Original Article

# Investigation of the Effect of Puncture Order and Position on the Difficulty of Lower and Middle Abdominal Port Placement

**Chihiro Nakai, Koji Yamanoi*, Akihito Horie, Ken Yamaguchi, Junzo Hamanishi, Masaki Mandai**
Department of Gynecology and Obstetrics, Graduate School of Medicine, Kyoto University, Kyoto, Japan

## Abstract

**Objectives:** Port placements at the mid-abdomen (mainstay of robotic surgery [Rob]) appear to be difficult compared to that at lower abdomen (mainstay of conventional laparoscopy [Con-Lap]). We hypothesized that the reason for this may be the difference in port puncture places.
**Materials and Methods:** We examined how the differences between the place and puncture order of ports affected Con-Lap cases with ports mainly placed in the lower abdomen and Rob cases with ports mainly placed in the middle abdomen. The trocar time was measured from the time when the puncture position and skin incision were determined and initiated, respectively, to the time when the port was punctured and fixed and used as the indicator of difficulty.
**Results:** In the Con-Lap group analysis, the trocar time of the left lower port was longer (right lower: 77 s, middle lower: 117.5 s, and left lower: 138 s, $P < 0.0001$). In the Rob group analysis, the trocar time of the left most port was significantly longer (right-most: 89.0 s, right-middle: 92.5 s, left-middle: 121.0 s, and left-most: 197.0 s; $P < 0.0001$). In addition, the total trocar time was significantly longer in the first puncture at the right-middle port in the Rob group (right-most first: 8.4 min, right-middle first: 12.4 min, and left-middle first: 8.5 min, $P = 0.0063$).
**Conclusion:** In the mid-abdomen port placement, mainstay of Rob cases, the puncture order, and port site have a significant impact on the difficulty of the procedure. It is preferable to avoid initially puncturing the right-middle port in case of the Rob.

**Keywords:** Laparoscopy, robotic-assisted surgery, trocar order, trocar place

## Introduction

Laparoscopic surgery is the most common procedure in the field of gynecologic surgery. For a long time, laparoscopic surgery has been performed with direct manipulation of the camera and forceps by a physician, and ports have been placed mainly in the lower abdomen. Even today, laparoscopic surgery, also known as Conventional laparoscopy surgery (Con-Lap), is still common in Japan, especially for benign adnexal tumors. Recently, robotic surgery (Rob) has been widely used in the world and the number of Rob cases is rapidly increasing.[1-3]

Port puncture is an important first step in laparoscopic surgery. In Con-Lap, the port is mainly placed in the lower abdomen. In contrast, in Rob, the port is placed mainly at the mid-abdomen, particularly at the level of the umbilicus. In addition, the distance between the ports is also different. The recommended distance in Con-Lap is around 9–12 cm, whereas, in Rob, it is 7–8 cm. We have started port placements at the mid-abdomen with the introduction of Rob in our department, but we feel it more difficult during daily surgery than lower abdominal port placement with Con-Lap. We

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**Address for correspondence:** Dr. Koji Yamanoi, Department of Gynecology and Obstetrics, Graduate School of Medicine, Kyoto University, 54 Shogoin-kawahara-cho, Sakyo-ku, Kyoto 606-8507, Japan.
E-mail: kojiymni@kuhp.kyoto-u.ac.jp



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imagine that the reason for this may be the difference in port puncture places as mentioned above, but there are no studies that have verified this issue.

Although there have been many reports about port placement, most of them have safety issues such as large vessel and organ damage during the initial puncture.[4-7] There were several reports regarding the differences in puncture force and tissue damage due to differences in the shape of the trocar tip.[8,9] However, to the best of our knowledge, there has been no report that examined the effect of the different positions and puncture orders of the ports.

In this study, we examined how the differences in the place and puncture order of the ports affected the difficulty in overall port placement procedure using time as an indicator. Concretely, we analyzed them among the lower abdominal ports, which was the mainstay of the Con-Lap, and among mid-abdominal ports at the level of the umbilicus, which was the mainstay of Rob.

## Materials and Methods

### Study design

This is a cross-sectional study on port placement time in laparoscopic surgery. In our department, we mainly placed the ports

in the lower abdomen in Con-Lap. On the other hand, we mainly placed the ports in the middle abdomen at the level of the umbilicus in Rob. Therefore, we examined the Con-Lap cases, where the ports are placed mainly in the lower abdomen, and the Rob cases, where placed mainly in the middle abdomen, respectively, using the procedure time as an indicator of difficulty.

### Ethical approval

In the present study, patients were not required to give informed consent to the study because we used anonymous clinical data which were obtained after each patient agreed to surgery by written consent. This study was approved by the Institutional Review Board of Kyoto University Hospital (number: R3552).

### Participants

Patients who underwent Rob ($n$ = 43) at our hospital from October 1, 2019, to August 31, 2021, were included in the study. The installment of the ports that could be seen on video was analyzed.

Patients who underwent Con-Lap ($n$ = 62) at our hospital from April 1, 2021, to August 31, 2021, were included in the study. The installment of the ports that could be on video was analyzed. The distribution of age and body mass index of participants is described in Supplementary Table 1.

