Validation and Verification of Three-dimensional Systems in Laparoscopic Distal Pancreatectomy

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Abstract. *Aim: The three-dimensional (3D) visualization system has been introduced for the technical improvement of laparoscopic surgery, but clinical evidence for its usefulness is lacking. This study aimed to evaluate the usefulness of a 3D system in laparoscopic surgery. Patients and Methods: Between 2015 and 2016, a randomized controlled trial was performed on 61 patients who underwent laparoscopic distal pancreatectomy. The primary outcome was the shortening of operative time. The hospital course, number of technical errors, and clinicians' subjective scores were compared as secondary outcome. Results: There were no significant differences in operative times, hospital course and technical errors. However, depth perception was significantly improved and physical demand was reduced in the 3D group. These advantages became clearer in the later period of the study, with longer operative times, and in spleen-preserving procedures. Conclusion: Subjective scoring through 3D systems was significantly superior, which might lead to better surgical performance in difficult cases.*

Laparoscopic techniques can minimize surgical wounds, accelerate postoperative recovery, and reduce the duration of hospital stay compared to open techniques (1, 2). Previously, laparoscopic surgery depended on two-dimensional (2D) visualization technology, which presented remarkable

challenges for those using this technique. These laparoscopic techniques have been further improved by the development of better surgical instruments (3-5). In particular, progression in camera technology has extended the scope of the application of laparoscopic systems, and more detailed surgery has become possible. Nevertheless, the improvement in high-quality cameras has not completely resolved the key limitations of 2D laparoscopy, such as lack of depth perception and visual strain (6, 7).

In the 1990s, three-dimensional (3D) visualization technology was proposed to facilitate laparoscopic performance (8, 9). In the early stage of 3D system introduction, there was a limitation of image enhancement, and its utilization was also insignificant. However, rapid innovation has provided more advanced 3D technologies that are important for the further development of minimally invasive surgery (10, 11).

A report indicated that the technical features and advantages of 3D systems are ineffective and limited (12), but other studies and reviews have suggested that 3D technology improves practical efficiency (13-15). In this study, we focused on laparoscopic distal pancreatectomy (LDP) as a form of laparoscopic abdominal surgery that requires at least 1 h of operative time. Our aim was to assess the benefits and harms of using the 3D *versus* the 2D system during LDP and to compare the parameters of imaging quality, adverse effects of surgery, and overall demands of laparoscopic technologies. Through this study, we expect to be able to comprehensively understand the 3D laparoscopic system and provide detailed information on its clinical application.

Patients and Methods

Study design. This study was performed in compliance with the Declaration of Helsinki. The study protocol was approved by the Institutional Review Board of ASAN Medical Center (IRB No. 2014-0924) and by the Clinical Research Information Service (registration number: NCT02757690). Written informed consent was obtained

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Figure 1. CONSORT diagram for the study.

from all participants. Between 2015 and 2016, patients preoperatively diagnosed with a benign or borderline lesion in the distal pancreas by two radiologists using computed tomography (CT) or magnetic resonance imaging (MRI) were assessed for eligibility. Patients were divided into two groups (3D and 2D) using the block randomization method (16). Two expert surgeons and two first assistants participated. 2D surgery was performed using on Olympus (Seoul, Korea) 2D high definition (HD) laparoscopic system, and 3D surgery was performed using an ENDOEYE FLEX 3D system (LTF-190-10-3D; Olympus). Exclusion criteria were as follows: age ≤ 20 years or ≥ 80 years, body mass index (BMI) > 30 kg/m², history of severe or recurrent pancreatitis, tumor size in preoperative CT imaging > 10 cm, history of major abdominal operation, and additional resection for an extra-pancreatic organ. The primary outcome was reduction of the operative time by at least 10 min through the 3D system. Operative time was defined as the time from port insertion to wound closure. The secondary outcome was to determine whether use of the 3D system was superior or not inferior to the 2D system for the following factors: Intra-hospital course, short-term outcomes, subjective scoring, and number of technical errors during the operation.

Sample size. Our recent records of surgery were analyzed and showed that the average operation time for LDP was 200 ± 59 min. The minimum number of patients to verify our hypothesis that the operative time could be reduced by at least 10 min using the 3D system was calculated. A sample size of 26 patients for each group was necessary to detect superiority using a one-sided design (81% power, two-sample *t*-test). The margin of superiority was -0.167 . The true difference between the means was assumed to be -0.400 . The significance level (α) of the test was 0.02500. All data were drawn from populations with standard deviations of 0.600 and 0.800 (17, 18).

