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ORIGINAL ARTICLE

Laparoscopic inguinal hernia repair with a joystick-guided robotic scope holder (Soloassist II®): retrospective comparative study with human assistant

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Abstract

Purpose The purpose of this study was to evaluate the clinical usefulness of a joystick-guided robotic scope holder (Soloassist II®) in laparoscopic inguinal hernia repair.

Methods Among 182 inguinal hernia patients treated by laparoscopic transabdominal preperitoneal repair, 82 cases were completed with a human scope assistant, while Soloassist was used in 100 cases. We retrospectively compared perioperative results of Soloassist group and human scope assistant group. In 139 unilateral cases, we also used logistic regression of perioperative factors for the propensity score calculation to balance the bias.

Results All operations with Soloassist were carried out laparoscopically as solo-surgery without any system-specific complications. A statistically significant decrease in operation time was observed in Soloassist group compared with human assistant group (93.6 vs 85.9 min, $p = 0.05$). There was no prolongation of preoperative time or difference in the amount of intraoperative blood loss. Operation time was also significantly shorter in Soloassist group, when analyzing unilateral cases (85.5 vs 76.3 min, $p = 0.02$) and bilateral cases (126.9 vs 111.8 min, $p = 0.01$), independently. However, after propensity score matching in unilateral cases, there was no statistically significant difference between the two groups (83.8 vs 77.2 min, $p = 0.23$).

Conclusions The feasibility of Soloassist in laparoscopic inguinal hernia repair was demonstrated with no adverse device-related events. All surgeries could be completed as solo-surgery, while no additional time for preoperative setting was required. The mean operation time tends to be shorter in Soloassist group compared with human assistant group. Soloassist could be an effective device in laparoscopic inguinal hernia repair.

Keywords Laparoscopic inguinal hernia repair · Robotic scope holder · Soloassist · Solo-surgery

Introduction

Minimally invasive surgery has become a standard procedure for various operations and further refinements attribute to its progress including the introduction of energy devices, high-resolution images, and robotic technology. In the history of robotic technology, active robotic scope holders have been developed to manipulate the laparoscope intuitively by operators, in addition to providing a stable operative field and saving human resources [1–4]. In the co-axial operational position, the laparoscope has to be operated through the trocar between the operator's arms. Therefore, the scope assistant needs to reach into the space from across or from the same side as the operator. Especially in laparoscopic hernia surgery, which is generally performed by three ports, the surgeon is forced to manipulate the forceps at a much lower position compared with other laparoscopic surgeries because of the

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anatomical location of the groin area. Therefore, interference between the arms of the operator and the scope assistant tends to occur. We thought that the introduction of a scope holder could eliminate these cramped conditions and we could do the operative procedure in a standard position. There were some reports evaluating the efficacy of robotic scope holders, and their reliability, feasibility, and clinical benefits in laparoscopic inguinal hernia repair were reported [3–6].

Soloassist II® (AKTORmed, Barbing, Germany) is a robotic scope holder with computer-controlled electric motors, a more practical model compared with the previous version. Designed to be simple and compact, Soloassist can be easily installed on any part of the operating table while scope movements are controlled by the surgeon in a straightforward and intuitive fashion via an ergonomic joystick. Since December 2014, we introduced the Soloassist system and used it in various surgical procedures [7]. The purpose of this study was to evaluate the clinical feasibility and usefulness of Soloassist by comparing perioperative results before and after its introduction in laparoscopic inguinal hernia repair.

Materials and methods

Operative procedures with Soloassist

The Soloassist robotic camera control system is a joystick-guided robotic endoscope holder with computer-controlled electric motors (Fig. 1). The structure and mechanical characteristics of Soloassist were described in the previous reports [4, 7]. After introduction of general anesthesia, both arms of the patient were fixed to the body so that we could administer occult contralateral lesion. Basically, we attached Soloassist to the side rail of the operating table on the opposite side from the operator across the target lesion (Fig. 2). After sterilization and draping, a 12-mm port was inserted through the umbilicus using the laparotomy method and 8-mmHg pneumoperitoneum was developed. Regardless of unilateral or bilateral cases, a 12-mm port from right side and a 5-mm port from left side were inserted at the same level of the umbilicus. We used a 10 mm, 2D flexible laparoscope (ENDOEYE FLEX®, LTF-S190-10: Olympus Medical, Tokyo, Japan), or 3D flexible laparoscope (ENDOEYE FLEX 3D®, LTF-190-10-3D: Olympus). The operator stood on the opposite side of the lesion and the patient was in head-down tilted position with a mild rotation towards the operator (Fig. 3a). In bilateral cases, the operator moved to the opposite side and performed the same procedure with the reverse rotation (Fig. 3b). In all cases, prostheses were used for posterior reinforcement of inguinal hernia repair techniques by transabdominal preperitoneal (TAPP) approach, and the dissected peritoneum was closed with 3–0 absorbable thread by means of continuous intracorporeal suture (Online Resource 1).

