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Impact and characteristics of two- and three-dimensional forceps manipulation using laparoscopic hepaticojejunostomy mimicking a disease-specific simulator: A comparison of pediatric surgeons with gastrointestinal surgeons

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Abstract

Purpose: This study assessed the impact of 2D and 3D environments by comparing pediatric surgeons (PS) and gastrointestinal surgeons (GIS) using a laparoscopic hepaticojejunostomy simulator.

Methods: We developed a high-fidelity simulator of laparoscopic hepaticojejunostomy. Thirty-five participants (19 PS and 16 GIS) performed hepaticojejunostomy in both 2D and 3D environments. We evaluated the required time, total path length and average velocities of bilateral forceps in both situations using the para-axial port layout.

Results: Regarding the participants' characteristics, the performance history of laparoscopic hepaticojejunostomy differed significantly between PS and GIS. In PS, the 3D environment did not markedly affect compared with 2D. In GIS, however, the 3D environment affected the time and movement of the right forceps. There were no significant differences in the time between PS and GIS in either environment. In both environments, the right hand movement of the PS group was shorter and slower than that of the GIS group, but the left hand movement was the opposite.

Conclusion: There were significant differences in forceps movement characteristics between the PS and GIS. The effects of a 3D environment could not be clarified in this study because it may depend on the port layout used and the operative procedures.

Keywords: laparoscopic hepaticojejunostomy, simulator, pediatric surgeon, gastrointestinal surgeon, 3D, para-axial port layout setting

Introduction

Recently, laparoscopic surgery for congenital biliary dilatation (CBD) has become feasible and widespread not only in general surgery but pediatric surgery as well. However, the number of cases performed per institution is small at present, making it difficult to standardize and improve the technique through the accumulation of cases. In particular, laparoscopic hepaticojejunostomy demands a specific set of skills in needle driving and suturing. Therefore, the development of a simulator reproducing a disease-specific surgical procedure and a training regimen using that system is essential [1,2]. To this end, we developed a high-fidelity simulator of laparoscopic hepaticojejunostomy for CBD.

Several studies have described the benefits of three-dimensional (3D) systems over two-dimensional (2D) ones in endoscopic surgery [3,4]. In general, 3D systems are useful for building skill with needle driving and suturing. Poudel et al. [4] reported that the 3D environment helped shorten the training time of laparoscopic skills. We therefore believe that 3D environments have the potential to be very useful for pediatric surgeons. However, few studies have focused on the utility of 3D systems in the field of pediatric endosurgery.

The purpose of this study was to assess the impact of 2D and 3D environments on the time required and forceps manipulation ability and to clarify the characteristics of the forceps movement through a comparison between pediatric surgeons (PS) and gastrointestinal surgeons (GIS) using a laparoscopic hepaticojejunostomy simulator.

Materials and Methods

The simulator used was a high-fidelity laparoscopic hepaticojejunostomy system for CBD with surgical skill validation. We developed this evaluation model in collaboration with the company (Kyoto Kagaku Co., Ltd., Kyoto, JAPAN). We developed and reported a 1-year-old infant body model (body weight: 10 kg) based on computed tomography (CT) data and reproduced a pneumoperitoneum body model based on the clinical situation, as shown (Fig. 1a) [5].

Fig.1a

A hepatic duct (10 mm diameter), jejunum (20 mm diameter with 10-mm-diameter defect for anastomosis), and liver were placed in this model (Fig. 1b). The hepatic duct and jejunum were made of styrene, and the liver was made of urethane. The pneumoperitoneum model was covered with synthetic skin.

Fig.1b

A 0° 3D scope 10 mm in diameter (IMAGE1S™; KARL STORZ SE & Co. KG, Tuttlingen, Germany) was fixed using an arm. TrackSTAR (Northern Digital Inc., Ontario, Canada) was used as the spatial position-measuring instrument and placed on the thoracic side of the model to trace the tips of the forceps. The right and left forceps had sensors mounted on the tips, and their paths were traced on a computer with an electromagnetic tracking system, as was reported previously [6].

Tasks for participants

The participants had to perform hepaticojejunostomy. The port layout was the right para-axial position. The trocar for the right hand was placed at the right lower lateral abdomen, and that for the left hand was placed at the right upper lateral abdomen. The trocar for the scope was placed at the umbilicus (Fig. 1c). The participants used a 3.5-mm needle driver **Fig.1c** on the right hand and 3.5-mm Kelly-type forceps (KARL STORZ SE & Co. KG) on the left hand. The suture material used was an RB-1 curved needle with white and purple 5-0 VICRYL® (Ethicon Endosurgery, Cincinnati, OH, USA). Each suture was cut to 8 cm, two sutures were tied together to create a 16-cm double-ended needle.