Data collection. The analysis was divided into three parts: Clinical factors, subjective scoring of clinicians, and technical errors during surgery. The medical records were reviewed to collect their characteristics, hospital stay, time to start eating, recovery of general condition, pathological examination, blood results, and radiological examination parameters. The subjective scoring system was analyzed from the perspective of the operator and first assistant, which depended on three main categories: Image quality (scores of

1-9, bad to good), which included depth perception, sharpness, contrast, and ghosting; adverse effects (scores of 0-5, good to worse), which included visual strain, headache, facial discomfort, ear discomfort, and physical discomfort; and overall demand (scores of 0-5, easy to difficult), which included mental demand, physical demand, and performance success (12, 19). Finally, the operation video was analyzed to assess the operative time and the number of technical errors.

Statistical analysis. Statistical analyses were performed using SPSS version 21.0 (IBM, Armonk, NY, USA). Data are expressed as the average $\pm$ standard deviation for continuous variables and as frequency for categorical variables. Student's *t*-tests and chi-square tests were used to analyze differences between the values of continuous and categorical variables, respectively. A *p*-value of less than 0.05 was accepted as statistically significant.

Results

Study design. A total of 63 consecutive patients were divided into two groups: 31 and 32 patients were assigned to the 2D and 3D system, respectively. Of the 31 patients in the 2D group, two with a history of abdominal surgery were excluded because of a more severe adhesion than expected (Figure 1). Twenty-one patients in the 2D group underwent a spleen-preserving procedure and eight had a spleen-sacrificing procedure. In the 3D group, 19 patients underwent a spleen-preserving procedure and 13 had a spleen-sacrificing procedure.

Demographics and short-term outcomes of patients. The patient and tumour characteristics were compared (Table I). There were no significant differences in age, gender, BMI, past history, laboratory results, operator, and pathological diagnosis. In addition, the various clinical features and short-term outcomes were also analyzed (Table II). There was no

Table I. Host and tumor characteristics of the study population.

Characteristic	2D (n=29)	3D (n=32)	p-Value
Age, years			
Mean±SD	49.1±13.7	52.0±14.1	0.424
Gender, n			
Male/female	14/15	11/21	0.270
BMI, kg/m ²			
Mean±SD	23.9±3.3	24.5±5.4	0.623
Previous history of abdominal surgery, n			
No/yes	20/9	23/9	0.804
Previous history of pancreatitis, n			
No/yes	23/6	24/8	0.689
Operator, n			
Surgeon 1/2	22/7	21/11	0.381
Tumor location, n			
Body/tail	5/24	5/27	0.865
Tumor size, cm			
Mean±SD	3.63±1.68	3.56±1.92	0.883
Histological diagnosis, n			
IPMN	6	12	0.445
SPN	6	7	
NET	4	5	
MCN	3	4	
SCA	5	2	
Other	5	2	
Laboratory test, mean±SD			
WBC, ×10 ³ /μl	6.3±1.6	6.5±1.8	0.664
Hb, g/dl	13.2±1.6	13.1±1.4	0.755
Platelet count, ×10 ³ /μl	224.7±60.8	237.8±55.8	0.384
Prothrombin time, s	10.1±3.6	9.3±4.1	0.387
AST, IU/l	19.7±5.7	18.9±5.8	0.598
ALT, IU/l	20.3±11.8	17.5±8.4	0.274
Total bilirubin, mg/dl	1.2±3.4	0.4±0.2	0.228
Amylase, U/l	62.3±18.4	79.6±66.0	0.179
Lipase, U/l	41.1±26.4	49.2±47.3	0.418

2D: Two-dimensional; 3D: three-dimensional; SD: standard deviation; BMI: body mass index; IPMN: intraductal papillary mucinous neoplasm; SPN: solid pseudopapillary neoplasm; NET: neuroendocrine tumor; MCN: mucinous cystic neoplasm; SCA: serous cystic neoplasm; WBC: white blood cell count; Hb: hemoglobin; AST: aspartate transaminase; ALT: alanine transaminase.

transfusion during operation, and no significant difference in the ratio of spleen-preserving, inflammation, hemorrhage, recovery pattern, re-operation, and re-admission between the two groups.

Surgical technique and subjective scoring according to visualization system. Differences in the technical aspects were analyzed through a review of the surgical videos, and the subjective scoring of operators (Table III). The operative time, which was the subject of the primary outcome, was similar for both groups. Among the items of technical error, the frequency of missed grasps appeared to decrease slightly in the 3D

group, but this was not significant. However, image quality was superior and the mental and physical demands were significantly reduced in the 3D system. Next, the analysis was conducted between the first 10 cases and the later cases. The adverse effects (headache, physical discomfort) and overall demand (mental and physical demand) of the 3D system decreased remarkably in the later period.