Typical port and surgeon placement in the Con-Lap and Rob cases performed by our department are shown in Supplementary Figure 1a and b. In Con-Lap, a sharp-bladed plastic trocar was used for the puncture [Supplementary Figure 1c]. Because our department is a teaching institution, surgeries are performed by trainee in their 2 to 3 years of surgical training and are supervised by advanced surgeons with more than 10 years of surgical experience. In our department, advanced surgeons stand on the right side of the patient and trainees stand on the left side of the patient. Therefore, advanced surgeons mainly place ports on the left side, whereas trainees place on the right side. The port was usually 5 mm in diameter, and in 31 cases, a 12-mm port was used in port L1. In Rob cases, 8-mm ports were inserted in ports R1, R2, and R3 using a sharp-bladed trocar [Supplementary Figure 1d]. In port R4, a 12-mm AirSeal® Access port system and a bladeless trocar tip were used [Supplementary Figure 1e].

### Time measurement

The procedure time was measured by viewing the video retrospectively. The trocar time was measured from the time when the puncture position was determined, and the skin incision was started to the time when the port was punctured and fixed. The duration time from the end of a port insertion and fixation to the start of the skin incision for the next port puncture was defined as the preparation time. The port time was measured from the start of the initial port puncture until all ports were inserted, and fixation was completed.

### Statistical analysis

For the continuous variables, the Mann–Whitney $U$-test was used for comparisons between the two groups. When three or more groups were compared, a one-way analysis of variance test was first performed to determine if there was a significant difference in the overall distribution. If there was a significant difference, a Bonferroni's correction was performed for the comparisons between the two groups. $P < 0.05$ was considered a statistically significant difference.

## Results

### Analysis of the port placement in the lower abdomen in the Con-Lap cases

First, we examined the differences in the trocar time by position in the Con-Lap cases when the ports were placed mainly in the lower abdomen. The results showed significant differences in the trocar time among the positions [Figure 1a, $P < 0.0001$]. Specifically, the trocar time of L1 was significantly shorter than those of L2 and L3 [median time, L1: 77 s, L2: 117.5 s, L3: 138 s; L1 vs. L2: $P < 0.0021$; L1 vs. L3: $P < 0.0001$; Figure 1a]. In port L1, we used a 12-mm port in 31 patients. We considered the effect between the trocars with 5 mm and 12 mm. However, there was no significant difference in the trocar time [median time, 5 mm: 78.0 s, 12 mm: 70.0 s, $P = 0.470$, Supplementary Figure 2a].

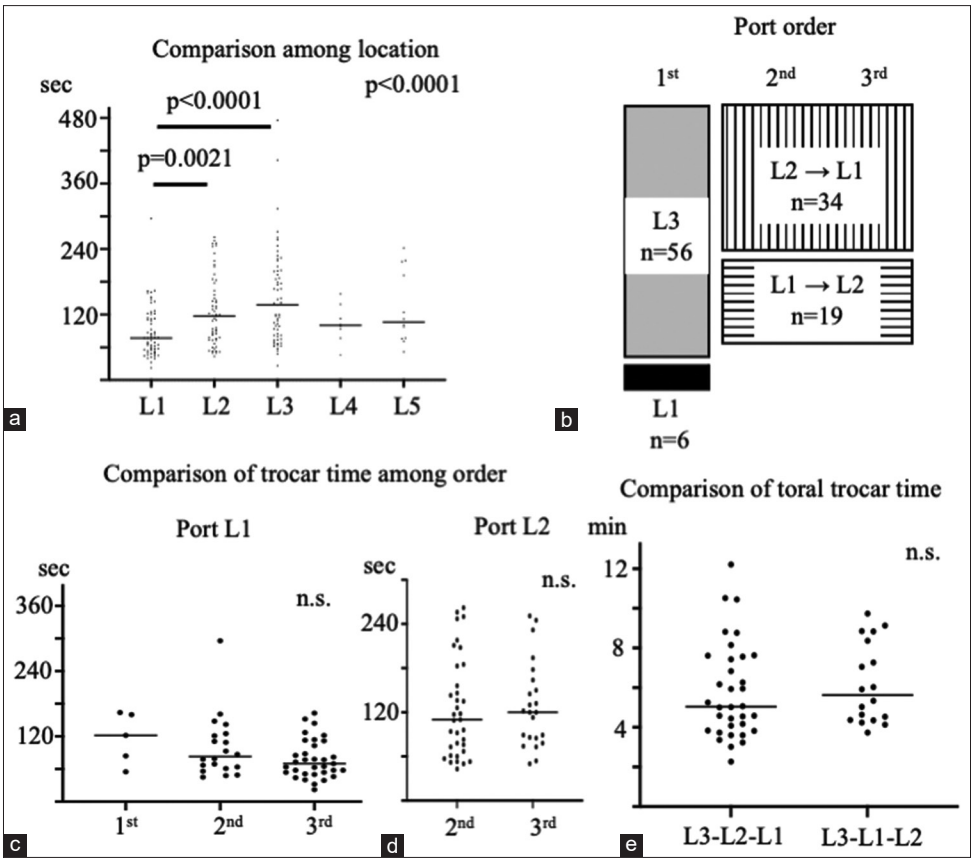


**Figure 1:** Analysis about Con-Lap. (a) Comparison of trocar time, (b) the order of port puncture, comparison of trocar time among order of puncture in port L1 (c), and L2 (d), (e) comparison of total trocar time between L3-L2-L1 and L3-L1-L2

