Three-dimensional Technology Facilitates Surgical Performance of Novice Laparoscopy Surgeons: A Quantitative Assessment on a Porcine Kidney Model

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OBJECTIVE To determine whether the use of 3-dimensional (3D) imaging translates into a better surgical performance of naïve urologic laparoscopic surgeons during pyeloplasty (PY) and partial nephrectomy (PN) procedures.

MATERIALS AND METHODS Eighteen surgeons without any previous laparoscopic experience were randomly assigned to perform PY and PN in a porcine model using initially 2-dimensional (2D) and 3D laparoscopy. A surgical performance score was rated by an "expert" tutor through a modified 5-item global rating scale contemplating operative field view, bimanual dexterity, efficiency, tissue handling, and autonomy. Overall surgical time, complications, subjective perception of participating surgeons, and inconveniences related to the 3D vision were recorded.

RESULTS No difference in terms if operative time was found between 2D or 3D laparoscopy for both the PY ($P = .51$) and the PN ($P = .28$) procedures. A better rate in terms of surgical performance score was noted by the tutors when the study participants were using 3D vs 2D, for both PY (3.6 [0.8] vs 3.0 [0.4]; $P = .034$) and PN (3.6 [0.51] vs 3.15 [0.63]; $P = .001$). No complications occurred in any of the procedures. Most (77.2%) of the participating naïve laparoscopic surgeons had the perception that 3D laparoscopy was overall easier than 2D. Headache (18.1%), nausea (18.1%), and visual disturbance (18.1%) were the most common issues reported by the surgeons during 3D procedures.

CONCLUSION Despite the absence of translation in a shorter operative time, the use of 3D technology seems to facilitate the surgical performance of naïve surgeons during laparoscopic kidney procedures on a porcine model. UROLOGY 85: 1252−1256, 2015. © 2015 Elsevier Inc.

Technology has driven important advances in the field of minimally invasive urologic surgery over the past 2 decades. Laparoscopy has become a standard technique for a wide range of surgical indications in urology, especially in kidney surgery. However, acquisition of laparoscopic skills can be challenging, given the absence of depth perception due to 2-dimensional (2D) vision. When viewing a 2D conventional laparoscopic image, both eyes see exactly the same image, missing the physiological binocular horizontal disparity (stereoscopy), which is at the basis of depth perception.[1] A recent European survey showed that despite urologic laparoscopy being available to residents in most training institutions, exposure to laparoscopy is still considered to be inadequate.[2]

The main distinctive features of robot-assisted laparoscopy over standard laparoscopy are represented by the EndoWrist technology (Intuitive Surgical Inc., Sunnivale, CA) and by the 3-dimensional (3D) stereoscopic vision, which significantly facilitates surgical tasks.[3,4] Industry has recently developed novel 3D systems for laparoscopic surgery, where the depth perception is achieved by different unique images received by each eye. Studies have suggested a possible advantage provided by

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Financial Disclosure: *The authors declare that they have no relevant financial interests.*

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Submitted: February 2, 2015, accepted (with revisions): March 13, 2015

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these systems during laparoscopic performance in the dry laboratory setting, especially for novice surgeons.[5-7]

The aim of this study was to determine the benefit of the latest generation 3D technology in laparoscopic kidney surgery for novice surgeons in an animal model and to record their subjective perception regarding 3D laparoscopy.

MATERIALS AND METHODS

Study Design

The present study was carried out at the Life and Health Sciences Research Institute, University of Minho (Braga, Portugal). Participants to the Fifth Minimally Invasive Urological Surgical Week annual course were asked to join the study. The study design was explained to each of them, and they gave their consent to participate. Baseline demographics of the participants were recorded, including age, year of completion of residency, position, practice setting, and previous experience. Each participant was assessed during the performance of a pyeloplasty (PY) and a partial nephrectomy (PN) procedure in a porcine model, using both 2D and 3D vision, under the guidance of an expert supervisor or tutor, who was not blinded to the type of laparoscopy being used. Each supervisor or tutor was assigned to a working station and was instructed to observe the participant performing the assigned task by looking at a screen, either a standard HD-2D screen or an HD-3D screen (in this case, using glasses). A computer-generated randomization sequence was used to determine if each participant would start with 2D or 3D first. Each participant was asked to answer 2 questions regarding their "3D experience." One was related to the "subjective perception" of their surgical performance ("Compared to standard 2D laparoscopy, you feel that 3D laparoscopy for kidney surgery is: overall easier, easier only when suturing is needed, approximately the same, overall more difficult?") and one related to the "side effects" experienced during the surgery ("Did you experience any issue by using 3D laparoscopy: headache, nausea, visual disturbances, others (specify)?").