Further analysis was conducted to determine whether these factors were affected by the operative time and surgical procedure. Firstly, the operative time was divided into three categories based on cutoffs of 120 min and 180 min. There were no differences in the average operative time between the 2D and 3D groups in the three categories. As the operative time increased, the number of technical errors also increased. The degree of increase was more pronounced for missed grasps, but there were no significant differences between the two groups (Figure 2A). In Figure 2B-D, the comparison of subjective scores by operative time showed that the advantages of the 3D system became clearer with longer operative time.

Secondly, we analyzed the influence of the surgical procedure. Patients were divided into two categories by spleen-preserving procedure (Table IV). The difference between the two groups was clear in the spleen-preserving procedure rather than the spleen-sacrificed procedure. In particular, depth perception, sharpness, and contrast increased relatively and mental and physical demand was relatively reduced in the 3D system.

Surgical technique and subjective scoring between operator and first assistant. A comparative analysis of the subjective scoring between the operators and first assistants was performed. Except for ear discomfort, there was no difference between the two groups (Table V). The six factors (depth perception, sharpness, contrast, physical discomfort, mental demand, and physical demand) that differed from the subjective scoring analysis between the operators (Table III) were compared with the results of the first assistant. Of these, three factors (depth perception, sharpness, contrast) related to imaging still showed superiority in 3D systems (Table VI).

Discussion

In 1992, the 3D visualization system was introduced to improve image quality and reduce the learning curve required for surgeons to reach high performance levels (20–22). Recently, improved optics has allowed for more accuracy in spatial distance and hand–eye coordination, which lead to increased accuracy in performance and hand-grasping (11, 23, 24). Nevertheless, the application of 3D systems is still limited, and additional research on their scope and utility is required. Most of the previous clinical studies

Table II. *Clinical outcomes after laparoscopic distal pancreatectomy.*

	2D (n=29)	3D (n=32)	p-Value
Operation			
Transfusion			
Absent/present	29/0	32/0	>0.99
Spleen-preserving			
Preserved/sacrificed	21/8	19/13	0.284
Immediately postoperative			
WBC, $\times 10^3/\mu\text{I}$	13.7 $\pm$ 5.7	11.2 $\pm$ 5.7	0.097
Hb, g/dl	11.4 $\pm$ 4.2	10.2 $\pm$ 4.6	0.280
Amylase, U/I	90.2 $\pm$ 47.0	112.9 $\pm$ 126.5	0.366
Lipase, U/I	99.5 $\pm$ 55.4	87.0 $\pm$ 68.1	0.438
Postoperative day 1			
WBC, $\times 10^3/\mu\text{I}$	12.5 $\pm$ 3.4	12.3 $\pm$ 3.5	0.821
Hb, g/dl	11.9 $\pm$ 2.2	11.9 $\pm$ 1.6	0.949
Platelet count, $\times 10^3/\mu\text{I}$	201.0 $\pm$ 69.5	211.4 $\pm$ 68.9	0.560
Total bilirubin, mg/dl	1.0 $\pm$ 0.6	0.8 $\pm$ 0.4	0.104
Amylase, U/I	161.8 $\pm$ 146.9	172.0 $\pm$ 293.0	0.867
Lipase, U/I	97.2 $\pm$ 134.7	80.7 $\pm$ 50.4	0.521
Postoperative day 6 or 7			
WBC, $\times 10^3/\mu\text{I}$	8.2 $\pm$ 1.8	8.1 $\pm$ 2.8	0.876
Hb, g/dl	12.6 $\pm$ 1.4	11.9 $\pm$ 1.6	0.081
Platelet count, $\times 10^3/\mu\text{I}$	311.5 $\pm$ 188.3	313.2 $\pm$ 184.5	0.972
Total bilirubin, mg/dl	0.5 $\pm$ 0.3	0.4 $\pm$ 0.3	0.319
Amylase, U/I	78.9 $\pm$ 67.0	72.3 $\pm$ 70.1	0.711
Lipase, U/I	57.0 $\pm$ 45.6	69.1 $\pm$ 96.4	0.541
Hospital course			
Time to restarting diet (water), days			
Mean $\pm$ SD	1.2 $\pm$ 0.7	1.1 $\pm$ 0.3	0.543
Blood transfusion, n			
Absent/present	29/0	32/0	>0.99
Pancreatic fistula (ISGPF grade), n			
Grade A/B/C	27/2/0	31/1/0	0.600
Postoperative ileus, n			
Absent/present	29/0	32/0	>0.99
Wound infection, n			
Absent/present	29/0	32/0	>0.99
Time to removal of drain, days			
Mean $\pm$ SD	4.7 $\pm$ 0.9	4.8 $\pm$ 2.6	0.756
Length of hospital stay, days			
Mean $\pm$ SD	6.5 $\pm$ 1.0	7.6 $\pm$ 3.5	0.110
Re-operation, n			
Absent/present	29/0	32/0	>0.99
Re-admission, n			
Absent/present	28/1	32/0	0.475

