Three-dimensional vs Standard Laparoscopy: Comparative Assessment Using a Validated Program for Laparoscopic Urologic Skills

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OBJECTIVE To compare the last generation of 3-dimensional imaging (3D) vs standard 2-dimensional imaging (2D) laparoscopy.

MATERIALS AND METHODS A prospective observational study was conducted during the 4th Minimally Invasive Urological Surgical Week Course held in Braga (Portugal) in April 2013. The course participants and faculty were asked to perform standardized tasks in the dry laboratory setting and randomly assigned into 2 study groups; one starting with 3D, the other with 2D laparoscopy. The 5 tasks of the European Training in Basic Laparoscopic Urological Skills were performed. Time to complete each task and errors made were recorded and analyzed. An end-of-study questionnaire was filled by the participants.

RESULTS Ten laparoscopic experts and 23 laparoscopy-naïve residents were included. Overall, a significantly better performance was obtained using 3D in terms of time (1115 seconds, interquartile range [IQR] 596-1469 vs 1299 seconds, IQR 620-1723; $P = .027$) and number of errors (2, IQR 1-3 vs 3, IQR 2-5.5; $P = .001$). However, the experts were faster only in the "peg transfer" task when using the 3D, whereas naïves improved their performance in 3 of the 5 tasks. A linear correlation between level of experience and performance was found. Three-dimensional imaging was perceived as "easier" by a third of the laparoscopy-naïve participants ($P = .027$).

CONCLUSION Three-dimensional imaging seems to facilitate surgical performance of urologic surgeons without laparoscopic background in the dry laboratory setting. The advantage provided by 3D for those with previous laparoscopic experience remains to be demonstrated. Further studies are needed to determine the actual advantage of 3D over standard 2D laparoscopy in the clinical setting. UROLOGY ■: ■−■, 2013. © 2013 Elsevier Inc.

Laparoscopy has been increasingly adopted in urology over the last 2 decades, and it is nowadays commonly used in the management of several urologic diseases. Traditionally, laparoscopy has been based on 2-dimensional (2D) imaging, which has represented a considerable challenge for those approaching this technique.[1] Thus, 3-dimensional (3D) visualization technology for laparoscopy has been proposed, since the early 1990s, as a way to facilitate laparoscopic performance. However, early 3D laparoscopic technology was limited in terms of image quality, so that its use had not been implemented.[2]

More recently, industry has developed novel 3D systems where the imaging is similar to stereoscopic vision, in which the depth perception is achieved by different unique images received by each eye. Thus, more recent studies have suggested a possible advantage provided by these new 3D systems during laparoscopic performance.[3-5] However, comparative assessments of new generation 3D vs 2D laparoscopy remain limited, especially in the urology field.

The aim of this study was to compare the effect of 3D imaging on laparoscopic performance in the laboratory

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setting using a recently developed validated assessment tool.

MATERIALS AND METHODS

Participants and Setting

The present study was carried out at the Life and Health Sciences Research Institute, School of Health Sciences, University of Minho, during the 4th Minimally Invasive Urological Surgical Week annual course in Braga, Portugal in April 2013. Faculty members and course participants agreed to participate and were included in the study. Each participant was asked to complete standardized tasks in the dry laboratory, using both 2D and 3D systems. A computer-generated randomization sequence was used to allocate the participants in 2 study groups; the first starting with 3D laparoscopy, the second with 2D laparoscopy.

Task Description

The 5 exercises of the European Training in Basic Laparoscopic Urological Skills (E-BLUS) were performed by each participant.[6] The E-BLUS was designed on the basis of the widely used Fundamentals of Laparoscopic Surgery program, with the addition of 2 tasks specifically conceived for urology training purposes. The face, content, and construct validity of E-BLUS were previously demonstrated. Briefly, the E-BLUS exercises consist of the following exercises: exercise 1 — to transfer objects one by one from one side of the board to the other and back avoiding to drop objects; exercise 2 — to cut a circle keeping within 2 black lines avoiding to cut in or beyond the 2 black lines; exercise 3 — to tie a single knot with 1 double-throw and 2 single-throws ensuring close margins juxtaposition; exercise 4 — to clip and cut a red tube (artery), followed by a blue tube (vein) avoiding to place clips or cut outside line limits; exercise 5 — to guide a needle through then rings, following a indicated route in which entering a ring from the wrong side was considered error. Each exercise was explained to the participants with a video. Moreover, each participant was allowed 5 minutes to familiarize with the exercise. The tasks were performed using 2 boxes trainer equipped with E-BLUS exercises, standard laparoscopic instruments (Karl Storz, Germany), Hem-o-lok applier (Teleflex), Vycril 3-0 sutures (Ethicon), and fixed-position 2D or 3D video camera with dedicated glasses.

