Skills Comparison in Pediatric Residents Using a 2-Dimensional versus a 3-Dimensional High-Definition Camera in a Pediatric Laparoscopic Simulator

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Abstract

Introduction

Advantages in 3-dimensional (3D) laparoscopy are mostly described in adults for better depth perception, precise visualization of anatomical structures, as well as for complex surgical maneuvers in small spaces. Using Visionsense III stereoscopic endoscopy system (Neuromed Spa), we performed a comparative study between surgical skills achievements using 2-dimensional (2D) and 3D laparoscopic equipment in a pediatric laparoscopic surgery simulator model.

Materials and Methods

Three skills were evaluated both in 2D and 3D modalities. Pediatric residents (*n* = 20) without any previous laparoscopic experience were randomly divided in 2 groups and evaluated doing the established tasks in a laparoscopic simulator validated for pediatric surgery. Switching the type of vision from 2D to 3D or vice versa, we evaluated bimanual dexterity, efficiency, and efficacy. Three tasks were proposed—task 1: transfer of objects (6 pegs transferred one-by-one on a pegboard); task 2: pattern cutting (cutting a paper, following a circular dotted line); and task 3: threading eyelet (transfer, twisting and passing through a eyelet-shaped support, a specific 3D object). Performance was measured using a scoring system rewarding precision and speed. Any physical discomfort related to the 3D vision was recorded.

Results

Of the 20 participants included, 10 began the skills in the 2D modality and then performed them in 3D, and the other 10 began in 3D and ended in 2D. Overall task 1 performance (time and number of errors) was significantly better using stereoscopic compared with monoscopic visualization. Both groups experienced a 35.6% decrease in the time needed to complete the peg transfer using 3D instead of 2D. In task 2, the 3D performance was superior (less time to correctly cut the paper along the dotted line), but did not reach statistical significance. In task 3, the residents experienced with 3D a 31.7% decrease in the time necessary to complete the passage of the object trough the eyelet.

Most participants (65%) “subjectively” defined 3D laparoscopy easier overall; 6 participants (30%) did not experience any issue related to the use of 3D technology; and 1 person (5%) of group 1 found more difficulties using 3D compared with 2D. Headache (25%), nausea (20%), and visual disturbance (1%) were the most common issues reported by the students during 3D procedures. Finally, the results show that residents achieved significantly better results working with 3D vision rather than with 2D vision.

Discussion

As other studies have demonstrated, there was improvement in the overall performance using the 3D laparoscope. This was the first attempt to verify 3D skills in naive subjects, directly on a simulator conceived exclusively for pediatric surgery; therefore, bias was limited by using a population without surgical experience.

Conclusions

3D laparoscopic surgical skills showed superior to 2D, with higher percentages of tasks completion, less time in performing them, and a shorter learning curve. Our results indicate that 3D was subjectively easier than 2D in performing complex tasks in the skills laboratory setting.

Key Words

laparoscopy
3-dimensional
pediatric surgery
laparoscopic simulator

Competencies

Patient Care
Medical Knowledge
Practice-Based Learning and Improvement

Introduction

Technology has driven important advances in the field of minimally invasive pediatric surgery over the past two decades and laparoscopy has become a standard technique for a wide range of surgical indications in pediatric surgery.

However, acquisition of laparoscopic skills can be challenging: the monocular, 2-dimensional (2D) visualization obtained with current mini-invasive systems, lacks of depth perception and this significantly reduces the surgeon’s ability to determine the size and the precise localization of anatomical structures, thus impairing the ability to operate efficiently.

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.

Industry has recently developed novel 3-dimensional (3D) systems for laparoscopic surgery, where the depth perception is achieved by different unique images received by each eye and merged together in the cortical areas.

Some examples are represented by Conmed 3D HD Vision System (Conmed Corp., Utica, NY), Olympus Endoeye Flex 3D Videoscope (Olympus America Corp.), Aesculap EinstenVision 3D System (Aesculap, Tuttlingen, Germany), and Storz Image1 S 3D (Karl Storz, Tuttlingen, Germany).

These camera systems are all mounted on 10-mm scopes, very useful for adult surgery but sometimes too big for neonatal or infantile procedures.

Advantages in 3D laparoscopy are, moreover, mostly studied and described in adults for better depth perception, precise visualization of anatomical structures, as well as for complex surgical maneuvers in small spaces, while research is lacking in pediatric general surgery.

The aim of this study was to determine the benefit of the 3D technology in pediatric laparoscopic surgery (PLS) in naive subjects in a PLS simulator[1] and to record their subjective perception regarding 3D laparoscopy.