We then examined whether the order of port puncture affected the trocar time. We first examined the order of the port puncture. As a result, more than 90% of the cases had the port L3 punctured first. Followed by puncturing port L3, a total of 34 cases had punctured ports L2 to L1, and 19 cases had punctured ports L1 to L2 [Figure 1b]. The order of puncture at all port sites is shown in Supplementary Figure 2b. The number of cases, in which ports L4 and L5 were punctured, was very limited, and they were punctured after ports L1, L2, and L3 were all punctured. In this study, we focused on the lower abdominal ports. Therefore, we examined the relationship between the order of puncture and trocar time for ports L1 and L2 whose puncture order had not yet been established. The results showed no significant differences among port puncture orders [about port L1: $P = 0.148$, about port L2: $P = 0.836$; Figure 1c and d]. In general, the order of port puncture in the lower abdomen was divided into the following order: L3 → L2 → L1 and L3 → L1 → L2. When the total trocar time was compared for these two orders, no significant differences were found [median time: L3 → L2 → L1: 5.0 min L3 → L1 → L2: 5.6 min, $P = 0.55$, Figure 1e].

As a result, among the lower-abdominal port puncture cases, which were mainly adopted in Con-Lap, the insertion of port L1 was significantly difficult compared to that of ports L2 and L3. There was no apparent difference in the trocar time among the port puncture orders.

## Analysis of port placement in the middle abdomen in the robotic cases

We then examined the differences in the trocar time in various positions in Rob cases when the port was mainly placed at the mid-abdomen. The results showed that there was a significant difference in the trocar time among the port positions [$P < 0.0001$, Figure 2a]. Specifically, the trocar time was significantly longer for port R4 than for the others [median time, R1: 89.0 s, R2: 92.5 s, R3: 121.0 s, R4: 197.0 s; R1 vs. R4: $P < 0.0001$; R2 vs. R4: $P = 0.003$; R3 vs. R4: $P = 0.0025$; Figure 2a].

We then examined whether the order of port puncture affected the trocar time. At first, we examined the order of port puncture. The results are shown in Figure 2b and Supplementary Figure 3a. In all cases, port R4 was punctured at the end. The most common sites that were punctured first was port R1 ($n = 21$), followed by ports R2 ($n = 12$) and R3 ($n = 10$). Therefore, we examined whether the order of puncture affected the trocar time for ports R1, R2, and R3, which were punctured in various orders.

The results showed no significant difference among the puncture order in ports R1 and R3 [about Port R1: $P = 0.471$, about Port R3: $P = 0.208$; Figure 2c and e]. However, there was a significant difference in port R2 [$P = 0.0003$, Figure 2d]. Specifically, the 1st puncture of port R2 had a significantly longer time compared to those of the 2nd and 3rd punctures of port R2 [median time, 1st: 186.5 s, 2nd: 84.0 s, 3rd: 78.5 s, 1st vs. 2nd: $P = 0.0005$; 1st vs. 3rd: $P = 0.0029$; Figure 2d]. In addition, we compared all first punctures among ports R1, R2, and R3, and there was a significant difference ($P = 0.04$). Specifically, the trocar time of the first puncture of port R1 was short compared to that of ports R2 and R3 [median time, R1: 92.0 s, R2: 186.5 s and R3: 198.5 s; Supplementary Figure 3b].

We then examined the trocar time of the 2nd, 3rd, and 4th punctures. If port R1 was punctured 1st, ports R2 and R3 were punctured 2nd and 3rd, respectively. If port R2 was punctured 1st, ports R1 and R3 were punctured 2nd and 3rd, respectively. If port R3 was punctured 1st, ports R1 and R2 were punctured 2nd and 3rd, respectively. We compared the sum of trocar time of the second and third ports that were punctured in the three various patterns. The results showed significant differences among the three patterns. Specifically, the sum of total trocar time of the 2nd and 3rd puncture sites was significantly longer when port R2 was punctured 1st [median time, 1st-R1 pattern: 3.2 min, 1st-R2 pattern: 4.7 min, 1st-R3 pattern: 2.1 min, $P = 0.012$; Supplementary Figure 3c]. As for the 4th puncture, which consisted of port R4, the trocar time was not significantly different among the three puncture patterns [Supplementary Figure 3d]. After all, when the total trocar times were compared according to the 1st port site, puncturing port R2 first corresponded to a significantly longer time [$P = 0.0063$, median, 1st-R1 pattern: 8.35 min, 1st-R2 pattern: 12.4 min, 1st-R3 pattern: 8.5 min, 1st-R1 vs. 1st-R2: $P = 0.011$; Figure 2f].