Imaging System

Two working stations were used. The first one was equipped with the new 3D Karl Storz camera system attached to a 32″ monitor. The other one was equipped with the latest generation of Karl Storz 2D high definition (HD) laparoscopic system, connected to a laparoscopic video tower with an HD flat screen video monitor. A fixed 10-mm telescope 0° was used as optic for both stations.

Outcomes Measures

Before performing laparoscopic tasks, each participant completed a baseline demographic questionnaire about age, practice setting (private, community, or teaching hospital), position (resident or postgraduated), and previous laparoscopic experience (expert: >50 procedures/year; naïve: none previous experience). Time to perform the task and number of errors were recorded for each task and considered as performance score. Then, an end-of-study questionnaire was administered regarding subjective perception of 3D vision vs 2D.

Table 1. Overall performance in completing the European Training in Basic Laparoscopic Urological Skills curriculum: comparison of the 2D vs 3D systems. Spearman coefficient (r_s) for correlation between performance and laparoscopic experience

Parameter	2D	3D	P†
Time used, s	1299 (620-1723)*	1115 (596-1469)*	.027
Error number made, n	3 (2-5.5)*	2 (1-3)*	.001
r_s Time‡	−699	−755	
r_s Error number‡	−446	−461	

* Values expressed as median interquartile range.
† Wilcoxon test.
‡ For each r_s a P <.05 was obtained.

Statistical Analysis

Statistical analysis was performed using the Statistical Package for Social Science 18.0 for Windows. Evaluation of data distribution showed a non-normal distribution of the study dataset. Wilcoxon test and Mann-Whitney test were used to analyze ordinal variables and Chi square test for categorical variables. Furthermore, Spearman correlation coefficient was rated to assess the correlation between the 2D or 3D performance and laparoscopic experience. A P value <.05 was considered as the threshold for statistical significance.

RESULTS

Overall, 33 urologic surgeons participated in the study, including 10 "experts" (median age 45 years; interquartile range [IQR] 38-54) and 23 "laparoscopy-naïve" residents (median age 27 years; IQR 25-28; P = 0.001). Most of the participants worked in a teaching hospital (29 of 33; 87.8%).

Table 1 summarizes the overall time used to complete the task and number of errors using 2D or 3D system. The use of 3D was associated with a faster (median 1115 [IQR: 596-1469] vs 1299 [IQR: 620-1723] seconds; P = .027) and more precise (median 2 [IQR: 1-3] vs 3 [IQR: 2-5.5] errors; P = .001) performance. Moreover, a significant inverse correlation was found between previous laparoscopic experience and performance, with both the 2D and the 3D systems (Fig. 1).

Stratifying participants according to their laparoscopic experience and E-BLUS exercises, few significant differences between 2D and 3D laparoscopy were detected (Table 2; Fig. 1). In detail, "experts" were faster using the 3D only when performing peg transfer (exercise 1; P = .01), whereas the "laparoscopic-naïve" were faster when carrying the clip and cut (exercise 4; P = .03). Moreover, the "laparoscopic-naïve" participants were more accurate with the 3D in 3 of 5 exercises (peg transfer, P = .03; cut a circle, P = .04; clip and cut, P = .01), whereas "experts" demonstrated the same level of accuracy regardless the system used, as demonstrated by the similar number of errors made for all the exercises.