Materials and Methods

Using Visionsense III Stereoscopic Endoscopy System (Neuromed Spa, Turin, Italy), a 3D HD camera with a 4-mm scope, Food and Drug Administration and European compliance (CE) approved for pediatric surgery, we performed a comparative study between surgical skills achievements using 2D and 3D laparoscopic equipment in a laparo-trainer conceived exclusively for pediatric surgery.

A total of 20 pediatric residents without any laparoscopic experience were randomly divided in 2 groups and evaluated doing object transfer and simple surgical maneuvers. Each student was then asked to fill out a small questionnaire answering 2 questions regarding their 3D experience.

One question was related to the subjective perception of their surgical performance (*Compared to standard 2D laparoscopy, you feel that 3D laparoscopy is: overall easier, approximately the same, overall more difficult?*) and the other was related to the side effects experienced during the exercises (*Did you experience any issue by using 3D laparoscopy: headache, nausea, visual disturbances, others?*).

The PLS (endotrainer box) had internal dimensions of 18 cm (length) × 10 cm (width) × 9 cm (height) as described by Nasr et al.[1] (Fig. 1).

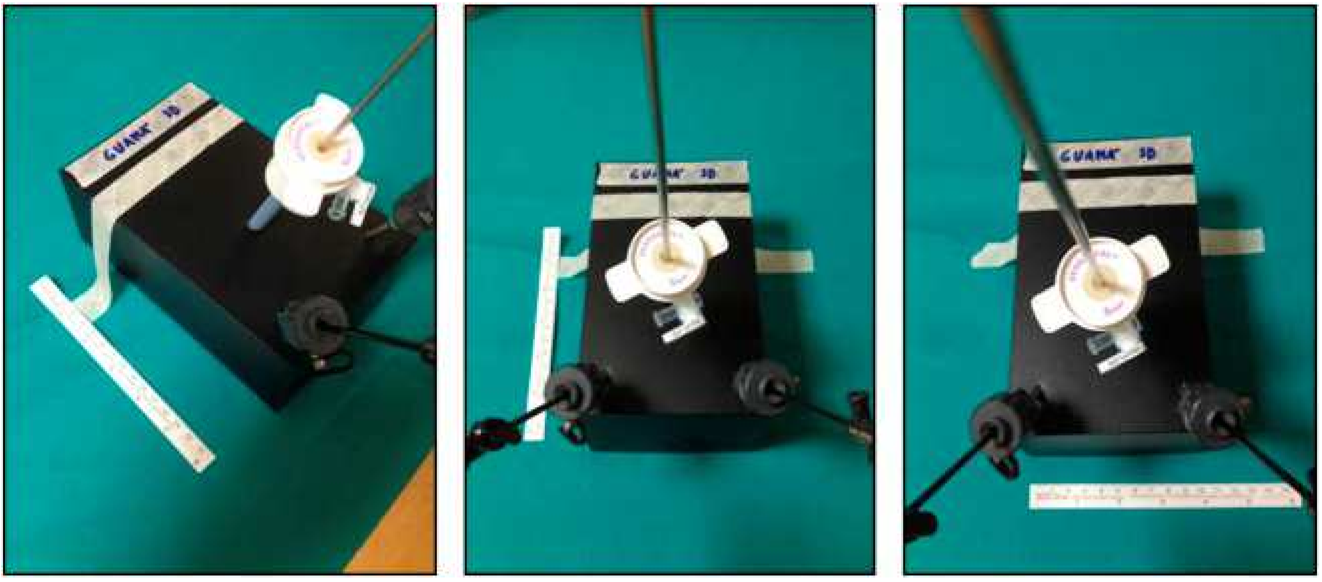

FIGURE 1. The pediatric laparoscopic simulator (endotrainer box) with internal dimensions of 18 cm (length) × 10 cm (width) × 9 cm (height) as previously described by Nasr.

We used two 3-mm working ports and a 5-mm camera port in a typical triangle-shaped position.

Both the 2D and 3D optical systems were mounted to a holding arm and held in a fixed position showing the complete area of interest within the box trainer.

Pediatric residents (*n* = 20) were randomly divided in 2 groups—group 1 (*n* = 10), in which the participants started with 2D first and group 2 (*n* = 10), in which the participants started with 3D first.

The study design was explained to each of them, and they gave their consent to participate. The students then were given a short time (3 min) to become familiar with the instruments and in case of the 3D group to get comfortable with 3D vision.