Surgical Procedures

The study was compliant with local institutional animal care and use committee. The Karl Storz 3D system (consisting of a 3D TIPCAM 1, a 3D camera control unit, a 3D monitor, and dedicated glasses) was used for this study. Female domestic pigs, weighing between 25 and 30 kg, were used in all the procedures. Under general anesthesia and mechanical ventilation, participants started by performing a dismembered PY. Subsequently, renal hilum was isolated and clamped to proceed with a lower pole PN. Renorrhaphy was carried out using a single layer of a running 0-Vicryl suture. The same surgical steps were performed by using 2D and 3D vision.

Assessment

Surgical performance score was recorded by the laparoscopic tutor using a modified 5-item global rating scale[8] that contemplated operative field view, bimanual dexterity, efficiency, tissue handling, and autonomy. For each item, a score between 1 (inadequate) and 5 (optimal) was assigned; hence, a final skill appraisal as the mean of the 5 items was computed. Furthermore, operative time of main surgical steps, intraoperative complications, and estimated blood loss were also recorded as secondary outcomes.

Finally, subjective opinion of each participant on 3D laparoscopy was investigated by asking the attendees 2 questions: one on grade of perceived degree of difficulty and the second one on possible "side effects" from the use of 3D vision.

Table 1. Characteristics of study participants

Practice setting	
Private hospital	2 (11.1)
Community public hospital	10 (55.6)
Teaching hospital	6 (33.3)
Position	
Staff	8 (44.4)
Resident/fellow	10 (55.6)
Previous laparoscopic kidney surgery experience	
<10 cases	14 (77.8)
10-50 cases	2 (11.1)
>50 cases	2 (11.1)
Previous 3D-laparoscopy experience	
0-5 cases	1 (5)
6-20 cases	0
>20 cases	0

3D, three dimensional.
Data are expressed as cases number (percentage).

Statistical Analysis

Data were collected and entered into an electronic database. Results were analyzed by Statistical Package for Social Science 18.0 for Windows (IBM Corporation, Armonk, NY). Statistical significance was set at $P < .05$ adopting the paired 2-sided Student t test and the chi-square test for quantitative and qualitative variables, respectively.

RESULTS

Overall, 18 course attendees (mean age, 36.4 ± 15.4 years) participated in the study. Most of them were residents or fellows (55.6%) and working in community public hospitals (55.6%). Previous laparoscopic experience was limited to <10 cases for most of the participants (77.8%). Only 1 participant (5%) had used 3D laparoscopic equipment before (Table 1).

Parameters related to surgical performance are summarized in Table 2. Operative time for PY was shorter for 3D laparoscopy but without reaching statistical difference (59.2 ± 18.8 vs 67.2 ± 18.4 minutes; $P = .51$). Time required to isolate the ureter was significantly shorter using 3D vision than 2D (17.9 ± 7.7 vs 23.05 ± 9.7 minutes, respectively; $P = .04$), whereas the time to spatulate the ureter and to perform the pyeloureteral anastomosis were both similar between 3D and 2D laparoscopy ($P = .48$ and $P = .75$, respectively). Mean surgical performance score was better when using 3D technology (3.6 ± 0.8 vs 3 ± 0.4; $P = .034$). A better operative field ($P = .03$) and bimanual dexterity ($P = .02$) were recorded for 3D laparoscopy, but no significant differences were detected in terms of efficiency ($P = .28$), tissue handling ($P = .13$), and autonomy ($P = .11$; Fig. 1A). No complications occurred during the PY procedures.