ISGPF: International Study Group for Pancreatic Fistula; WBC: white blood cell; Hb: hemoglobin.

were performed on relatively simple operations of less than 1 hour (12, 13, 15). 3D systems can be useful in relatively more complex and sophisticated operations (25-27). Considering the difficulty of the surgical technique and the operative time, we decided that LDP is a suitable model for confirming the usefulness of the 3D system. By conducting a randomized control study through a well-designed study, we found the following interesting results.

Firstly, an objective result of improvement in technique through the 3D system was not confirmed. As shown in Table

II, the operative time, which was the parameter and primary outcome of the surgical technique, was not shortened, and there were no significant differences in frequency of technical errors. These findings are consistent with those in published articles (12, 28). Considering that the participating surgeons were experts who had already performed more than 100 cases of LDP using the 2D system, it may be difficult to identify a dramatic improvement of their surgical technique.

Secondly, 3D systems exhibit superior image quality, particularly in depth perception, sharpness, and contrast.

Figure 2. Frequency of technical errors (A) and subjective scoring of laparoscopic distal pancreatectomy according to operative time (B-D) between 2D and 3D groups. Significantly different at * $p < 0.01$, ** $p < 0.005$ and *** $p < 0.001$.

Table III. Technical errors and subjective scoring of laparoscopic distal pancreatectomy according to study period and method.

	Total			Early period (case no. ≤ 10)			Late period (case no. ≥ 11)		
	2D (n=29)	3D (n=32)	p-Value	2D (n=10)	3D (n=10)	p-Value	2D (n=19)	3D (n=22)	p-Value
Operative time, min	158.7 $\pm$ 43.6	158.2 $\pm$ 41.3	0.968	149.6 $\pm$ 36.9	134.4 $\pm$ 39.2	0.384	163.4 $\pm$ 47.0	169.0 $\pm$ 38.2	0.675
Spleen preserved/sacrificed, n	21/8	19/13	0.284	7/3	6/4	0.639	14/5	13/9	0.326
Subjective scoring, mean $\pm$ SD									
Technical errors									
Missed grasps	15.4 $\pm$ 9.2	11.8 $\pm$ 7.3	0.114	15.6 $\pm$ 10.0	6.6 $\pm$ 3.8	0.029	15.3 $\pm$ 8.9	13.8 $\pm$ 7.3	0.585
Loss of materials	5.4 $\pm$ 3.9	5.6 $\pm$ 3.0	0.824	4.3 $\pm$ 4.1	4.1 $\pm$ 2.4	0.916	6.1 $\pm$ 3.7	6.1 $\pm$ 3.1	>0.99
For imaging quality									
Depth perception	3.9 $\pm$ 1.1	7.1 $\pm$ 1.7	<0.001	3.7 $\pm$ 1.3	6.9 $\pm$ 2.2	0.001	4.0 $\pm$ 1.1	7.2 $\pm$ 1.5	<0.001
Sharpness	4.5 $\pm$ 1.3	6.6 $\pm$ 2.0	<0.001	4.1 $\pm$ 1.2	5.9 $\pm$ 3.0	0.098	4.7 $\pm$ 1.3	6.9 $\pm$ 1.3	<0.001
Contrast	4.7 $\pm$ 1.1	6.6 $\pm$ 1.7	<0.001	4.5 $\pm$ 1.1	6.1 $\pm$ 2.4	0.073	4.8 $\pm$ 1.1	6.8 $\pm$ 1.2	<0.001
Ghosting	4.0 $\pm$ 1.5	4.3 $\pm$ 2.6	0.501	4.6 $\pm$ 1.2	6.1 $\pm$ 2.8	0.132	3.6 $\pm$ 1.6	3.5 $\pm$ 2.2	0.888
For adverse effects									
Visual strain	2.2 $\pm$ 1.3	1.8 $\pm$ 1.0	0.270	1.9 $\pm$ 1.4	2.0 $\pm$ 1.2	0.862	2.3 $\pm$ 1.3	1.8 $\pm$ 0.9	0.126
Headache	1.9 $\pm$ 1.1	1.3 $\pm$ 1.3	0.079	1.7 $\pm$ 0.9	2.0 $\pm$ 1.2	0.534	2.0 $\pm$ 1.2	1.0 $\pm$ 1.3	0.018
Facial discomfort	1.7 $\pm$ 1.4	1.3 $\pm$ 1.2	0.180	1.5 $\pm$ 1.4	1.6 $\pm$ 1.0	0.851	1.8 $\pm$ 1.4	1.1 $\pm$ 1.2	0.097
Ear discomfort	1.2 $\pm$ 1.2	0.7 $\pm$ 1.0	0.088	1.1 $\pm$ 1.4	0.6 $\pm$ 1.0	0.358	1.3 $\pm$ 1.1	0.8 $\pm$ 1.1	0.155
Physical discomfort	2.2 $\pm$ 1.1	1.6 $\pm$ 1.0	0.031	1.8 $\pm$ 1.0	1.9 $\pm$ 0.9	0.818	2.4 $\pm$ 1.1	1.5 $\pm$ 1.0	0.007
For overall demand									
Mental demand	2.6 $\pm$ 1.2	1.8 $\pm$ 1.0	0.009	2.5 $\pm$ 1.4	2.3 $\pm$ 1.2	0.736	2.6 $\pm$ 1.0	1.6 $\pm$ 0.9	0.002
Physical demand	2.4 $\pm$ 1.1	1.8 $\pm$ 1.0	0.031	2.1 $\pm$ 1.3	2.1 $\pm$ 1.2	>0.99	2.6 $\pm$ 1.0	1.7 $\pm$ 0.9	0.005
Performance success	2.9 $\pm$ 1.1	2.9 $\pm$ 1.4	0.940	2.8 $\pm$ 1.5	2.3 $\pm$ 1.3	0.438	3.0 $\pm$ 0.8	3.2 $\pm$ 1.4	0.629