Patients and evaluation

A total of 251 patients underwent inguinal hernia repair in our institutions between October 2013 and December 2017. Among them, 66 cases involved the anterior approach, whereas laparoscopic repair was involved in 185 cases. Three patients who underwent simultaneous cholecystectomy were excluded and for the remaining 182 patients, we retrospectively evaluated the perioperative results before and after introduction of Soloassist (Fig. 4). Before its introduction, 82 cases were performed with a human scope assistant, while Soloassist was used in 100 cases after the introduction. In this study, all operations were performed by two surgeons. Both

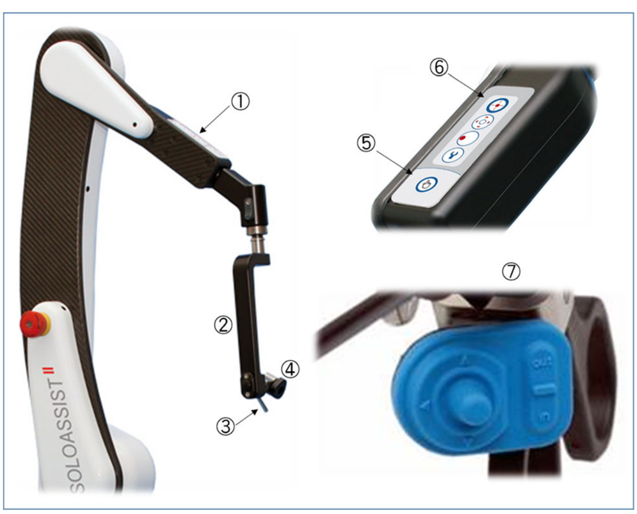

Fig. 1 Soloassist II® camera control system. ① Control panel. ② Universal joint. ③ Probe check. ④ Camera cramp. ⑤ Unlock button. ⑥ Trocar point. ⑦ Joystick

Fig. 2 Laparoscopic transabdominal preparatory repair for right inguinal hernia with Soloassist II