For PN as well, there was no significant difference in overall surgical time (58.3 ± 13.7 minutes for 2D vs 54.8 ± 10.5 minutes for 3D; $P = .28$). In addition, no significant differences were recorded for time to hilar control ($P = .12$) and time for resection and renorrhaphy ($P = .16$). A better surgical performance for this procedure was recorded for 3D laparoscopy (3.60 ± 0.51) compared with that for 2D laparoscopy (3.15 ± 0.63; $P = .01$). Significant

Table 2. Parameters related to the surgical performance

	2D System	3D System	*P* Value
Pyeloplasty			
Operative time			
Overall	67.27 ± 18.4	59.22 ± 18.87	.51
Isolation of ureter	23.05 ± 9.7	17.9 ± 7.7	.04
Spatulation of ureter	13.5 ± 6.5	12.1 ± 6.5	.48
Anastomosis	30.1 ± 11.1	28.9 ± 12.9	.75
GRS score	3.0 ± 0.4	3.6 ± 0.8	.03
Complications	0	0	—
Partial nephrectomy			
Operative time			
Overall	58.3 ± 13.7	54.8 ± 10.5	.28
Hilum control	24.7 ± 9.6	24.7 ± 7.5	.12
Tumor resection and renorrhaphy	32.7 ± 8.7	30.1 ± 6.2	.16
GRS score	3.15 ± 0.63	3.60 ± 0.51	<.01
Complications	0	0	—

GRS, global rating scale; 2D, two dimensional; 3D, three dimensional.

differences for all parameters were observed (Fig. 1B). Also, for PN procedures, no complications were registered.

Most participants (77.2%) "subjectively" defined 3D laparoscopy easier overall, whereas the remaining of them (22.8%) perceived an advantage of 3D vision only during suturing tasks ($P < .01$). Ten participants (45.5%) did not experience any issue related to the use of 3D technology, Headache (18.1%), nausea (18.1%), and visual disturbance (18.1%) were the most common issues reported by the surgeons during 3D procedures ($P < .01$).

COMMENT

One of the recognized limitations of conventional laparoscopy is the lack of depth perception, which represents a challenging issue, especially early in the surgical skills acquisition. The introduction of robotic technology has addressed this issue by providing 3D imaging through stereoscopic vision, one of the many attractive features of this technology, which however carries its own cost.

3D imaging is not new to laparoscopy. However, early experience in the 90s was limited by the poor image quality, which did not foster a clinical implementation of the technology.[9] More recently, industry was able to develop more advanced 3D imaging systems, which can provide a stereoscopic vision, so that the depth perception is more effectively obtained. The availability of such systems has generated renewed enthusiasm toward the use of 3D vision for laparoscopy. As a result, few studies have been reported suggesting overall a better surgical performance when using 3D systems during laparoscopic (nonrobotic) tasks in a preclinical setting (Table 3).[5-7,10-14]

Findings from our study suggest that the use of 3D technology facilitates laparoscopic surgical performance of naïve surgeons during kidney procedures in a porcine model. Notably, this is the first study reported in urology using this type of preclinical in vivo model. Other available studies have used well-validated laparoscopic (nonrobotic) tasks in an ex vivo (dry lab) setting. Our own group conducted a study where participants (10 laparoscopic experts and 23 laparoscopy-naïve residents) were asked to perform standardized tasks (European Training in Basic Laparoscopic Urological Skills) in the dry laboratory setting by using 3D and 2D laparoscopy. Overall, a better performance was obtained using 3D in terms of time. 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.[7] Smith et al[6] also concluded that stereoscopic vision improves novice surgeon performance during acquisition of minimally invasive surgical skills in terms of precision and efficiency. Honeck et al[10] highlighted that the advantage of 3D imaging relies on improved spatial orientation and depth perception. Alaraimi et al compared the performance of novices with 3D vs 2D laparoscopy using Fundamentals of Laparoscopic Surgery tasks in a randomized trial. They found that stereoscopic vision translated into an improved accuracy in laparoscopic skills for novices, as manifested by reduced numbers of repetitions and errors.[10] Lusch et al used the same 3D camera system we used in our study (ie, Karl Storz), and they tested medical students, residents, and expert surgeons. Adjusting for the surgical level, results obtained with a 3D camera image were superior in most of the tasks, suggesting a significant improvement in depth perception, spatial location, and precision of surgical performance. The authors concluded that also expert laparoscopic surgeons may benefit from 3D imaging.[12]