Each participant was assessed during the performance of 3 tasks, using both 2D and 3D vision, under the guidance of a tutor, who was not blinded to the type of laparoscopy being used.

Each 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).

Switching the type of vision from 2D to 3D or vice versa, we evaluated bimanual dexterity, efficiency, and efficacy; performance was measured using a scoring system rewarding precision and speed.

Visionsense miniature stereocamera physically resembles standard monocular cameras but allows through sensors the generation of true stereovision. The system is composed by a 3D HD camera, with remote control buttons and a rod to change focus; a 3D scope with size diameter less than 0.4 cm; a coupler to attach all 2D scopes available on the market; autofocus from 0.5 to 5 cm; a console (PC-based unit); and a 24-in 3D flat screen display. It can drive multiple 3D displays or 3D and 2D displays in parallel or 2D mode for 2D viewing.

Polarizing eyeglasses enable stereoscopic vision while conducting a surgical procedure; the glasses can be worn on top of regular eyeglasses.

Tasks accomplished were as follows (Fig. 2):

FIGURE 2. Tasks accomplished by pediatric residents: peg transfer, cutting exercise, and specific 3D object transfer.

Task 1: Transfer of Objects

Participants were asked to pick up 6 objects (little black caps) from the left side of a pegboard with their nondominant hand (i.e., left hand), transfer them to their right hand, and place the objects over pegs on the right side and vice versa.

In this task, we evaluated

- time needed to complete the exercise (*seconds*), considering a maximum time of 5 minutes and

- errors occurred during the procedure (*numbers* of pegs that could not be transferred in the allotted time).

Task 2: Pattern Cutting

Precision cutting involves cutting a marked circle with a diameter of 30 mm on a mounted piece of white paper (60 × 45 mm).

Task score was based on

- time needed to complete the exercise (*seconds*) considering a maximum available time of 5 minutes and
- error score (length of deviations >5 mm in *mm*).

Task 3: Threading Eyelet

Participants were asked to point and pass a specific 3D object (a little arrow) through an eyelet-shaped support.

Task score was based on

- time needed to complete the exercise (*seconds*) in the maximum time allowed of 5 minutes.

Results

Task 1: Transfer of Objects

Overall task performance (time and number of errors) was significantly better using stereoscopic compared with monoscopic visualization: Time-2D = 279.8 ± 52.74 seconds, Time-3D = 180.25 ± 31.89 seconds, p = 0,002 and Errors-2D = 4 ± 0.55, Errors-3D = 2.85 ± 0.35, p = 0.001 (Table 1 (1)).

TABLE 1. Results of Task 1

	2D	**3D**	**p Value**
	Group 1 + 2		
(1) Results of peg transfer in group 1 (performance using 2D then 3D) + group 2 (performance using 3D then 2D)			
Time (mean ± DS)	279.8 ± 52.741	180.25 ± 31.89	0.002
Errors (mean ± DS)	4 ± 0.55	2.85 ± 0.35	0.001
	Group 1		
(2) Results of peg transfer in group 1 (performance using 2D then 3D)			
Time (mean ± DS)	303 ± 90.34	177.9 ± 47.21	0.013
Errors (mean ± DS)	3.9 ± 0.98	2.8 ± 0.56	0.041
	Group 2		
(3) Results of peg transfer in group 2 (performance using 3D then 2D)			
Time (mean ± DS)	256.6 ± 70.39	182.6 ± 52.79	0.073
Errors (mean ± D S)	4.1 ± 0.71	2.9 ± 0.53	0.007

Taking into consideration both groups, the pediatric residents experienced a 35.6% decrease in the time to complete peg transfer using 3D.

If we consider the 2 groups separately (Table 1 (2) and (3)), we can see that in group 2 there was an improvement in the time needed to complete the task using the 3D camera (2D 256.6 ± 70.39 s versus 3D 182.6 ± 52.79 s), but this parameter did not reach statistical significance ($p = 0.073$).

In group 1, the same parameter was significantly better in 3D ($p = 0.013$).

Concerning the numbers of errors, we found a 29% decrease passing from 2D to 3D vision.

Task 2: Pattern Cutting

Overall task performance (time and number of errors) was superior in 3D but did not reach statistical significance: Time-2D = 311.15 ± 39.49 s, Time-3D = 305.85 ± 40.07 s, $p = 0.84$ and Errors-2D = 0.25 ± 0.21, Errors-3D = 0.1 ± 0.14, $p = 0.22$ (Table 2 (1)).