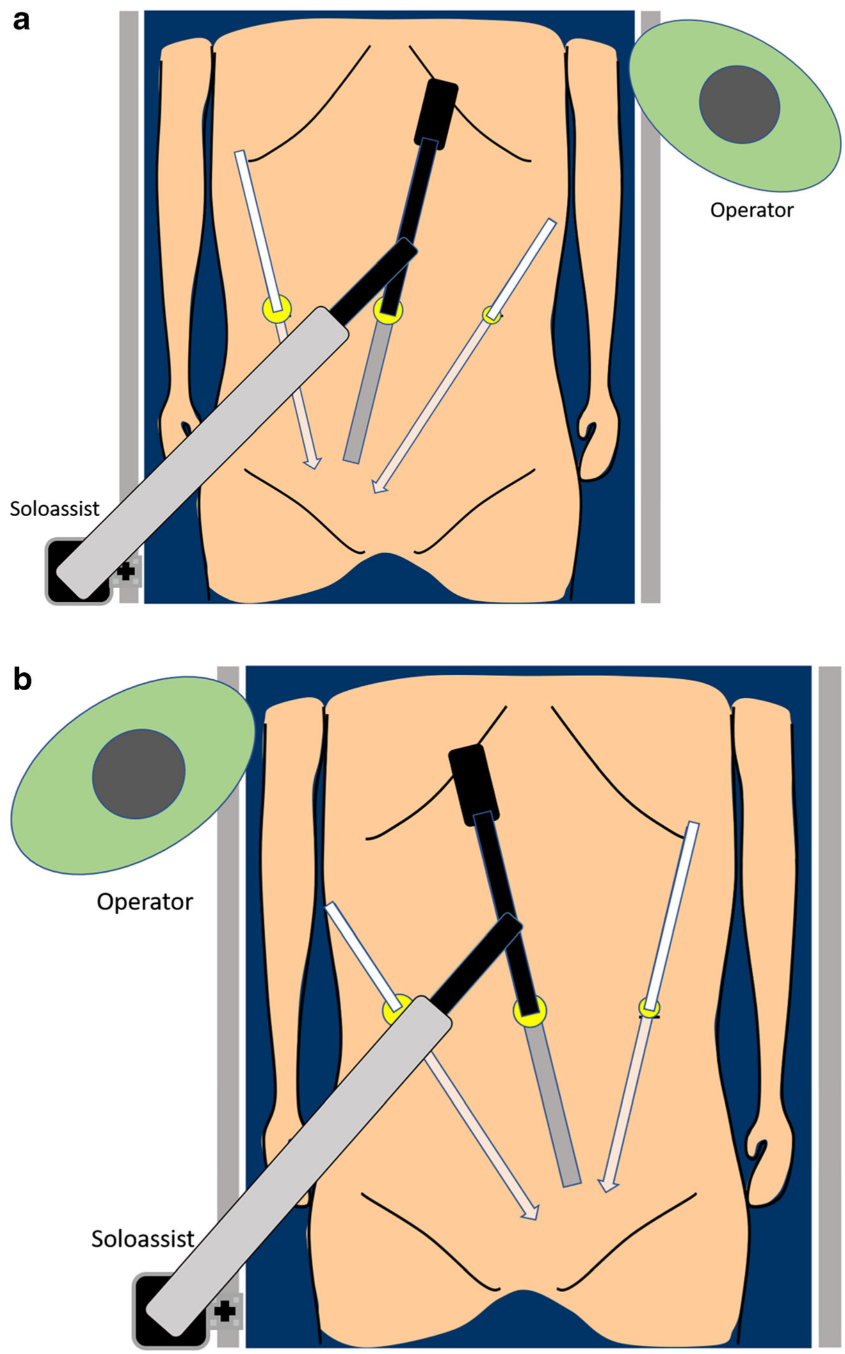

Fig. 3 Surgeon position and Soloassist II for laparoscopic inguinal hernia repair in bilateral case. In bilateral inguinal hernia cases, the position of Soloassist and the surgeon is the complete opposite across the lesion during right side procedure (**a**) and for left side repair, the surgeon moves to the same side as Soloassist (**b**). There is no need to move Soloassist

had extensive experience with laparoscopic surgery by 2013. We have previously reported that at least five interaction are required to become proficient in using Soloassist [7]. The surgeons already had 10 or more instances of using Soloassist, including cholecystectomy, appendectomy, colorectal surgery, and gastrectomy, before the first experience of TAPP. All patients gave their informed consent for laparoscopic procedures with or without robotic scope holder. The type of groin hernia was recorded according to the Japanese Hernia Society Classification [8].

Statistical analysis

First, we investigated operation time, amount of intraoperative bleeding, length of hospital stay after surgery before and after the introduction of Soloassist in all 182 cases. In cases where the amount of bleeding was small and could not be counted, the amount of intraoperative bleeding was recorded as 3 ml. For the purpose to evaluate whether the time required for the setting of Soloassist had an influence on operating room occupation time objectively, the time from room-entry to initial

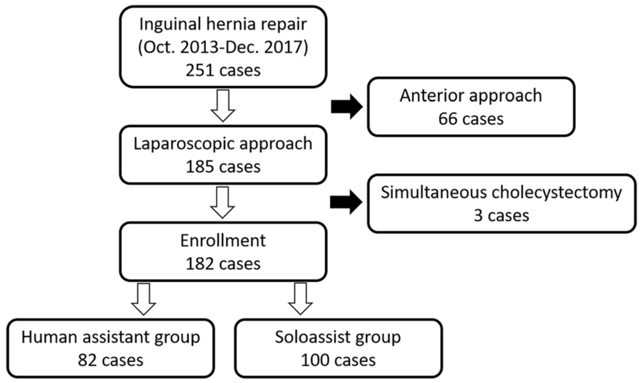

Fig. 4 Flow chart for enrollment

skin incision was calculated as the set-up time. Second, we conducted a similar analysis in unilateral and bilateral cases independently.