As a result, among the middle-abdominal port puncture cases, which were mainly adopted in Rob, the difficulty of port insertion varied among the port place and port puncture orders.

## Analysis of preparation time in Con-Lap and robotic

The total port time consisted of the trocar time and preparation time, which included the time to determine the location of the puncture and to secure the field of view [Figure 3a]. We then analyzed the preparation time.

In the case of the Con-Lap, as mentioned earlier, port-puncture orders were divided generally into two patterns: L3-L2-L1 or L3-L1-L2. When the preparation time was compared

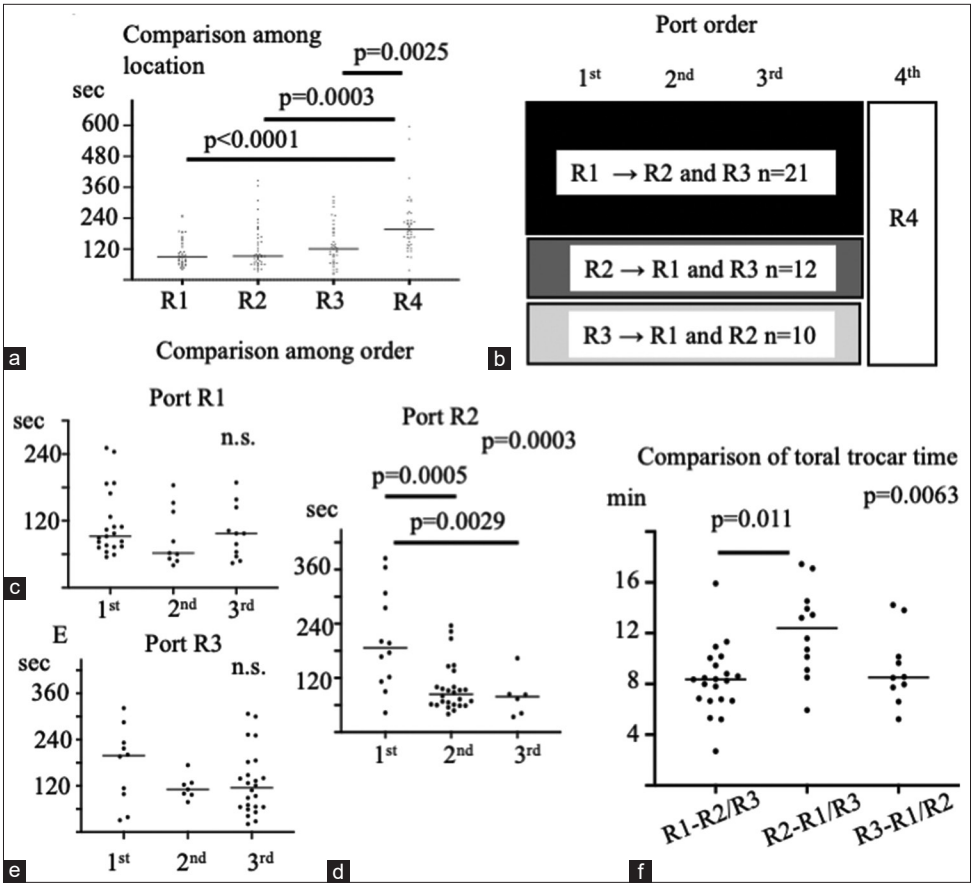


**Figure 2:** Analysis about the Rob cases. (a) Comparison of trocar-time among port sites, (b) the order of puncture, comparison of trocar-time among order of puncture in port R1 (c), R2 (d), R3 (e), (f) Comparison of total trocar-time among order of R1-R2/R3, R2-R1/R3 and R3-R1/R2. Rob: Robotic