Table IV. Technical errors and subjective scoring of laparoscopic distal pancreatectomy according to spleen preservation and method.

	Spleen preserved			Spleen sacrificed		
	2D (n=21)	3D (n=19)	p-Value	2D (n=8)	3D (n=13)	p-Value
Operative time, min	157.9±46.6	163.1±44.1	0.720	160.8±37.2	151.2±37.3	0.574
Subjective scoring, mean±SD						
Technical errors						
Missed grasps	16.7±8.9	12.9±8.1	0.198	11.7±9.7	9.9±5.4	0.636
Loss of materials	5.5±4.4	5.2±2.4	0.780	5.0±2.1	6.3±3.8	0.460
For imaging quality						
Depth perception	3.7±1.0	7.1±2.0	<0.001	4.4±1.3	7.1±1.3	<0.001
Sharpness	4.3±1.3	7.1±1.7	<0.001	5.0±1.1	5.8±2.2	0.331
Contrast	4.6±1.2	6.8±1.5	<0.001	5.0±0.5	6.2±1.9	0.089
Ghosting	4.1±1.4	4.2±2.5	0.923	3.6±1.8	4.6±2.9	0.393
For adverse effects						
Visual strain	2.2±1.2	1.6±1.0	0.091	2.0±1.6	2.2±1.0	0.787
Headache	2.0±1.1	1.4±1.3	0.136	1.6±1.1	1.2±1.4	0.495
Facial discomfort	1.8±1.4	1.2±1.2	0.120	1.4±1.4	1.4±1.1	0.986
Ear discomfort	1.2±1.3	0.7±1.0	0.190	1.1±1.4	0.7±0.9	0.330
Physical discomfort	2.2±1.1	1.6±0.9	0.092	2.3±1.0	1.6±1.1	0.211
For overall demand						
Mental demand	2.6±1.0	1.6±0.9	0.003	2.4±1.5	2.1±1.1	0.608
Physical demand	2.6±1.0	1.6±0.9	0.004	2.1±1.4	2.2±1.1	0.959
Performance success	3.0±1.0	2.6±1.5	0.307	2.8±1.4	3.4±1.1	0.264

Table V. Subjective scoring (mean±SD) of laparoscopic distal pancreatectomy of the operator and first assistant according to method.