Before starting the tasks, the left side of the hepatic duct and left side of the defect hole on the jejunum were tied using sutures (Fig. 2a). The participants had to perform **Fig.2a** anastomosis with running sutures and finally finished after performing intracorporeal knot tying twice at the right side of the anastomosis (Fig. 2b,c). **Fig.2b** **Fig.2c**

Each participant had to perform these tasks twice in total: once in a 2D environment and once in a 3D environment (order was randomized).

Study participants

A total of 35 surgeons participated in this study. Most examinees were participants of the

34th Japanese Society of Pediatric Surgeons Fall Symposium & Pediatric Surgery Joint Meeting 2018 and the 20th Needlescopic Surgery Meeting in Japan. Data obtained from staff of the Department of Digestive Surgery Breast and Thyroid Surgery of our institution who cooperated with our study was added to GIS group. The examinees were divided into two groups (PS and GIS groups). The PS group included 19 surgeons, and the GIS group included 16 surgeons. All participants of the PS group and nine participants of the GIS group were surgeons at various institutions, and seven participants of the GIS group were surgeons at our institution. All participants provided their informed consent.

Assessment points

The assessment points were as follows, improving upon the methods previously reported by Uemura, Jimbo, and Ikee [2,7-9]:

1. Time required to complete the task

   The required time, which was defined as the performance time from the start to completion of the task, was measured in seconds (s).

2. Total path length of each forceps

   The total path length of each forceps was considered to be the total spatial movement measured in the task in meters (m) and was determined using the

TrackSTAR system.

3. Average velocity of each forceps tip

The average velocity of each tip of the forceps was measured in millimeters per second (mm/s) using the TrackSTAR system and defined as the velocity for each 0.05 second in the task.

Statistical analyses

All data were expressed as the mean ± standard deviation. Two-tailed paired and unpaired Student's *t*-test and analyses of variance were conducted for comparisons using EZR version 1.38 (Saitama Medical Center, Jichi Medical University, Saitama, Japan) [10]. All data were defined as being statistically significant at p values <0.05.

Results

All participants completed the task, and the results of the skill evaluation are described below.

Background characteristics of the participating surgeons

The background characteristics of the participating surgeons are shown in Table 1. One PS was left-handed, but all other surgeons were right-handed. Three surgeons in the PS group and 7 in the GIS group had their endoscopic surgical skills certified by the Japan Society for Endoscopic Surgery.

Table 1

There were no significant differences in the age, career, dominant hand, or number of laparoscopic surgeries performed between the PS and GIS group. However, significant differences were noted in the number laparoscopic hepaticojejunostomies performed (p = 0.019).

Comparing 2D with 3D environment performance in the PS group

Table 2 shows the comparison of the 2D and 3D environment performance in the PS group. There were no significant differences in any parameters between the environments. However, the total path length of the forceps was shorter and the average velocities of the

Table 2

forceps tips were slower in the 3D environment than in the 2D environment.

Comparing 2D with 3D environment performance in the GIS group

Table 2 shows the comparison of the 2D and 3D environment performance in the GIS group. The time required to complete the task was significantly shorter (p = 0.013) and the average velocity of the right forceps significantly faster (p = 0.014) in the 3D environment than in the 2D environment.

Table 2

Comparing PS with GIS performance in the 2D environment

Table 3 shows the comparison of the PS and GIS groups in the 2D environment. The time required to complete the tasks using a 2D system was 1111.06 ± 414.15 s for the PS group and 875.79 ± 471.21 s for the GIS group (p = 0.13).

Table 3

The total path length of the right forceps using 2D was 83.46 ± 108.51 m for the PS group and 163.43 ± 133.65 m for the GIS group (p = 0.060). The total path length of the left forceps using 2D was 211.87 ± 122.25 m for the PS group and 52.33 ± 44.84 m for the GIS group. The total path length of the left forceps in the PS group using 2D was significantly longer than that in the GIS group (p < 0.01).