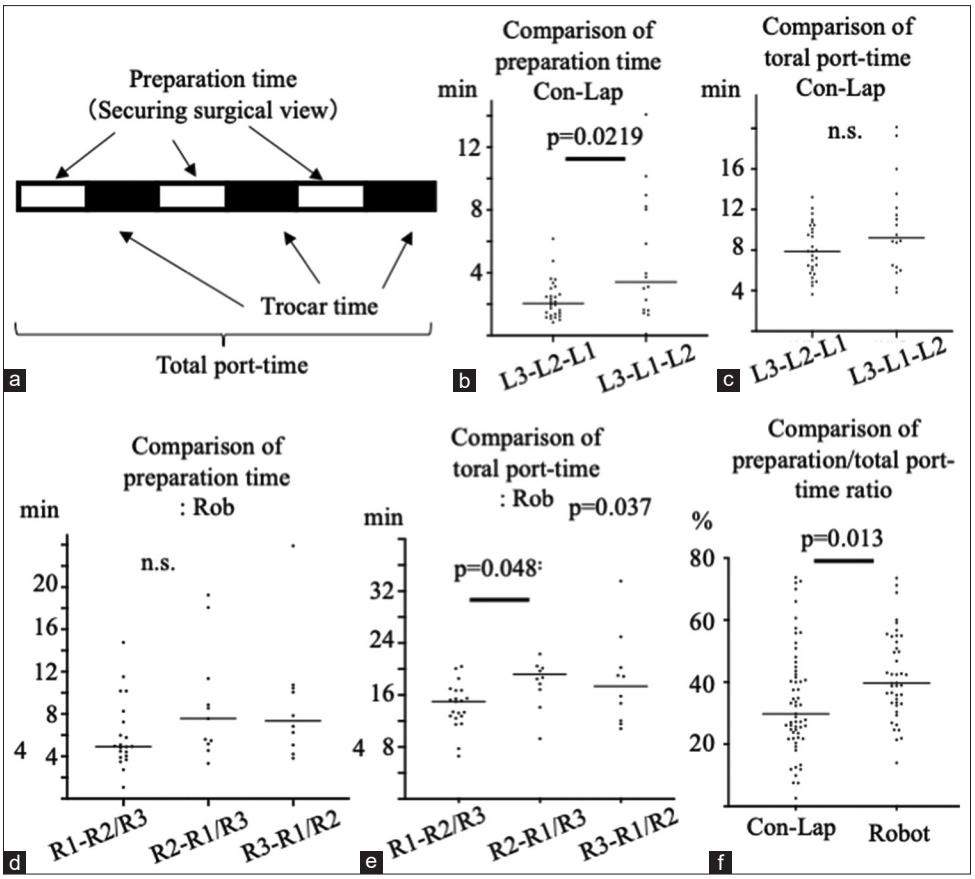


**Figure 3:** Analysis of preparation time. (a) A schematic view, comparison of preparation time (b), port-time (c) in Con-Lap cases, preparation time (d) and port-time (e) in Rob cases, (f) comparison of preparation/total port-time ratio between Con-Lap and Rob cases. Rob: Robotic

between these two patterns, it was significantly longer for L3-L1-L2 [median time, L3-L1-L2: 3.4 min, L3-L2-L1: 2.0 min, $P = 0.0219$; Figure 3b]. However, a comparison of the total port time showed no significant difference between the two patterns [L3-L1-L2: 9.2 min, L3-L2-L1: 7.9 min, $P = 0.0872$; Figure 3c].

In the case of Rob, we divided the puncture-order patterns into three according to the first puncture site. We then analyzed the data. As a result, there was no significant difference in the preparation time among the three patterns [median time, 1st-R1: 4.9 min, 1st-R2: 7.6 min, 1st-R3: 7.3 min, $P = 0.211$; Figure 3d]. We then compared the total port time among the three patterns, and there was a significant difference ($P = 0.037$). Especially, the 1st puncture with port R2 took a significant long time compared to that of the 1st puncture with port R1 [median time, 1st-R1: 15.0 min, 1st-R2: 19.2 min, 1st-R3: 17.4 min, 1st-R1 vs. 1st-R2: $P = 0.048$; Figure 3e].

Finally, we examined the ratio of the trocar time to the preparation time for Con-Lap and Rob. The results showed that the ratio required for the preparation time was significantly larger for Rob compared to that for Con-Lap [Median: Con-Lap: 29.8%, Rob: 39.7%, $P = 0.013$; Figure 3f].

## Discussion

In this study, we examined in detail how the difference in port sites and puncture order affect the difficulty in port placement procedure. Concretely, we analyzed Con-Lap cases where ports were placed mainly in the lower abdomen and Rob cases where ports were placed mainly in the mid-abdomen. A summary of our results is shown in Figure 4a.

First, we found that the trocar time was longer on the left side in both Con-Lap cases (lower-abdomen cases, port L3) and Rob cases (mid-abdomen cases, port R4). This result suggests that port puncture on the patient's left side is somewhat more difficult than on the right side. As for Rob, one of the reasons was the different diameter of the trocar tip, with port R4 being a 12-mm Airseal port, whereas ports R1 through R3 were 8-mm ports. However, in Con-Lap, about 40% of the ports L1 used were 12-mm diameter ports, but there was no difference in the trocar time compared to that seen with 5-mm diameter ports. We thought that the influence of factors other than diameter size should have existed.

At our department, the left side ports were usually placed by a trainee and not by advanced surgeons. This may explain our results. However, the trainee also punctured port L2 in Con-Lap and port R3 in Rob, and their trocar time was shorter

a

| | Location | order | Preparation time |
|---|---|---|---|
| Lower abdo. (Laparo) | L1-easy **(L2, L3-difficult)** | independent | short |
| Middle abdo. (Robot) | **R4-difficult** | ***Dependent (especially R2)*** | ***long*** |