As this was a retrospective study without randomization, there was a possibility of confounding between the two groups involved. Therefore, in order to account for the bias, a logistic regression of the following factors was used for calculating the propensity score in unilateral cases: age, sex, body mass index (BMI), American Society of Anesthesiologist score (ASA score), location of the lesion, anti-coagulant usage, and surgical history. 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 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 was used for comparison of categorical values. An open-source software, EZR ver. 1.37, was used for statistical analyses. All tests were two-sided, and a p value of < 0.05 was considered statistically significant.

Results

Demographic characteristics and perioperative information are given in Table 1. There were no statistical differences in background factors such as age, sex, BMI, and ASA score between the human assistant group and the Soloassist group. The number of bilateral cases was larger in the Soloassist group than in the human assistant group but there was no significant difference. Thirty-nine patients had a history of

Table 1 Demographic characteristics of all patients

Variables	Human assistant ($n = 82$)		Soloassist II ($n = 100$)		p value
	Mean	Range	Mean	Range	
Age (SD), year	65.2 (13.4)	16–94	66.1 (15.6)	20–96	$p = 0.69$
Sex, male/female	73/9		88/12		$p = 0.83$
BMI (SD), kg/m^2	22.1 (2.9)	15.1–32.1	22.9 (4.0)	12.4–34.0	$p = 0.10$
ASA score (%)					
1	30 (36.9)		28 (28.0)		$p = 0.12$
2	43 (52.4)		54 (54.0)		
3	9 (11.0)		18 (18.0)		
Location (%)					
Right	42 (51.2)		41 (41.0)		$p = 0.33$
Left	24 (29.3)		32 (32.0)		
Bilateral	16 (19.5)		27 (27.0)		
Previous abd. surgery (%)	13 (15.9)		26 (26.0)		$p = 0.10$
Recurrence (%)	3 (3.7)		7 (7.0)		$p = 0.51$
Postprostatectomy (%)	2 (2.4)		3 (3.0)		$p = 0.82$
Anticoagulant use (%)	5 (6.1)		20 (20.0)		$p < 0.01$
Operation time (SD), min	93.6 (26.5)	44–147	85.9 (26.0)	38–150	$p = 0.05$
Set-up time (SD), min	34.9 (4.9)	23–53	34.2 (7.8)	21–74	$p = 0.51$
Bleeding (SD), ml	7.1 (9.6)	3–50	6.2 (11.6)	3–100	$p = 0.57$
Complication (%)	2 (2.4)		2 (2.0)		$p = 1.00$
Seroma	1 (1.2)		2 (2.0)		
Port site hernia	1 (1.2)		0 (0.0)		
LOHS (SD), day	3.8 (2.3)	1–16	3.4 (1.8)	1–15	$p = 0.26$

SD, standard deviation; *BMI*, body mass index; *ASA score*, American Society of Anesthesiologist score; *Set-up time*, duration between room-entry to skin incision; *LOHS*, postoperative length of hospital stay prior abdominal surgery: 13 cases (15.9%) in the human assistant group and 26 cases (26.0%) in the Soloassist group. There were five cases with the history of prostatectomy: two cases (2.4%) in the human assistant group and three cases (3.0%) in the Soloassist group. Three cases (3.7%) of the human assistant group and seven cases (7.0%) of the Soloassist group were recurrent cases previously repaired by anterior approach. The anticoagulant users were more frequently observed in the Soloassist group (20%), compared with the human assistant group (6.1%) ($p < 0.01$). There were no system-specific troubles during surgery, such as the need to replace the joystick or an emergency stop due to unnecessary robot movement, and never converted to a human assistant.

Statistically significant decrease of operation time was observed in the Soloassist group (85.9 min.) compared with the human assistant group (93.6 min.) ($p = 0.05$). There was no statistical difference in set-up time and the amount of intraoperative blood loss. Postoperative hospital stay was also similar between two groups. Postoperative complications were observed in four cases. Seroma was recognized in one case of the human assistant group and two cases of the Soloassist group, and early reoperation due to port site hernia was performed in one case of the human assistant group.