	2D (n=29)			3D (n=32)		
	Operator	First assistant	p-Value	Operator	First assistant	p-Value
For imaging quality						
Depth perception	3.9±1.1	4.2±1.0	0.326	7.1±1.7	6.7±1.6	0.324
Sharpness	4.5±1.3	4.9±1.3	0.196	6.6±2.0	6.0±2.1	0.254
Contrast	4.7±1.1	5.0±1.3	0.370	6.6±1.7	6.0±1.8	0.204
Ghosting	4.0±1.5	4.1±1.8	0.752	4.3±2.6	5.3±2.1	0.123
For adverse effects						
Visual strain	2.2±1.3	2.1±1.2	0.752	1.8±1.0	2.2±1.0	0.131
Headache	1.9±1.1	1.8±1.5	0.841	1.3±1.3	1.7±1.1	0.248
Facial discomfort	1.7±1.4	1.8±1.4	0.850	1.3±1.2	1.6±1.1	0.196
Ear discomfort	1.2±1.2	1.6±1.3	0.202	0.7±1.0	1.5±1.1	0.007
Physical discomfort	2.2±1.1	2.1±1.5	0.762	1.6±1.0	2.0±1.1	0.156
For overall demand						
Mental demand	2.6±1.2	2.3±1.3	0.386	1.8±1.0	2.2±1.3	0.158
Physical demand	2.4±1.1	2.1±1.2	0.304	1.8±1.0	2.3±1.4	0.153
Performance success	2.9±1.1	2.6±0.9	0.253	2.9±1.4	3.1±1.2	0.514

Consistent with these results, the mental and physical demands on surgeons decreased in the 3D group, which is supported by a previous study that investigated image quality and overall demand of the 3D system (12). These findings may be explained by the advanced visualization optics that allows for more accuracy in spatial distance perception and hand–eye coordination. The better image quality might relate

to optical shuttering glasses, which reduce photo transmission to the retina and lead to a decline in the sensory impact on color vision (29). Interestingly, these advantages became clearer in the later period of the study, with longer operative times, and in more complex surgical procedures. This reflects the feasibility and accessibility of this system, which may reduce the burden on the operator, particularly in

Table VI. Technical errors and subjective scoring (mean±SD) of the first assistant in laparoscopic distal pancreatectomy.

	First assistant		
	2D (n=29)	3D (n=32)	p-Value
For imaging quality			
Depth perception	4.2±1.0	6.7±1.6	<0.001
Sharpness	4.9±1.3	6.0±2.1	0.022
Contrast	5.0±1.3	6.0±1.8	0.014
Ghosting	4.1±1.8	5.3±2.1	0.022
For adverse effects			
Visual strain	2.1±1.2	2.2±1.0	0.590
Headache	1.8±1.5	1.7±1.1	0.668
Facial discomfort	1.8±1.4	1.6±1.1	0.686
Ear discomfort	1.6±1.3	1.5±1.1	0.625
Physical discomfort	2.1±1.5	2.0±1.1	0.756
For overall demand			
Mental demand	2.3±1.3	2.2±1.3	0.860
Physical demand	2.1±1.2	2.3±1.4	0.660
Performance success	2.6±0.9	3.1±1.2	0.077

difficult cases. Although these advantages are not directly related to shortening of the operative time, operations will be more effective as the burden on the operator decreases.

Thirdly, the first assistant unlike the operator, experienced no reduction of physical demand through the 3D system. Among the subjective scoring results of the operators, only the imaging quality-related factors showed superiority for the first assistant. As far as we are aware, this study is the first to compare operator and first assistant scoring, these results may be a reflection of a difference in concentration and burden between the two.

This study was the first study to validate the clinical usefulness of the 3D system for LDP with an operative time of at least 1 h. The 3D system did not shorten the operative time nor reduce technical errors. However, superiority of the 3D system was confirmed by subjective scoring such as imaging quality and physical demand, particularly in longer and more complicated procedures. Through extensive research on the 3D system, we hope to find a clearer answer to the clinical usability and scope of the 3D system.

Conflicts of Interest

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

Authors' Contributions

Substantial contributions to the conception or design of the work: Eunsung Jun, Abdulwahab A. Alshahrani, Sang Hyun Shin, Dae Wook Hwang, Ki Byung Song, Jae Hoon Lee, Young-Joo Lee, Song Cheol Kim; Acquisition of data: Dae Wook Hwang, Ki Byung Song,

Jae Hoon Lee, Young-Joo Lee; Analysis and interpretation of data: Eunsung Jun, Abdulwahab A. Alshahrani, Sang Hyun Shin, Young-Joo Lee; Statistical Analysis: Sang Hyun Shin, Dae Wook Hwang, Ki Byung Song, Jae Hoon Lee; Drafting of manuscript: Eunsung Jun, Abdulwahab A. Alshahrani, Song Cheol Kim; Critical revision: Eunsung Jun, Abdulwahab A. Alshahrani, Song Cheol Kim; Thereafter, in the final revision of this manuscript, all Authors discussed the interpretation of the data and intellectual contents.