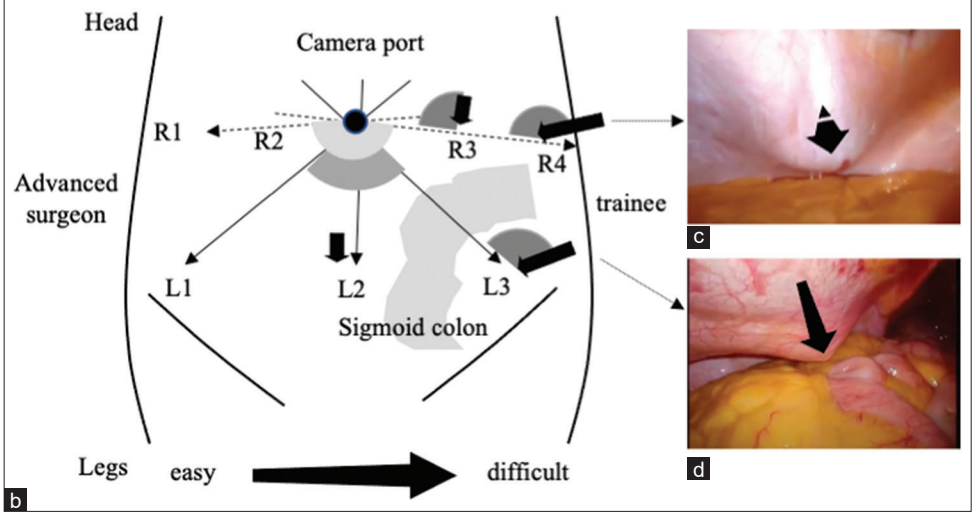


**Figure 4:** Summary and discussion of the angle between the camera and the working angle. (a) Results summary, (b) relationship between camera and working angle for Con-Lap (solid line) and Rob (dotted line), Image during port-R4 puncture (c) and port-L3 puncture (d). Rob: Robotic

than those of port L3 in Con-Lap and port R4 in Rob. The reason the outermost part near the trainee took more time was owing to the angle between the camera and port-puncture directions.

The port puncture was performed by viewing the camera image, and the angle between the camera direction and the puncture direction was apparently larger in the case of puncture–Rob R4 compared to those in Rob-R3 and Con-Lap-L3 compared to those in Con-Lap-L2 [Figure 4b]. Furthermore, the angle became the largest in the case of Rob R4, and it was close to the so-called "mirror image" [Figure 4c and d]. In laparoscopic surgery, it is important to establish hand–eye coordination, which can be affected by the angle between the camera image direction and the working direction. Recently, it has been reported that, while it is easy to perform at 0°, it is very difficult to perform at 180°, the so-called mirror image. Furthermore, there is a large difference in the proficiency between experts and nonexperts.[10,11] The puncture of Rob port R1 and Con-Lap port L1 are also performed in the identical conditions, but the reason the results differ significantly from Rob port R4 and Con-Lap port L3 may be because Rob port R1 and Con-Lap port L1 have been performed by advanced surgeons. In addition, on the left side of the patient, the sigmoid colon runs in parallel with the common iliac artery. As a result, the digestive tract becomes closer to the abdominal wall compared to that on the right side [Figure 4b]. Such differences between the right and left sides in terms of anatomical structure may also be another reason of difficulty.

It is very interesting to note that the effect of the order of puncture is not related to trocar time in Con-Lap, while a significant difference has been found in Rob. In particular, the 1st puncture of Rob port R2 was difficult compared to 2nd and 3rd puncture, even in the same position. In addition, the puncture of the 2nd and 3rd port got also difficult in the cases, in which port R2 was punctured 1st compared to the other patterns. As a result, the total port time of the 1st-port R2 pattern was significantly longer. It is not clear why the difficulty of the port puncture varies widely depending on the puncture order. When port R2 was punctured 1st, the puncture in port R1 was difficult to see, which might have affected the results. In addition, the cases in which port R2 had to be punctured 1st might have been those in which port placement was relatively difficult. We assumed that the port puncture order was affected to the difficulty in procedure to some degree, especially in Rob cases where the mid-abdomen placement was the mainstay. From this point of view, it seems that port puncture in Rob should at least avoid puncturing port R2 at first. Thus, we should start with port R1 whenever possible.

In addition, the preparation time for puncture was also significantly different between the Con-Lap and Rob cases. In the Rob cases, we should carefully consider the location of the puncture more precisely because forceps interference

would have a major impact on the console procedure, requiring longer preparation time. Furthermore, especially in ports R2 and R3 in Rob, the field of view is somewhat more difficult to achieve owing to its closeness to the camera port compared to those in ports R1 and R4. In addition, the range and angle to be followed by the camera are wider than in the case of the lower abdomen [Figure 4b]; hence, the range to be manipulated by the camera would become larger. The combination of these factors may require more preparation time for Rob. To reduce the difficulty, we can consider the factor of the angle of camera manipulation. For example, when puncturing ports R4 or R4, observation from port R2 allows a longer distance and a smaller angle to move the camera, which may lead to a smaller effort to move the camera and an easier puncture.

## Conclusion

This study reveals that the difficulty of port puncture can be dependent on puncture order and/or port site. The puncture of port R4 in Rob cases can be the most difficult, which is partly because puncturing it should be performed in a nearly mirror-image situation. In the training for port punctures, training in various camera angles should be important. Furthermore, the order of puncture is also important, especially when placing the ports for Rob cases. Although it may depend on the abdominal conditions, it is preferable to avoid puncturing port R2 at first, when possible. As laparoscopic surgery evolves, including Rob, the acquisition of port placement techniques is essential.[12] Even in the Con-Lap cases, ports are sometimes forced to be placed in the middle abdomen.[13,14] We hope that this study can be used in establishing a better training method for port puncture techniques.