The average velocity of the right forceps tip using 2D was 65.36 ± 65.40 mm/s for the PS group and 186.35 ± 96.16 mm/s for the GIS group. The average velocity of the right forceps tip in the PS group using 2D was significantly slower than that in the GIS group ($p < 0.01$). The average velocity of the left forceps tip using 2D was 182.22 ± 64.67 mm/s for the PS group and 59.09 ± 34.22 mm/s for the GIS group. The average velocity of the left forceps tip in the PS group using 2D was significantly faster than that in the GIS group ($p < 0.01$).

Comparing PS with GIS performance in the 3D environment

Table 3 shows the comparison of the PS and GIS groups in the 3D environment. The time required to complete the tasks using a 3D system was 939.57 ± 302.37 s for the PS group and 755.17 ± 442.27 s for the GIS group ($p = 0.15$).

Table 3

The total path length of the right forceps using 3D was 55.13 ± 51.21 m for the PS group and 143.53 ± 98.55 for the GIS group ($p < 0.01$). The total path length of the left forceps using 3D was 188.02 ± 111.91 m for the PS group and 44.35 ± 40.75 m for the GIS group. The total path length of the left forceps in the PS group using 3D was significantly longer than that in the GIS group ($p < 0.01$).

The average velocity of the right forceps tip using 3D was 56.18 ± 46.59 mm/s for the PS group and 201.78 ± 112.36 mm/s for the GIS group. The average velocity of the right forceps tip in the PS group using 3D was significantly slower than that in the GIS group ($p < 0.01$). The average velocity of the left forceps tip using 2D was 188.05 ± 65.29 mm/s for the PS group and 57.72 ± 39.70 mm/s for the GIS group. The average velocity of the left forceps tip in the PS group using 3D was significantly faster than that in the GIS group ($p < 0.01$).

Discussion

The purpose of this study was to assess the impact of 2D and 3D environments on the time required and forceps manipulation ability and to clarify the characteristics of the forceps movement through a comparison between PS and gastrointestinal surgeons GIS using a laparoscopic hepaticojejunostomy simulator. We used three assessment points to evaluate the endoscopic surgical skills of the participants, as described in our previous report [5-9].

The major findings in the present study were as follows: (1) Regarding the background of participants, there were significant differences in the experience with performed laparoscopic hepaticojejunostomy between the PS and GIS groups. (2) In the PS group, the 3D environment did not affect the forceps manipulation compared with the 2D environment (3) In the GIS group, the 3D environment affected the time required to complete the task and the average velocity of the right forceps. (4) There were no significant differences in the time required to complete the task between the PS and GIS group in either environment. (5) In both environments, the right hand movement of the PS group was shorter and slower than that of the GIS group, but the left hand movement of the PS group was longer and faster than that of the GIS group.

Our study results showed no marked difference in the movement of forceps or operation time between the 2D and 3D environments in the PS groups. Harada et al. [11] reported that a 3D system improves efficiency and dexterity with simple tasks. Suturing, including needle driving, is one of the most difficult and complicated techniques performed during endoscopic surgery, and the para-axial position—as was used in our simulator—seems to increase the difficulty even further. The lack of any substantial difference between the 2D and 3D environments was attributed to the marked difficulty of the task, especially for the PS group. So it is unclear whether the 3D environment affect surgery, because the sample size may have been too small to find a significant difference. In terms of required time, both PS and GIS groups had shorter time in the 3D environment, which may have the effect of reducing the operation time in the 3D environment.

The total path length of the right forceps in the PS group was significantly shorter and the average velocity of the right forceps tip significantly slower than in the GIS group. For the left hand, these results were reversed, with the total path length of the left forceps being significantly longer and the average velocity of the left forceps tip significantly faster in the PS group than in the GIS group.

In this study design, the right forceps was the needle driver, and the left forceps was a Kelly-type device used to assist the right hand.

Ieiri et al. [12] reported that in a study of trainee surgeons, a shorter path length and slower manipulation increased the quality of endoscopic procedures. We found here that the movement of the right hand in the PS group was shorter and slower than in the GIS group, and the movement of the left hand in the GIS group was shorter and slower than in the PS group. These suggest that PS can use their right hand more efficiently than GIS and GIS can use their left hand more efficiently than PS. We consider that these differences in forceps movement characteristics may be due to differences in the usual surgical environment of the two groups. PS usually perform laparoscopic surgery in a small space, so their movements of both hands of forceps are restricted. Therefore, in the process of suturing, it is mostly done using only the right hand, so they usually use their right hand more frequently than GIS. GIS perform laparoscopic surgery primarily in a para-axial setting, such as gastrectomy, colectomy, and pancreatectomy, because they are accustomed to performing surgery in an expansive space, so they usually use their left hand more frequently than PS.