Patients' characteristics and perioperative data of unilateral cases are shown in Table 2. The background data were similar in both groups. Indirect hernias, type I according to the Japanese hernia society classification, were 50 cases (75.8%) and 52 cases (71.2%) in the human assistant group and the Soloassist group, respectively. Operation time was significantly shorter in the Soloassist group (76.3 min.) compared with the human assistant group (85.5 min.) ($p = 0.02$). There was no difference in all other perioperative results.

Patients' characteristics and perioperative data of bilateral cases are shown in Table 3. Nineteen patients had bilateral type I inguinal hernias and in 13 patients, bilateral type II inguinal hernias were observed. In this cohort, there was no difference in their background, but operation time was also much shorter in the Soloassist group (111.8 min.) than in the human assistant group (126.9 min.) ($p = 0.01$).

After 1:1 propensity score analysis, a total of 139 unilateral cases included 72 matched patients (Table 4). Distribution of propensity scores for the human assistant group and the Soloassist group before and after propensity score matching is shown in Fig. 5. The distribution of propensity scores was scattered before matching (Fig. 5a), but it became similar after matching (Fig. 5b). The backgrounds of the matched patients were well balanced. The operation time was shorter in the Soloassist group in average (77.2 min.), but no statistically significant difference was observed compared with the human assistant group (83.8 min.) ($p = 0.23$). As all procedures were performed by two surgeons in the human assistant group, while by a single surgeon in the Soloassist group, the total staff time per operation was significantly longer in the human assistant group, compared with the Soloassist group

Table 2 Demographic characteristics of unilateral inguinal hernia

Variables	Human assistant ($n = 82$)		Soloassist II ($n = 100$)		p value
	Mean	Range	Mean	Range	
Age (SD), year	64.9 (13.7)	16–94	65.6 (16.6)	20–96	$p = 0.77$
Sex, male/female	58/8		62/11		$p = 0.62$
BMI (SD), kg/m^2	21.9 (2.9)	15.1–27.7	22.9 (4.3)	12.4–34.0	$p = 0.12$
ASA score (%)					
1	26 (39.4)		23 (31.5)		$p = 0.18$
2	32 (48.5)		35 (47.9)		
3	8 (12.1)		15 (20.5)		
Hernia type* (%)					
I	50 (75.8)		52 (71.2)		$p = 0.47$
II	16 (24.2)		21 (28.8)		
Location (%)					
Right	42 (63.6)		41 (56.2)		$p = 0.37$
Left	24 (36.4)		32 (43.8)		
Operation time (SD), min	85.5 (21.6)	44–147	76.3 (20.8)	38–123	$p = 0.02$
Set-up time (SD), min	34.5 (3.9)	24–43	34.1 (6.5)	21–57	$p = 0.59$
Bleeding (SD), ml	6.1 (8.2)	3–50	7.3 (13.4)	3–100	$p = 0.52$
LOHS (SD), day	3.8 (2.3)	2–16	3.5 (2.0)	1–14	$p = 0.53$

SD, standard deviation; *BMI*, body mass index; *ASA score*, American Society of Anesthesiologist score; *Set-up time*, duration between room-entry to skin incision; *LOHS*, postoperative length of hospital stay

*The type of groin hernia was classified according to the Japanese Hernia Society Classification

Table 3 Demographic characteristics of bilateral inguinal hernia

Variables	Human assistant ($n = 16$)		Soloassist II ($n = 27$)		p value
	Mean	Range	Mean	Range	
Age (SD), year	66.5 (12.4)	45–91	67.3 (12.7)	41–93	$p = 0.83$
Sex, male/female	15/1		26/1		$p = 0.73$
BMI (SD), kg/m^2	22.8 (3.1)	18.6–32.1	23.1 (3.2)	17.6–32.5	$p = 0.76$
ASA score (%)					
1	4 (25.0)		5 (18.5)		$p = 0.52$
2	11 (68.8)		19 (70.4)		
3	1 (6.3)		3 (11.1)		
Hernia type* (%)					
I/I	8 (50)		11 (40.7)		$p = 0.61$
I/II	2 (12.5)		5 (18.5)		
II/II	5 (31.3)		8 (29.6)		
Others	1 (6.3)		3 (11.1)		
Operation time (SD), min	126.9 (18.1)	85–147	111.8 (20.7)	62–150	$p = 0.01$
Set-up time (SD), min	36.1 (8.0)	23–53	34.7 (10.7)	22–74	$p = 0.61$
Bleeding (SD), ml	11.3 (13.5)	3–50	7.2 (13.7)	3–70	$p = 0.34$
LOHS (SD), day	3.7 (2.0)	1–10	3.1 (0.73)	1–5	$p = 0.26$