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References

- Buia A, Stockhausen F and Hanisch E: Laparoscopic surgery: A qualified systematic review. *World J Methodol* 5(4): 238-254, 2015. PMID: 26713285, DOI: 10.5662/wjm.v5.i4.238.
- Mizrahi I and Mazeh H: Role of laparoscopy in rectal cancer: A review. *World J Gastroenterol* 20(17): 4900-4907, 2014. PMID: 24803801, DOI: 10.3748/wjg.v20.i17.4900.
- Spaner SJ and Warnock GL: A brief history of endoscopy, laparoscopy, and laparoscopic surgery. *J Laparoendosc Adv Surg Tech A* 7(6): 369-373, 1997. PMID: 9449087, DOI: 10.1089/lap.1997.7.369.
- Daher R, Chouillard E and Panis Y: New trends in colorectal surgery: Single port and natural orifice techniques. *World J Gastroenterol* 20(48): 18104-18120, 2014. PMID: 25561780, DOI: 10.3748/wjg.v20.i48.18104.
- Dhumane PW, Diana M, Leroy J and Marescaux J: Minimally invasive single-site surgery for the digestive system: A technological review. *J Minim Access Surg* 7(1): 40-51, 2011. PMID: 21197242, DOI: 10.4103/0972-9941.72381.
- Kong SH, Oh BM, Yoon H, Ahn HS, Lee HJ, Chung SG, Shiraishi N, Kitano S and Yang HK: Comparison of two- and three-dimensional camera systems in laparoscopic performance: A novel 3d system with one camera. *Surg Endosc* 24(5): 1132-1143, 2010. PMID: 19911222, DOI: 10.1007/s00464-009-0740-8.
- Smith R, Schwab K, Day A, Rockall T, Ballard K, Bailey M and Jourdan I: Effect of passive polarizing three-dimensional displays on surgical performance for experienced laparoscopic surgeons. *Br J Surg* 101(11): 1453-1459, 2014. PMID: 25131843, DOI: 10.1002/bjs.9601.
- Karatas OH and Toy E: Three-dimensional imaging techniques: A literature review. *Eur J Dent* 8(1): 132-140, 2014. PMID: 24966761, DOI: 10.4103/1305-7456.126269.
- Buchs NC and Morel P: Three-dimensional laparoscopy: A new tool in the surgeon's armamentarium. *Surg Technol Int* 23: 19-22, 2013. PMID: 23700184.
- Wilhelm D, Reiser S, Kohn N, Witte M, Leiner U, Muhlbach L, Ruschin D, Reiner W and Feussner H: Comparative evaluation of hd 2d/3d laparoscopic monitors and benchmarking to a theoretically ideal 3d pseudodisplay: Even well-experienced laparoscopists perform better with 3d. *Surg Endosc* 28(8): 2387-2397, 2014. PMID: 24651895, DOI: 10.1007/s00464-014-3487-9.