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Nil.

### Conflicts of interest

There are no conflicts of interest.

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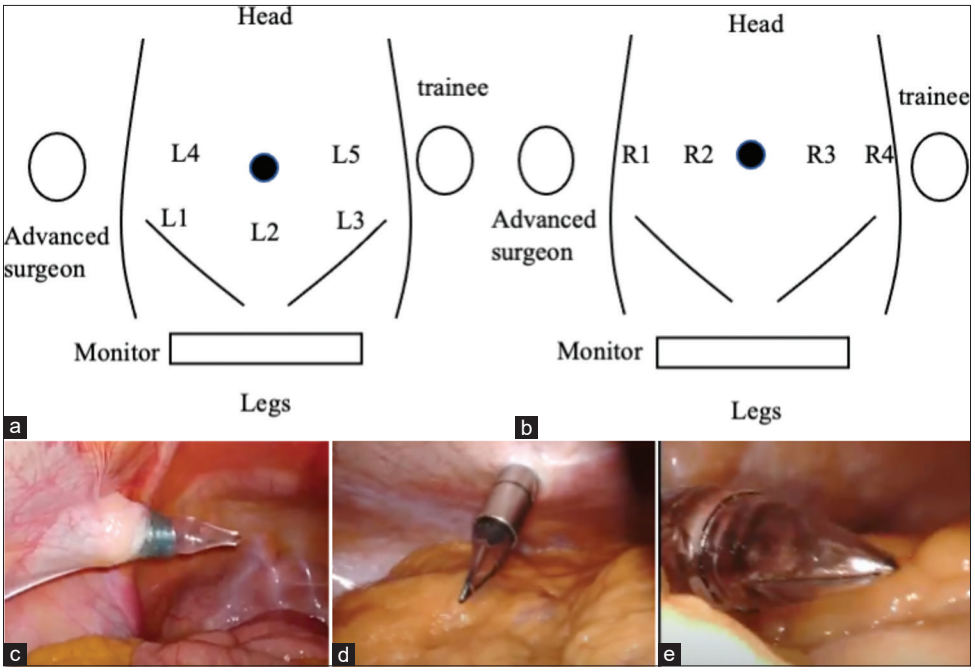
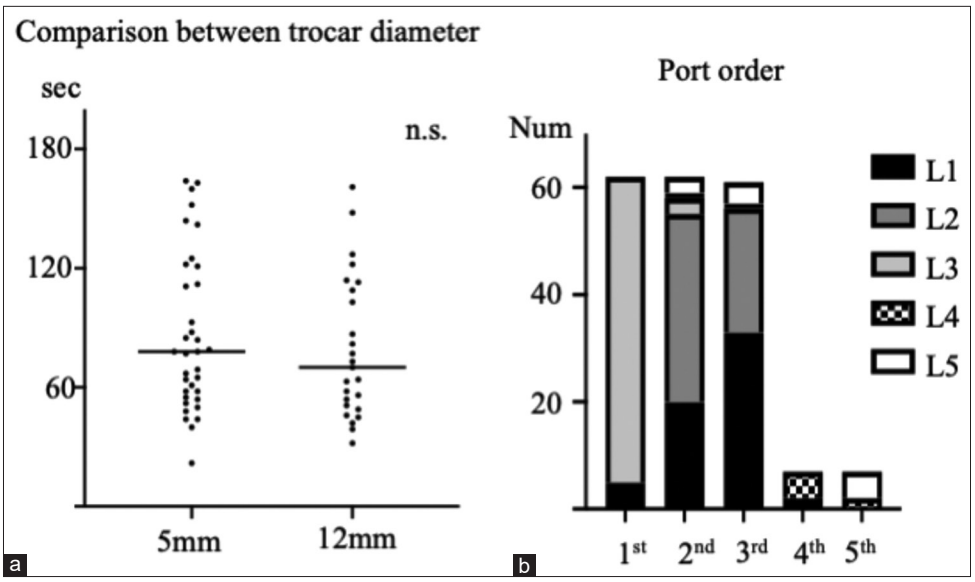
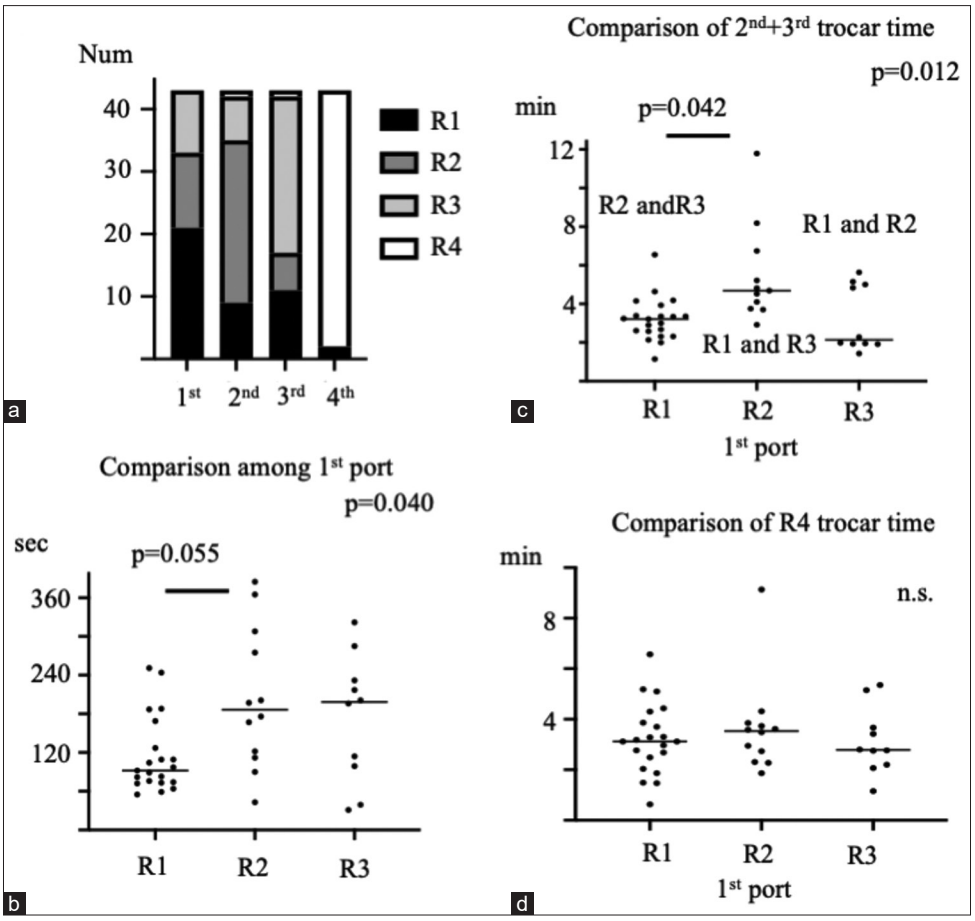
## Supplementary Material