SD, standard deviation; *BMI*, body mass index; *ASA score*, American Society of Anesthesiologist score; *Set-up time*, duration between room-entry to skin incision; *LOHS*, postoperative length of hospital stay

*The type of groin hernia was classified according to the Japanese Hernia Society Classification

(167.6 min. vs. 77.2 min. $p < 0.01$). When we counted the frequency of camera cleaning in each propensity score matched 20 patients with available videos, the average was significantly less in the Soloassist group (2.3 vs 0.7 times, $p < 0.01$). There was no significant difference in other perioperative outcomes.

Discussion

This study found that laparoscopic inguinal hernia repair with the usage of Soloassist was successfully accomplished in all 100 cases without any system-specific complications, and there was no case of conversion to a human scope assistant, indicating its feasibility. In recent years, full robotic surgery represented by da Vinci surgery has attracted much attention, but in the history of its development, a robotic scope holder has also been developed and improved. Initially, scope holders were invented only with the intention to fix the scope [9, 10] and recently, robotic scope holders have been developed that allow the operator to control the scope intuitively without removing their hands from the forceps [1–4]. In the late 1980s, transurethral resection of the prostate was done with a robotic arm, called "PROBOT," developed at the Imperial College of London [11]. In 1994, a group in Montreal reported three cases of laparoscopic cholecystectomy involving the use of a robotic laparoscope manipulator [12]. In 1990s, AESOP (Computer Motion, Santa Barbara, CA, USA) had appeared on the market and had applied to general clinical practice [13]. Even after that, robotic scope holders with various mechanisms have been developed, but reports evaluating their usefulness were sporadic and had not been widely used in clinical practice to date.

Aino et al. conducted a prospective randomized study comparing the infrared-guided robotic camera holder, EndoAssist® (Armstrong Healthcare, High Wycombe, UK), with human camera control in 93 cases of laparoscopic cholecystectomy and demonstrated the shorten operation time with EndoAssist [2]. Our previous report of retrospective analysis in laparoscopic cholecystectomy also demonstrated shortened operation time with Soloassist compared with the human assistant [7]. In the present study, operation time was shorter in the Soloassist group; however, the difference was not statistically significant after propensity score matching in laparoscopic unilateral inguinal hernia repairs. Above all, the most notable point in this study was that at least the operation time was not extended with the use of Soloassist, as well as preoperative room occupying time. Our previous report of similar analysis in laparoscopic colorectal resection revealed that Soloassist system provided the possibilities of saving human resources without extra time or system-specific morbidity [14].

We considered that robotic scope holders can provide some benefits in relation to comfortable operative situations. First, with a human assistant, the laparoscope is often not steady or centered to the surgeon's satisfaction. The use of Soloassist which can be controlled intuitively by an operator could

Table 4 Demographic characteristics of unilateral inguinal hernia after propensity score matching

Variables	Human assistant ($n = 36$)		Soloassist II ($n = 36$)		p value
	Mean	Range	Mean	Range	
Age (SD), year	66.8 (14.7)	16–94	62.7 (18.6)	20–89	$p = 0.29$
Sex, male/female	30/6		32/4		$p = 0.73$
BMI (SD), kg/m^2	22.1 (2.5)	17.0–26.7	21.7 (3.6)	12.4–31.1	$p = 0.63$
ASA score (%)					
1	9 (25.0)		13 (36.1)		$p = 0.38$
2	20 (55.6)		17 (47.2)		
3	7 (19.4)		6 (16.7)		
Hernia type* (%)					
I	27 (75.0)		25 (69.4)		$p = 0.60$
II	9 (25.0)		11 (30.6)		
Location (%)					
Right	22 (61.1)		21 (58.3)		$p = 0.81$
Left	14 (38.9)		15 (41.7)		
Operation time (SD), min	83.8 (25.6)	44–147	77.2 (19.5)	38–123	$p = 0.23$
Set-up time (SD), min	33.9 (4.2)	24–40	33.4 (6.2)	21–49	$p = 0.71$
Bleeding (SD), ml	6.2 (7.0)	3–30	9.7 (18.0)	3–100	$p = 0.29$
LOHS (SD), day	3.7 (2.0)	2–13	3.5 (2.5)	1–14	$p = 0.72$

