vinci has been applied clinically and attracted a lot of attention [18–20]. Otherwise, according to the aggregate results of the nationwide database, clinical benefit to the patient could not be found, while higher medical expenses and longer operation time were required [25–27]. In 2017, the result of well-designed multicenter randomized controlled trial comparing robot-assisted laparoscopic resection and conventional laparoscopic resection in rectal cancer surgery was published [28]. Because rectal resection requires the procedures in a narrow pelvic space, it thought to emphasize the advantages

of robotic surgery, but the clinical benefit of robotic surgery was not demonstrated. There was no significant benefit not only in conversion rate, configured as a primary endpoint, but also in bladder dysfunction, sexual function, and pathological resection margin positivity. However, we believe there are valuable advantages for robotic surgery that surgeon can control forceps by four fingers without twisting the wrist widely for complicated procedure in sitting position under a clear 3D image. In other words, surgeons can perform surgery with a relatively relaxed position, so stress and fatigue might be reduced, though quantitative evaluation is difficult. When using the robotic scope holder, it is a great advantage that the assistant's shoulders and arms are not in the vicinity of the surgeon during the operation, providing a highly flexible, relaxed working environment. According to the report with the usage of the most recently commercialized robotic system: AUTOLAP (MST, Yokneam, Israel), significant satisfaction of the surgeons was demonstrated [29]. Although it cannot fulfill all the advantages of full robotic surgery, the use of robotic scope holder and 3D laparoscope makes it possible that we can secure a stable field of view intuitively under 3D vision with a comfortable arm position [15].

It is important to consider that some concerns have been raised regarding an apparent shortage of general surgeons and a decline in residency applications to surgical department [30–33]. As the result of the present study that the number of participating surgeons was apparently smaller in the SA group, we could reduce the human resources and personnel cost by introducing Soloassist. We believe that the reduction in the number of participating surgeons by using ideal robotic scope holders will provide significant benefit in the future. Indeed, the operation schedule is planned on the assumption that four gastrointestinal surgeons participate in our hospital. When three surgeons including operator, assistant, and scope assistant were involved in single operation, it was impossible to perform another operation at the same time. But, after introducing two units of Soloassist, it became easy to finish scheduled surgery within working hours because Soloassist enable us to conduct two operations simultaneously. This allowed us to reduce the overtime work of not only surgeons but also other staffs in the operating room. Gillen et al. calculated the relative operating time (in personnel/minutes/operation) and showed it was significantly shorter ( $p < 0.001$ ), meaning Soloassist use enabled to reduce absolute overall staff-working time [15]. Dunlap KD et al. postulated that operating room managers must properly appraise new tools and blend their resources to achieve optimal cost benefits with the advancement of technology. They reviewed the results of five previous research studies comparing robotic scope holder to human assistant and concluded that the robotic arm not only outperforms human camera holders,

but also reduces laparoscopic surgical operating time, resulting in improved efficiency and cost savings to the institution [34].

In conclusion, for maximizing the benefits of image technology progress, there is no doubt that a stable surgical view is desirable. The development of a practical scope holder which is less expensive to introduce and to maintain than full-robot surgery is expected for the progress of surgery. Therefore, we believe that robotic scope holders might play an important role between conventional laparoscopic surgery and full robotic surgery. To clarify the efficacy of robotic scope holder, such as Soloassist, prospective randomized study is expected comparing the results with human assistant, robotic scope holder, and full-robotic surgery.

### Compliance with ethical standards

**Disclosure** Drs. Yasushi Ohmura, Hiromitsu Suzuki, Kazutoshi Kotani, and Atsushi Teramoto have no conflicts of interest or financial ties to disclose.

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