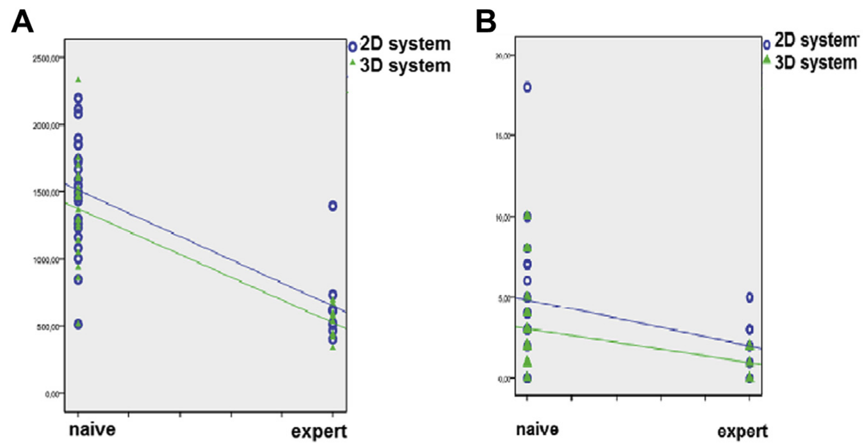

Figure 1. Execution time **(A)** and errors **(B)** made for the overall 5 European Training in Basic Laparoscopic Urological Skills task related to laparoscopic experience. (Color version available online.)

Overall, comparative assessment between experts and naïve suggested that previous experience with laparoscopy significantly improves task performance regardless of the system used.

In terms of subjective perception, participants indicated exercise number 5 (needle guidance) as the one with the highest benefit provided by the 3D vision (P not evaluable). Only 33% of the "laparoscopic-naïve" indicated the 3D laparoscopy to be easier than 2D laparoscopy, whereas for the other participants they were considered similar ($P = .027$).

COMMENT

Despite its increasing adoption in urology over the last 2 decades, it is well established that laparoscopy carries intrinsic limitations, including reduced depth perception of the operative field caused by the use of 2D monitors, poor hand-eye coordination as a result of location of the monitor, variable amplification, and mirrored movement, and reduced haptic feedback from the use of long surgical instruments.

To partially overcome these challenges, recent technological advances allowed the development of 3D imaging with the rationale that an improved depth perception might translate into a better surgical performance. However, studies comparing 3D vs 2D systems have shown conflicting findings (Table 3). Moreover, available studies have been mostly done in the general surgery field, with only very limited evidence available for urology.

In the present study, we evaluated whether the use of a last generation 3D system provides an advantage in term of performance in a recently validated curriculum for urologic laparoscopy.[6]

Interestingly, although an overall significant advantage was found for the 3D in terms of time and precision during the assessed tasks, there was some degree of variability when stratifying participants according to their level of previous laparoscopic experience.

Those with previous laparoscopic background (defined as "experts") did not subjectively recognize an advantage with using 3D system, although they performed better with the peg transfer task, which was devised to assess the ambidexterity. Thus, it can be speculated that performing in 3D could facilitate hand versatility in surgeon with pre-existing laparoscopic skills. The assumption is also supported by the finding that all the participants perceived "needle guidance" as the task where 3D system could translate in an actual benefit. Guiding a needle through sequential rings route was suggested as a method to train needle position, eye-hand coordination, and ambidexterity.[6] This skill benefit could be translated in easier urologic surgical steps, such as performing urethral bladder neck anastomosis during radical laparoscopic prostatectomy or suturing during pyeloplasty.

Laparoscopic-naïve participants were more precise (ie, less number of errors) when using the 3D system in 3 over 5 tasks: "cutting a circle", "clipping and cutting", and "peg transfer". The "clipping and cutting" is a simplified representation of the clipping and cutting of the renal vessels that occurs during nephrectomy. As such, it can be regarded a specific urologic skill.

Another interesting finding was the overall correlation between "experience" and performance, which was found with both the 2D and the 3D. This finding supports the construct validity of the E-BLUS training program.

Our study findings are in line with recent studies, suggesting that a higher level of technology, from camera to image display, translates into a better performance in the laboratory setting. Honeck et al[3] compared novices or experts laparoscopic surgeons using 2D vs 3D imaging and reported a slightly better performance with the 3D system. Moreover, they reported a better perception and spatial resolution among the experts with the use of the 3D. In another recent study, enrolling 20 medical students and 10 laparoscopic experts, Storz et al[7] showed that the use of 3D imaging allowed the surgeons to be faster and more accurate. In 4 of the 5 tasks, the study participants made

Table 2. Performance (A: completion time; B: errors made) using 2D and 3D camera systems according to previous laparoscopic experience