SD, standard deviation; *BMI*, body mass index; *ASA score*, American Society of Anesthesiologist score; *Set-up time*, duration between room-entry to skin incision; *LOHS*, postoperative length of hospital stay

*The type of groin hernia was classified according to the Japanese Hernia Society Classification

contribute to decreasing the surgeon stress. Another advantage is that the assistant's shoulder and arms are not in the vicinity of the surgeon during the operation, providing a highly flexible, relaxed working environment. In the co-axial operational position, the scope assistant has to operate the laparoscope through the trocar between the operator's arms. Therefore, the scope assistants are sometimes forced to manipulate the laparoscope at the extreme position and the operators must move their arms to avoid collision with the assistant's arms. The usage of scope holder makes it possible to improve such working environment and allows us to do the operative procedure in a relaxed position. Takahashi et al. [3] examined perioperative results of 25 cases in laparoscopic inguinal hernia repair with ViKY® (EndoControl, Grenoble, France) and reported that stress of the surgeon was reduced, leading to high satisfaction scores using the Likert scale. Moreover, according to the previous reports, scope cleaning and unnecessary scope movement decreased by using robotic scope holders [6, 13, 15]. We recently reported the results of a similar retrospective study in laparoscopic cholecystectomy counting the frequency of scope cleaning due to intraoperative contamination. Scope cleaning was more frequently required in the human assistant group compared with the Soloassist group: the averages were 3.2 and 0.9, respectively [7]. In hernia surgery, the amount of intraoperative bleeding that could potentially cause a scope contamination was expected to be small, but this study also showed statistically significant difference. The decreased frequency of scope cleaning might eliminate cumbersome tasks and surgeon stress.

As a human-machine interfaces, various guiding methods have been designed, such as foot pedal, voice command, infrared signal, and joystick [1–4]. Foot pedals are intuitive because they free the hands from the scope guidance task, but the feet are inherently clumsier than hands for precise tasks. EndoAssist® and recently released EMARO® (HOGY Medical, Tokyo, Japan) are unique and reliable freestanding laparoscopic camera manipulators controlled by infrared signals from a head attachment worn by the operator. With these devices, both the head and the foot are required to work cooperatively to avoid unintentional movements. As a voice-controlled robotic scope holder, ViKY is a superior and reliable system [3]. However, the voice-controlled device could not always recognize our commands. Additionally, there are only two settings regarding moving distances and the direction of movement is limited to four axes for scope readjustment. With the Soloassist, fine movements are adjusted with a joystick, whereas dynamic movement can be enabled manually with the unlock button, and the distance and direction can be determined freely.

There are some concerns that lack of training as a scope assistant might be an obstacle to develop a skillful laparoscopic surgeon. We also believe that training the next generation of surgeons is an important responsibility. To meet such demands, joystick may be an easy-to-use interface that can be