Tanagho et al also tested their study participants (with a different level of laparoscopic experience) using drills from the validated Fundamentals of Laparoscopic Surgery skill set (peg transfer, pattern cutting, and suturing or knot tying). A greater speed was recorded for 3D, and also, fewer errors were committed in the peg transfer task. Subjective measures of efficiency and accuracy also favored 3D visualization. The advantage of 3D vision persisted regardless of the participants' level of technical expertise (novice vs intermediate or expert). Participants overwhelmingly preferred 3D visualization.[13] This was also our findings, as most participants (77.2%) "subjectively" defined 3D laparoscopy easier overall, whereas remaining ones (22.8%) perceived an advantage of 3D vision only for suturing tasks.

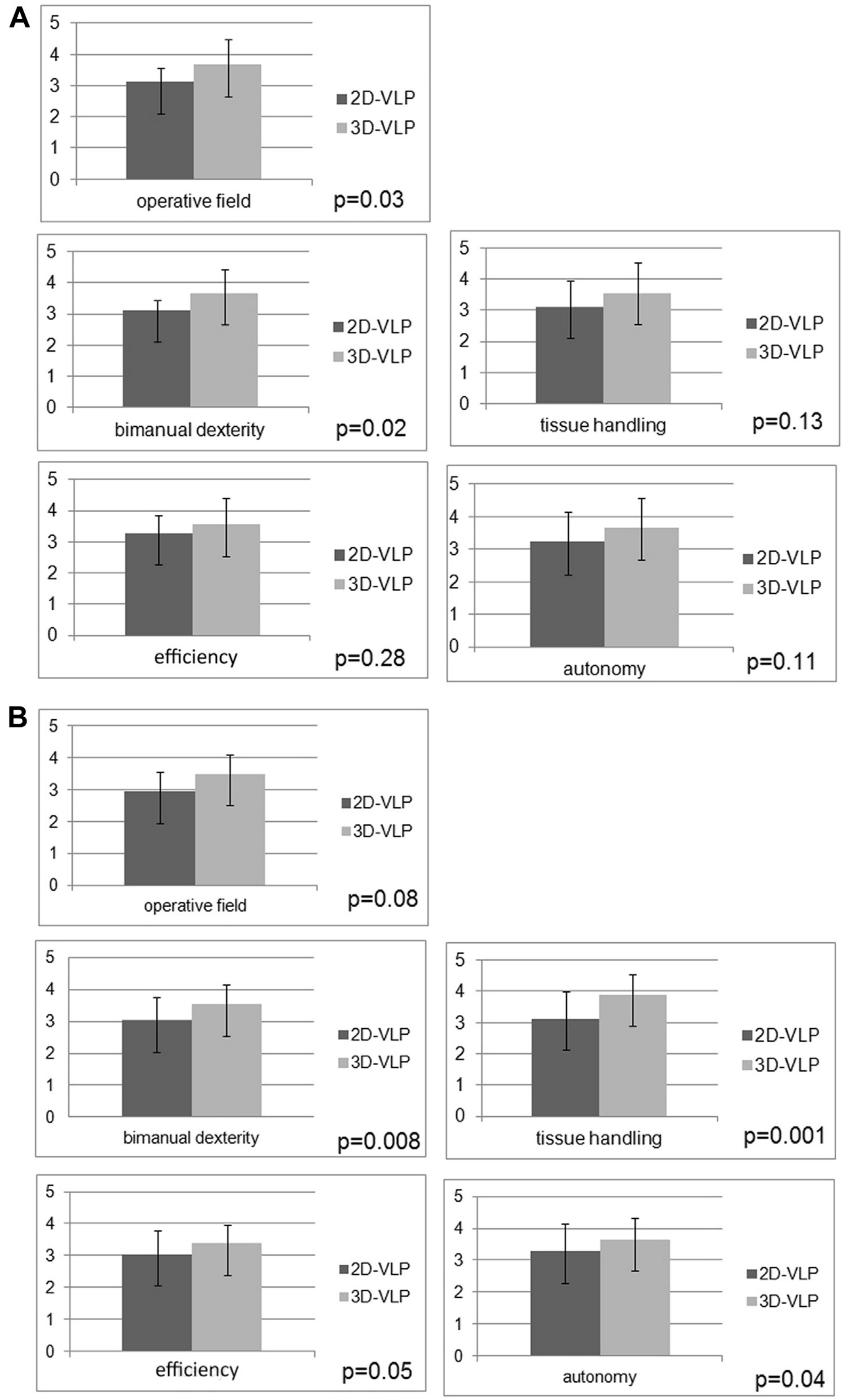

Figure 1. (A) Illustration of surgical performance score for pyeloplasty procedure. **(B)** Illustration of surgical performance score for partial nephrectomy procedure. VLP, videolaparoscopy.

Interestingly, we could not detect any difference in operative time. On might argue that this is related to the fact that study participants were novice for laparoscopy. Alaraimi et al had the same finding in their randomized study involving novice surgeons only.[10] On the other hand, Bilgen et al[15] reported a small case series and found that the use of a 3D system (Viking system) allowed them to save about 10 minutes for laparoscopic cholecystectomy procedure. Specifically to urology, Aykasan et al recently reported a comparative outcome analysis of laparoscopic radical prostatectomy by using 3D vs 2D imaging.[16] They found that the 3D procedure was faster (mean operative time, 131 vs

Table 3. Studies comparing 3D to 2D laparoscopy in an ex vivo setting: a literature overview

Reference	Participants (n)	Assessment Tool (Tasks)	Advantages Provided by 3D Laparoscopy
Cicione et al[7]	Laparoscopic experts (10) and laparoscopy-naïve residents (23)	EBLUS	Efficiency and proficiency
Smith et al[6]	Novice surgeons (20)	Standardized nonvalidated tasks	Efficiency and proficiency
Lusch et al[12]	Medical students (10), residents (7), experts (7)	Standardized nonvalidated tasks	Depth perception, spatial location, precision of surgical performance
Mistry et al[14]	Medical students (31)	MISTELS	None