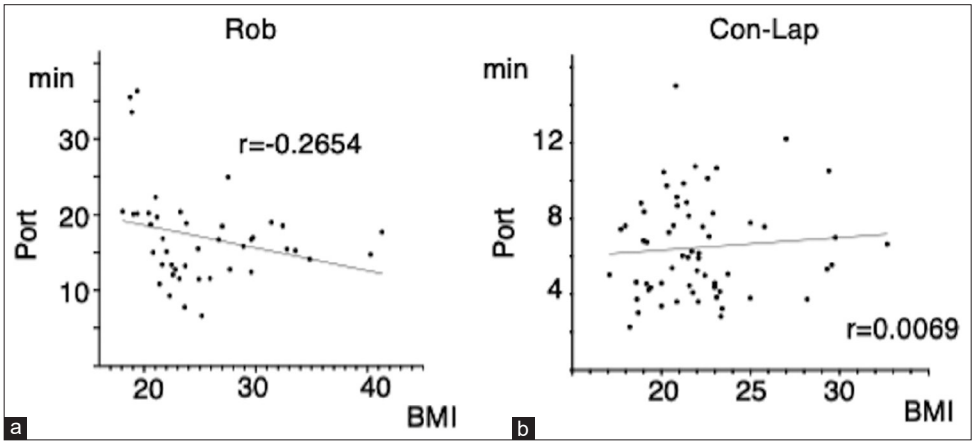

**Supplementary Figure 1:** Standard port placement, surgeon's position, and the type of trocar used at Con-Lap, Rob cases in our department. (a) Standard port placement at Con-Lap and surgeon's position. For each port place, we named them L1 ~ L5, as shown. Dark black circle indicates the umbilicus, (b) standard port placement at Rob and surgeon's position. For each port place, we named them R1 ~ R4, as shown. Dark black circle indicates the umbilicus, (c) trocar tip shape used in Con-Lap, (d) trocar tip shape used in Rob-8mm port, (e) trocar tip shape used in Rob-12mm AirSeal® port. Rob: Robotic




**Supplementary Figure 2:** Analysis of the port placement in the lower abdomen in the Con-Lap cases. (a) A comparison of trocar time between 12 and 5 mm port for port L1. No significant differences were found, (b) the details of port puncture order are as shown




**Supplementary Figure 3:** Analysis of port placement in the middle abdomen in the Rob cases. (a) The details of port puncture order are as shown, (b) a comparison of trocar time among first-puncture port. There is a significant difference among port places, (c) a comparison of the sum of 2nd and 3rd trocar time among first-puncture port. There is a significant difference among first-puncture port places, (d) a comparison of the 4th trocar time among first-puncture port. No significant differences were found




**Supplementary Figure 4:** Correlation between BMI and total port time in Rob and Con-lap cases. (a) Correlation analysis in Rob cases, (b) correlation analysis in Con-Lap cases. BMI: Body mass index, Rob: Robotic

**Supplementary Table1: Distribution of Age and BMI of participants in this research**

| | Rob | Con-Lap |
|---|---|---|
| Age | 53(47-62) | 48(40-54) |
| BMI | 23.6(21.3-28.3) | 21.6(20.0-23.1) |

Median and IQR are described