A previous report suggested that pediatric surgeons were able to perform endoscopic procedures with the same quality as general surgeons after short-term training [12-14]. In addition, Tomikawa et al. [8] showed the effectiveness of training on both spatial path lengths and average tip speeds of needle holders. The improvements in the spatial path lengths and average tip speeds in the left hand were particularly significant.

However, these studies were performed using a co-axial port layout.

Both PS and GIS perform definitive operations for CBD, including pancreaticobiliary maljunction. In this study, the participating PS had experienced CBD more frequently than the GIS. We expected that the PS would show better performance concerning forceps manipulation than the GIS. However, the results obtained differed between the groups. The above finding may be primarily attributed to the para-axial port layout used, which was not familiar to the PS, potentially causing some confusion. Familiarity with the port layout may be affecting the results, but we could not investigate that in this study. But Jimbo et al reported that expert PS showed the equally performance regarding the suturing in both co-axial and para-axial setting using laparoscopic hepaticojejunostomy simulator [2]. They divided the PS into the 2 groups (expert and novices) and compared the suturing performance in both co-axial and para-axial setting. Novices showed inferior performance in para-axial setting comparing with co-axial setting. In this study, PS group included experts and novices. Evaluation between experts and novices of PS group in both environment should be required. In addition, we should evaluate the effect of a 3D environment in a co-axial setting the next step.

Conclusion

There were significant differences in forceps movement characteristics between the PS and GIS group. The effects of a 3D environment could not be clarified in this study because it may depend on the port layout used and the operative procedures.

Acknowledgments

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Disclosure

This research received rental services of the 3D laparoscopic system from MC MEDICAL Inc. All authors have no conflicts of interest of financial ties to disclose.

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Figure Legends

Figure 1. a Pediatric pneumoperitoneum body model. **b** The laparoscopic view of the simulator. The liver, hepatic duct (10-mm diameter), and jejunum (20-mm diameter with 10-mm-diameter defect for anastomosis) were placed in the abdominal cavity of the pneumoperitoneum body model. **c** A schematic illustration showing the port layout of the simulator and a laparoscopic view of the simulation of hepaticojejunostomy.

Figure 2. Task process **a**: Before starting the task **b**: Anastomosis with running sutures **c**: Tying knots twice and finishing the task.