- 11 Sakata S, Watson MO, Grove PM and Stevenson AR: The conflicting evidence of three-dimensional displays in laparoscopy: A review of systems old and new. *Ann Surg* 263(2): 234-239, 2016. PMID: 26501704, DOI: 10.1097/SLA. 0000000000001504.
- 12 Hanna GB, Shimi SM and Cuschieri A: Randomised study of influence of two-dimensional *versus* three-dimensional imaging on performance of laparoscopic cholecystectomy. *Lancet* 351(9098): 248-251, 1998. PMID: 9457094, DOI: 10.1016/S0140-6736(97)08005-7.
- 13 Kaufman Y, Sharon A, Klein O, Spiegel D, Auslander R and Lissak A: The three-dimensional "insect eye" laparoscopic imaging system-a prospective randomized study. *Gynecol Surg* 4(1): 31-34, 2007. DOI: 10.1007/s10397-006-0245-6.
- 14 Wenzl R, Lehner R, Vry U, Pateisky N, Sevelde P and Husslein P: Three-dimensional video-endoscopy: Clinical use in gynaecological laparoscopy. *Lancet* 344(8937): 1621-1622, 1994. PMID: 7983998, DOI: 10.1016/S0140-6736(94)90412-X.
- 15 Sahu D, Mathew MJ and Reddy PK: 3d laparoscopy – help or hype; initial experience of a tertiary health centre. *J Clin Diagn Res* 8(7): NC01-03, 2014. PMID: 25177597, DOI: 10.7860/JCDR/2014/8234.4543.
- 16 Suresh K: An overview of randomization techniques: An unbiased assessment of outcome in clinical research. *J Hum Reprod Sci* 4(1): 8-11, 2011. PMID: 21772732, DOI: 10.4103/0974-1208.82352.
- 17 Chow SC, Shao J and Wang H: A note on sample size calculation for mean comparisons based on noncentral t-statistics. *J Biopharm Stat* 12(4): 441-456, 2002. PMID: 12477068 DOI: 10.1081/BIP-120016229.
- 18 Julious SA: Sample sizes for clinical trials with normal data. *Stat Med* 23(12): 1921-1986, 2004. PMID: 15195324 DOI: 10.1002/sim.1783.
- 19 Mohamed R, Raman M, Anderson J, McLaughlin K, Rostom A and Coderre S: Validation of the national aeronautics and space administration task load index as a tool to evaluate the learning curve for endoscopy training. *Can J Gastroenterol Hepatol* 28(3): 155-159, 2014. PMID: 24619638.
- 20 Tevæarai HT, Mueller XM and von Segesser LK: 3-D vision improves performance in a pelvic trainer. *Endoscopy* 32(6): 464-468, 2000. PMID: 10863913, DOI: 10.1055/s-2000-643.
- 21 Peitgen K, Walz MV, Walz MV, Holtmann G and Eigler FW: A prospective randomized experimental evaluation of three-dimensional imaging in laparoscopy. *Gastrointest Endosc* 44(3): 262-267, 1996. PMID: 8885344, DOI: 10.1016/S0016-5107(96) 70162-1.
- 22 McDougall EM, Soble JJ, Wolf JS, Jr., Nakada SY, Elashry OM and Clayman RV: Comparison of three-dimensional and two-dimensional laparoscopic video systems. *J Endourol* 10(4): 371-374, 1996. PMID: 8872737, DOI: 10.1089/end.1996.10.371.
- 23 Rassweiler J, Safi KC, Subotic S, Teber D and Frede T: Robotics and telesurgery – an update on their position in laparoscopic radical prostatectomy. *Minim Invasive Ther Allied Technol* 14(2): 109-122, 2005. PMID: 16754625, DOI: 10.1080/13645700510010908.
- 24 Cicione A, Autorino R, Laguna MP, De Sio M, Micali S, Turna B, Sanchez-Salas R, Quattrone C, Dias E, Mota P, Bianchi G, Damiano R, Rassweiler J and Lima E: Three-dimensional technology facilitates surgical performance of novice laparoscopy surgeons: A quantitative assessment on a porcine kidney model. *Urology* 85(6): 1252-1256, 2015. PMID: 26099869, DOI: 10.1016/j.urology.2015.03.009.
- 25 Baum S, Sillem M, Ney JT, Baum A, Friedrich M, Radosa J, Kramer KM, Gronwald B, Gottschling S, Solomayer EF, Rody A and Joukhar R: What are the advantages of 3d cameras in gynaecological laparoscopy? *Geburtshilfe Frauenheilkd* 77(1): 45-51, 2017. PMID: 28190888, DOI: 10.1055/s-0042-120845.
- 26 Kozlov Y, Kovalkov K and Nowogilov V: 3D laparoscopy in neonates and infants. *J Laparoendosc Adv Surg Tech A* 26(12): 1021-1027, 2016. PMID: 27926352, DOI: 10.1089/lap.2016.0155.
- 27 Leon P, Rivellini R, Giudici F, Sciuto A, Pirozzi F and Corcione F: 3D vision provides shorter operative time and more accurate intraoperative surgical performance in laparoscopic hiatal hernia repair compared with 2D vision. *Surg Innov* 24(2): 155-161, 2017. PMID: 28118788, DOI: 10.1177/1553350616687434.
- 28 Sorensen SM, Savran MM, Konge L and Bjerrum F: Three-dimensional *versus* two-dimensional vision in laparoscopy: A systematic review. *Surg Endosc* 30(1): 11-23, 2016. PMID: 25840896, DOI: 10.1007/s00464-015-4189-7.
- 29 Gurusamy KS, Sahay S and Davidson BR: Three dimensional *versus* two dimensional imaging for laparoscopic cholecystectomy. *Cochrane Database Syst Rev* 1: CD006882, 2011. PMID: 21249683, DOI: 10.1002/14651858. CD006882.pub2.

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