	Exercise 1 Peg Transfer			Exercise 2 Cut a Circle			Exercise 3 Knot			Exercise 4 Clip and Cut			Exercise 5 Needle Guidance		
A	2D	3D	P*	2D	3D	P*	2D	3D	P*	2D	3D	P*	2D	3D	P*
Expert N = 10	102 (94.5-146.5)	101 (74.7-120)	**.01**	75.5 (59.5-104.5)	54.5 (40.7-106.5)	.17	85.5 (75.5-96.7)	104 (64-111)	.50	111 (102-125.5)	114.5 (101-123)	.87	158 (137-163.2)	150.5 (121-160.5)	.09
Naive N = 23	209 (171-249)	182 (163-226)	.10	228 (197-314)	223 (160-217)	.31	329 (227-440)	301 (222-392)	.42	310 (223-390)	226 (187-320)	**.03**	360 (314-600)	403 (292-450)	.10
P†	**.001**	**.001**		**.001**	**.001**		**.001**	**.001**		**.001**	**.001**		**.001**	**.001**	
B															
Expert N = 10	0.5 (0-1)	0 .5 (0-1)	.31	0	0	1	0.5 (0-1.25)	0 (0-0.25)	.096	0	0 (0-0.25)	.317	0	0	1
Naive N = 23	1 (0-2)	0 (0-1)	**.03**	1 (0-2)	0	**.04**	1 (0-2)	1 (0-1)	.14	2 (1-4)	1 (0-1)	**.01**	0	0	.31
P†	.530	.18		**.03**	0.23		.49	**.044**		**.01**	**.051**		.34	.167	

* Wilcoxon text.
† Mann-Whitney test; in bold significative level.

fewer mistakes in 3D than in 2D vision. In 4 of the tasks, they needed significantly more time in the 2D mode. The student group and the expert group showed similarly improved performance, whereas the surgeon group additionally saved more time on difficult tasks. The authors concluded that 3D HD using a state-of-the-art 3D monitor permits superior task efficiency, even as compared with the latest 2D HD video systems. In our study, the benefit of the 3D was more significant for laparoscopic-naïve urologists than experts in carrying standardized tasks.

Notably, the present study represents the first to use an assessment tool specifically designed for urology, which was also recently adopted by the European Association of Urology Section of Uro-Technology for the development of the E-BLUS program. This tool was already validated in terms of face, content, and construct validity.[6] In general, the fact of using a standardized and validated tool enabled us to perform a reliable and objective analysis.

However, limitations of the study itself are to be recognized. Despite our study sample comparing favorably with those in other similar studies, we did not formally power the study so that differences between the study groups might have been left undetected. Moreover, in clinical practice, the scope can be moved to have more depth spatial information,[8] whereas in our study, the camera was maintained in a predetermined fixed position. Ultimately, our experience was carried out in a laboratory setting, so that it remains to be determined the translation of these findings in the clinical setting, in which other factors, besides the technology itself, play a major role in determining surgical performance. In other words, actual laparoscopic procedures represent a more challenging task; thus, the predictive validity of the E-BLUS remains to be further studied. In this respect, clinical studies comparing 3D vs 2D are still limited; Gurusamy et al[9] found no evidence that 3D is superior to 2D in laparoscopic cholecystectomy in the clinical setting in terms of postoperative complications, conversion to open surgery, and operating time.

CONCLUSION

The latest generation of 3D imaging for laparoscopy seems to facilitate surgical performance of urologic surgeons without laparoscopic background. For those with established laparoscopic background, the advantage provided by the use of 3D remains to be determined. Further studies with larger sample size are needed to determine the actual effect of using 3D laparoscopy in the clinical setting.

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Table 3. Overview on main comparative studies about 3D vs 2D laparoscopic systems