Fig. 1

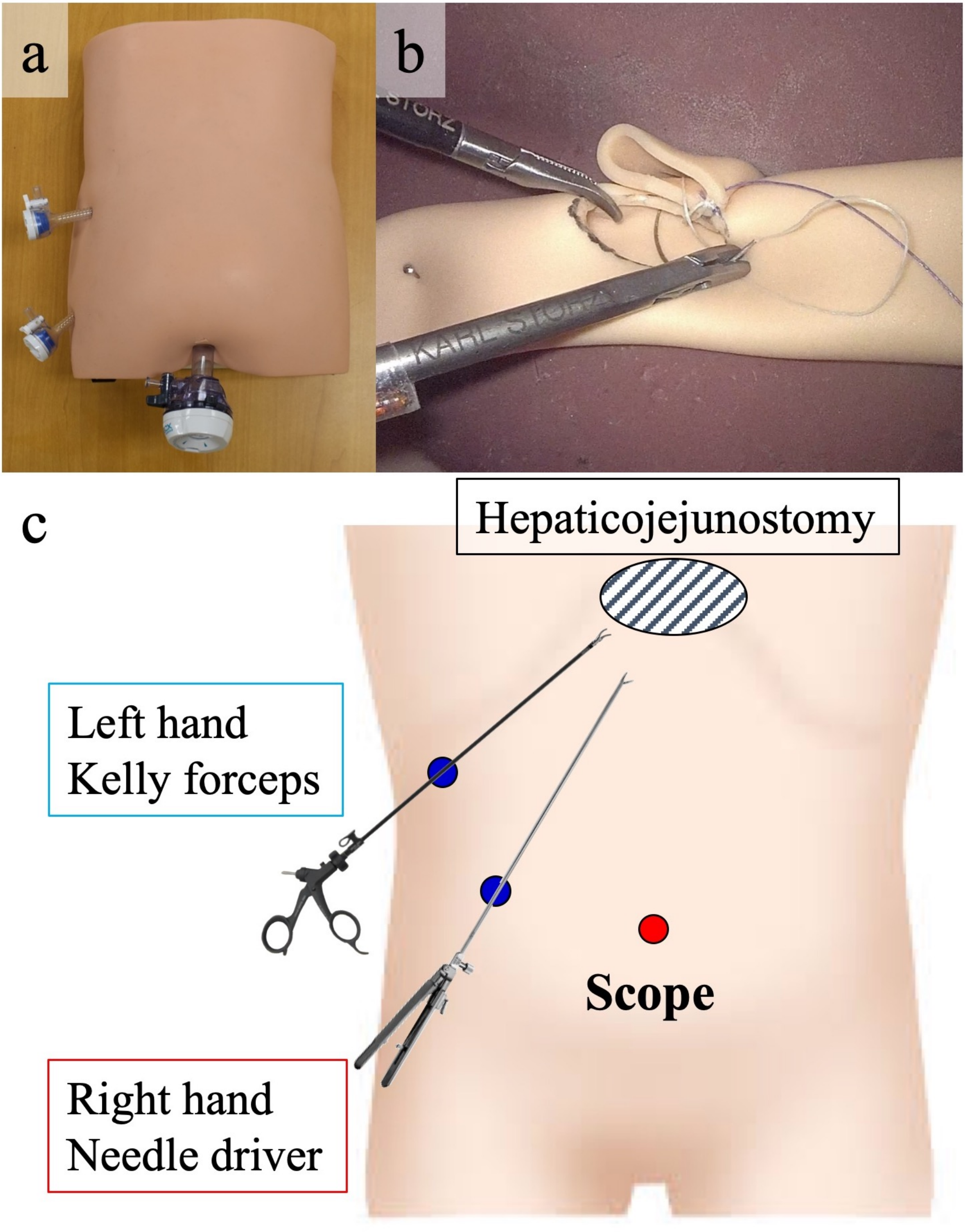
a
b
KARL STORZ
c
Hepaticojejunostomy
Left hand
Kelly forceps
Scope
Right hand
Needle driver