Storz et al[5]	Medical students (20) and laparoscopic experts (10)	Standardized nonvalidated tasks	Efficiency
Honeck et al[10]	Laparoscopic experts (10) and novices (10)	Standardized nonvalidated tasks	Spatial orientation and depth perception
Tanagho et al[13]	Surgeons with different levels of experience (33)	FLS	Efficiency and proficiency
Alaraimi et al[11]	Novices (56)	FLS	Efficiency and proficiency

EBLUS, European Training in Basic Laparoscopic Urological Skills; FLS, Fundamentals of Laparoscopic Surgery; MISTELS, McGill Inanimate System for Training and Evaluation of Laparoscopic Skills; other abbreviations as in Tables 1 and 2.

190 minutes for 2D; $P < .001$), and this was mostly related to the performance of urethra-vesical anastomosis. Moreover, they obtained a higher early recovery of continence with 3D patients (50% vs 25%; $P = .02$). Thus, they speculate that 3D laparoscopy can be regarded as an acceptable alternative to robot-assisted laparoscopy for radical prostatectomy.

Our study presents few limitations that need to be recognized. The 5-item global rating scale used is a practical tool to measure surgical skills, which has been validated in different studies.[8] However, the assessment based on this tool remains subjective, which implies a bias as the "experts" tutoring the study participants were not blind to the vision system used. In addition, the limited sample size might have translated into a lack of statistical significance for some of the study comparisons.

CONCLUSION

The use of 3D imaging seems to quantitatively improve and to subjectively facilitate the surgical performance of naïve surgeons during laparoscopic kidney procedures in a porcine model. Further studies assessing the impact of 3D vision system on laparoscopic learning curve are warranted to corroborate these findings.

Acknowledgment. The authors thank the fifth Minimally Invasive Urological Surgical Week course attendees who participated in this study. They also thank the personnel at the Research Endoscopic Laboratory at the University of Minho, as well as Karl Storz (Tuttlingen, Germany), for providing instrumentation used in the study.

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APPENDIX

SUPPLEMENTARY DATA

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.urology.2015.03.009.