Ref.	Participants	3D System	2D System	Task Performed	Authors Conclusions
Hanna GB et al[10]	Four specialist registrars	3D-video and camera system (Carl Zeiss)	Three chip camera (Karl Storz)	RCT on 60 VLP cholecystecomies. Four surgery steps adopted as task: 1. Dissection of cystic duct and artery in Calot's triangle 2. Insertion of catheter for cholangiography 3. Ligation of cystic duct and external knot 4. Separation of gall-bladder from the liver bed	Better subjective depth perception using 3D but 2D was judged better in terms of sharpness, contrast, and ghosting.
McDougall ME et al[11]	Twenty-two between urology or gynecology VLP experts	Endolive Stereo Endoscope system (Carl Zeiss) and StereoVu Video Laparoscope system (Welch Allyn Surgical Imaging System)	Conventional systems of Circom/ACMI, Olympus, Karl Storz, Richard Wolf Medical Instruments	Eleven 2D and nine 3D retroperitoneal nephrectomies in pigs Sixteen 2D and 11 Burch bladder neck suspensions in pigs.	For all the surgeons, the 3D system did not improve image quality and procedure performance.
Kum CK et al[12]	Thirteen medical students and 5 general surgeons	Baxter Healthcare	Three-chip cameras (Olympus)	Performing a knot in a training box	3D use significantly faster both for students and surgeons.
Lagrange A et al[13]	Seventeen medical students, 5 surgeons and 5 residents (2 urology – 1 gynecology – 2 surgeons); randomized starting	Endosite 3Di visual system (Viking Systems) and daVinci Robotic Surgical System (Intuitive Surgical)	High-definition cameras (Stryker)	Three tasks from LTS-2000 Simulator (RealSim Systems): peg transfer, ring manipulation and Cannulation	Overall, 3D does not confer an advantage over 2D. The 3D robot offers advantage in more complicated tasks
Storz et al. (2012)[7]	Twenty medical students and 10 VLP experts; randomized starting	6CCD stereo endoscopic camera head (Richard Wolf)	6CCD stereo endoscopic camera head (Richard Wolf)	Five tasks: 1. Eight black circular target spots had to be touched 2. Seven circular target spots had to be touched 20 times in a randomly defined order 3. Move a metal loop on a metal wire without touch it 4. Move a straight needle across five holes	Use of 3D improves task efficiency especially when performing difficult tasks

Continued

Table 3. Continued

Ref.	Participants	3D System	2D System	Task Performed	Authors Conclusions
				5. Continuous suturing using a circular needle	
Tanagho Y.S. et al[4]	Previous VLP skill described as 23 novices, 5 intermediate, 3 expert, 2 unsure; randomized starting.	Viking 3DHD Laparoscopic Vision System (Viking System)	Viking 2DHD Laparoscopic Vision System (Viking Systems)	Three tasks of Fundamentals of Laparoscopic Surgery program (peg transfer, pattern cutting, suturing/knot tying)	3D use was shorter in each task and associated with improved precision. Any potential side effect from 3D use occurred.
Kong SH et al[14]	Twenty-one medical students and 6 surgeons	RAHPACAM 105i and DV LENS (WDV-200H) (Wasol)	OTV-S6, camera head (Olympus)	Task 1: put a thread in six holes using two mosquito Task 2: using a gastrectomy training box vessel dissection was simulated	Completion time was not different. Using 2D more Errors were made. 53.6% of participants preferred 3D while the 16.7% the 2D and the 29.8% tasted none difference
Wagner OJ et al[5]	Thirty-four participants with mixed VLP experience	Binocular vision; EndoSite 3Di Digital Vision System (Viking Systems) and DaVinci S Surgical System (Intuitive Surgical) in 3D modality	Monocular vision; One 3CCD digital Karl Storz system and DaVinci S Surgical System (Intuitive Surgical) in 2D modality	Open vs 2D vs 3D through the performing of three pods of The Chamberlain Group: Sea Spike Pod, Suturing, S-Hook	Task performance with each 3D was superior to that with 2D, independently of surgeon experience. 3D robotic performance was superior to that VLP in more difficult task
Honeck et al[3]	Ten experts and 10 novices divided in 2 study group (2D vs 3D)	Einstein system, Scholly Fiber-optics, Germany	Karl Storz 2D system	Five task: placing three rings in a three cones; displacing the previous rings; needle passage through a ring, cutting a suture; tying one knot.	3D system improved task performance event for expert surgeons

RCT, randomized control trial; VLP, videolaparoscopy.

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EDITORIAL COMMENT

I liked this simple study, although it was somewhat underpowered to underpin the proof of the concept; there were not enough participants, and the tasks perhaps were not as difficult to extrapolate the outcomes to those performed during complex laparoscopic surgery. The bottom line, however, was that comparative assessment suggested that previous experience with laparoscopy significantly improves task performance regardless of the system used; 3D might, however, flatten the learning curve for clinicians commencing their laparoscopic training. This is very important when we consider how we should go about setting up training for newcomers to the field of laparoscopic urologic surgery.

There remains a lot to be done to substantiate the concept proposed, especially its predictive validity, but this study certainly seems to be a step in the right direction.

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