Fig. 2

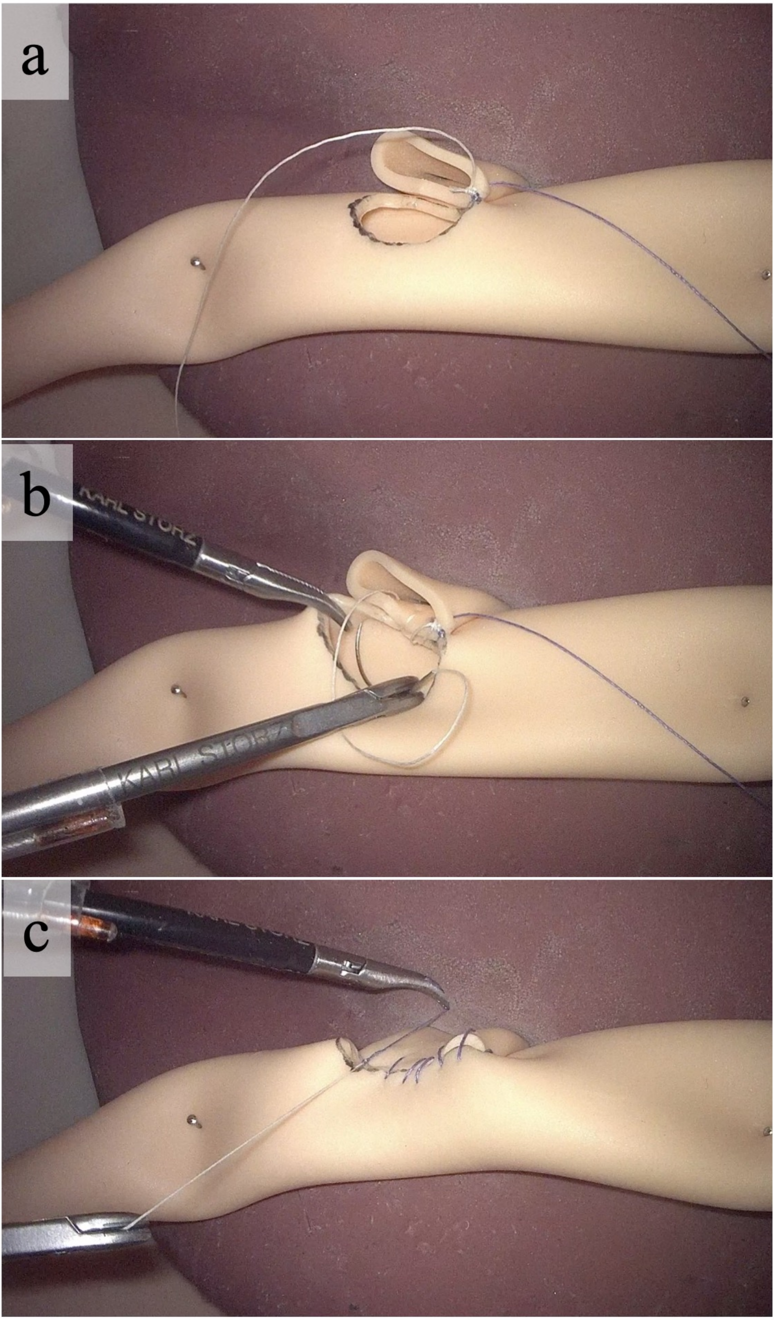

Table 1. Background characteristics of the participating surgeons

Table 1

	PS[1] (n = 19)	GIS[2] (n = 16)	*p* value
Age (years)	41.5 ± 7.3	44.3 ± 7.4	0.28
Right handed:Left handed	18:1	16:0	1[4]
Career as a medical doctor (years)	16.3 ± 8.0	18.4 ± 7.3	0.42
Laparoscopic surgeries performed			
≥101	11	11	0.16[4]
51-100	3	5	
1-50	4	0	
0	1	0	
Laparoscopic hepaticojejunostomies performed			
≥6	4	0	0.019[4]
1-5	8	3	
0	7	13	
Qualified surgeons[3]	3	7	0.132[4]

1) PS: pediatric surgeon, 2) GIS: gastrointestinal surgeon

3) Endoscopic surgical skill qualification system by Japan Society for Endoscopic Surgeons

4) Fisher's exact test

Table2: Comparison 2D with 3D in PS or GIS

Table 2

	2D	3D	*p* value
PS[1]			
Required time (s)	1111.06 ± 414.15	939.57 ± 302.37	0.090
Rt. total path length (m)	83.46 ± 108.51	55.13 ± 51.21	0.085
Lt. total path length (m)	211.87 ± 122.25	188.02 ± 111.91	0.078
Rt. average velocity (mm/s)	65.36 ± 65.40	56.18 ± 46.59	0.40
Lt. average velocity (mm/s)	182.22 ± 64.67	188.05 ± 65.29	0.70
GIS[2]			
Required time (s)	875.79 ± 471.21	755.17 ± 442.27	0.013*
Rt. total path length (m)	163.43 ± 133.65	143.53 ± 98.55	0.24
Lt. total path length (m)	52.33 ± 44.84	44.35 ± 40.75	0.29
Rt. average velocity (mm/s)	186.35 ± 96.16	201.78 ± 112.36	0.014*
Lt. average velocity (mm/s)	59.09 ± 34.22	57.72 ± 39.70	0.63

1)PS: Pediatric Surgeon, 2) GIS: Gastrointestinal Surgeon, *Significant difference

Table3: Comparison PS with GIS using 2D or 3D

Table 3

	PS[1] (n=19)	GIS[2] (n=16)	*p* value
2D			
Required time (s)	1111.06 ± 414.15	875.79 ± 471.21	0.13
Rt. total path length (m)	83.46 ± 108.51	163.43 ± 133.65	0.060
Lt. total path length (m)	211.87 ± 122.25	52.33 ± 44.84	< 0.01*
Rt. average velocity (mm/s)	65.36 ± 65.40	186.35 ± 96.16	< 0.01*
Lt. average velocity (mm/s)	182.22 ± 64.67	59.09 ± 34.22	< 0.01*
3D			
Required time (s)	939.57 ± 302.37	755.17 ± 442.27	0.15
Rt. total path length (m)	55.13 ± 51.21	143.53 ± 98.55	< 0.01*
Lt. total path length (m)	188.02 ± 111.91	44.35 ± 40.75	< 0.01*
Rt. average velocity (mm/s)	56.18 ± 46.59	201.78 ± 112.36	< 0.01*
Lt. average velocity (mm/s)	188.05 ± 65.29	57.72 ± 39.70	< 0.01*

1) PS: Pediatric Surgeon, 2) GIS: Gastrointestinal Surgeon, *Significant difference