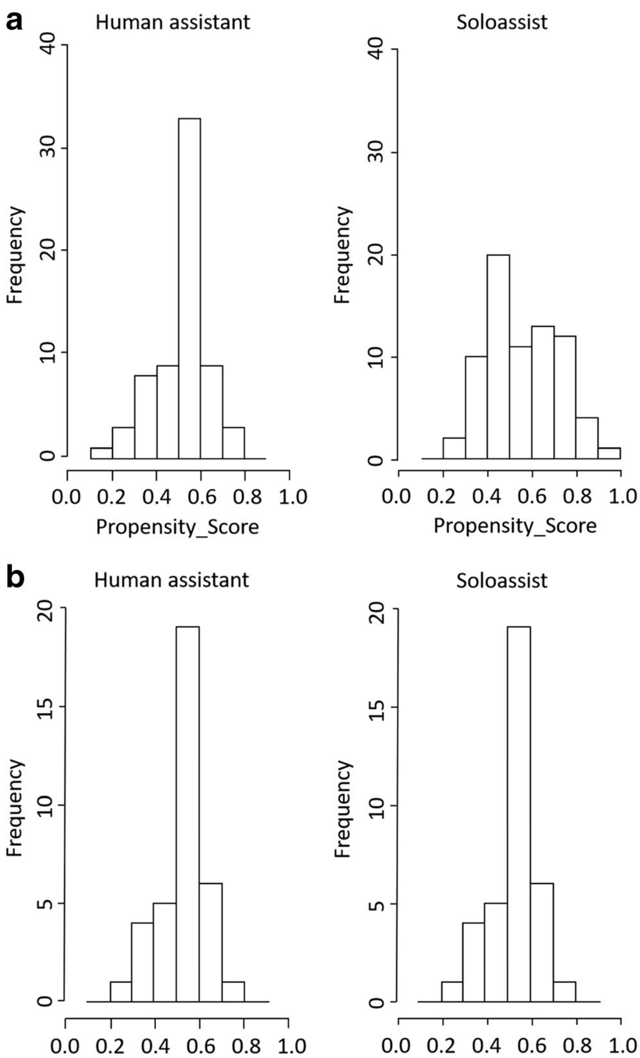

Fig. 5 Distribution of propensity score of unilateral inguinal hernia patients. The propensity scores before matching were scattered (**a**), but it became similar distribution after matching (**b**)

used for training as a scope assistant from a remote position without entering the working space of the operator. This idea could be a useful method especially in the initial stage of introduction. However, robotic scope holders were originally developed to control the operative field intuitively by the operator. We have previously reported that 5 cases of experience are required for learning curve using Soloassist [7]. So, surgical residents could get used to manipulating the joystick in a shorter period than we expected. We have already used Soloassist in routine laparoscopic surgeries and with the attendance of an experienced surgeon, the surgical residents are also performing TAPP as solo-surgery. The experienced surgeons attending as the supervisor feel that higher quality instruction is possible because they can provide the educational advices without operating the laparoscope in a narrow space.

There are two ways to install the robotic scope holders. One is a freestanding type installed onto the floor. Due to the fact that these devices are relatively heavy and bulky to maintain its stability, they occupy precious space near the operating table. Moreover, they cannot follow the movement of the operating table, so it is prohibited to change the inclination of the operating table without removing the laparoscope [1, 2]. On the other hand, the scope holders attached to the operating table are designed relatively small which permits tilting the operating table easily compared with the freestanding scope holder. Newly developed surgery supporting devices sometimes require complicated settings and consume a longer time to set it up. A recent report noted that it took a longer time to set up the robotic devices [16]. Since Soloassist can be easily installed on any part of the operating table within a short time, our study revealed the use of Soloassist did not affect set-up time.

The most notable feature of the Soloassist is that it is designed in a really simple and slim shape. Most prior robotic scope holders 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. With Soloassist, the angle of the rotation is determined indirectly by using draw-wire sensors which are installed at the bottom of the main body, located underneath the operating table. As a result, the shape of the arm is really slim. Additionally, Soloassist has a unique arm named "universal joint" that allows us to avoid the interference between the forceps by rotating it.

In conclusion, the feasibility of Soloassist application to laparoscopic inguinal hernia repair was demonstrated with no device-related adverse events. All surgery could be completed as solo-surgery, while no additional set-up and operation time was required. Considering a recent shortage of general surgeons and a decline in residency applications to surgical departments [17, 18], it is necessary to evaluate the efficacy of robotic scope holders objectively and to verify whether we can perform operations without deteriorating the quality of care even with less man power.

Authors' contributions Study conception and design, Yasushi Ohmura, Hiromitsu Suzuki, Kazutoshi Kotani, Atsushi Teramoto; acquisition of data, Yasushi Ohmura, Hiromitsu Suzuki; analysis and interpretation of data, Yasushi Ohmura, Hiromitsu Suzuki; drafting of manuscript, Yasushi Ohmura.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical statement All procedures performed in studies involving human participants were in accordance with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Human and animal right This article does not contain any studies with animals performed by any of the authors.

Informed consent Informed consent was indeed obtained from all individual participant included in the study.

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