TABLE 2. Results of Task 2

	2D	3D	p Value
Group 1 + 2			
(1) Results of the cutting exercise in group 1 (performance using 2D then 3D) + group 2 (performance using 3D then 2D)			
Time (mean ± DS)	311.15 ±39.49	305.85 ± 40.07	0.84
Errors (mean ± DS)	0.25 ± 0.21	0.1 ± 0.14	0.22
Group 1			
(2) Results of the cutting exercise in group 1 (performance using 2D then 3D)			
Time (mean ± DS)	317.1 ± 64.43	295.8 ± 60.37	0.59
Errors (mean ± DS)	0.3 ± 0.34	0.1 ± 0.23	0.29
Group 2			
(3) Results of the cutting exercise in group 2 (performance using 3D then 2D)			
Time (mean ± DS)	305.2 ± 59.4	315.9 ± 64.56	0.78
Errors (mean ± DS)	0.2 ± 0.30	0.1 ± 0.23	0.556

Taking into consideration both groups, the medical students experienced only a 1.7% decrease in the time to complete the cutting in 3D.

If we consider the 2 groups separately (Table 2(2) and (3)), we can see the same results.

These results could suggest that for this task it is more important to have a good bimanual dexterity rather than a good 3D visualization; in fact this exercise implies the ability to apply traction, the use of the nondominant hand to create a convenient working angle, and accurate cutting.

Task 3: Threading Eyelet

Overall task performance was significantly better using stereoscopic compared with monoscopic visualization: Time-2D = 136.5 ± 21.97 s, Time-3D = 93.25 ± 17.59 s, p = 0,003 (Table 3 (1)).

TABLE 3. Results of Task 3

	2D	3D	p Value
Group 1 + 2			
(1) Results of specific 3D object transfer in group 1 (performance using 2D then 3D) + group 2 (performance using 3D then 2D)			
Time (mean ± DS)	136.5 ± 21.97	93.25 ± 17.59	0.003
Group 1			
(2) Results of specific 3D object transfer in group 1 (performance using 2D then 3D)			
Time (mean ± DS)	126.5 ± 32.84	81 ± 16.31	0.012
Group 2			
(3) Results of specific 3D object transfer in group 2 (performance using 3D then 2D)			
Time (mean ± DS)	146.5 ± 34.52	105.5 ± 33.03	0.068

Taking into consideration both groups, the medical students experienced a 31.7% decrease in the time to complete the passage of the object trough the eyelet in 3D.

If we consider the 2 groups separately (Table 3 (2) and (3)), we can see that in group 2 there is an improvement in the time needed to complete the task using the 3D camera (2D 146.5 ± 34.52 s versus 3D 105.5 ± 33.03 s), but this parameter did not reach statistical significance ($p = 0.068$). In group 1, the same parameter was significantly better in 3D ($p = 0.012$).

The answers to the questionnaire were the following:

Question 1: subjective perception of surgical performance ("Compared to standard 2D laparoscopy, you feel that 3D laparoscopy is: overall easier, approximately the same, overall more difficult?"): most participants (65%) "subjectively" defined 3D laparoscopy easier overall. Six participants (30%) did not experience any issue related to the use of 3D technology. One person (5%) from group 1 found 3D more straining.

Question 2: Side effects of 3D vision ("Did you experience any issue by using 3D laparoscopy: headache, nausea, visual disturbances, others?"): concerning the side effects of 3D vision, we found that 25% of participants reported headache, 20% reported nausea, and 1% reported visual disturbances.

No side effects were reported during 2D procedures.

Discussion

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. Available studies comparing 2D and 3D laparoscopic imaging show conflicting data concerning a potential benefit of stereoscopic visualization on surgical performance.[2]

This may be attributed to the technology at hand in earlier studies that were not able to show significant difference in surgical performance in both experimental and clinical settings.

In fact, early experience in the 90 seconds was limited by the poor image quality, which did not foster a clinical implementation of the technology.

More recently, industry was able to develop more advanced 3D imaging systems, which can provide a true 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, studies have been reported suggesting overall a better surgical performance when using 3D systems during laparoscopic (nonrobotic) tasks in a preclinical setting.[3]

Stereoscopic vision seems also to improve learning curve in novices.

However, most studies included relatively small numbers of participants (5-10 per subgroup) or a small number of phantom tasks with some including nonvalidated tasks or they included both.[4]

Findings from our study suggest that the use of 3D technology facilitates laparoscopic surgical performance of naive MDs.

Overall task performance (time and number of errors) was significantly better using stereoscopic compared with monoscopic visualization both in task 1 (peg transfer) and in task 3 (threading eyelet).

If we look at the recent literature, Smith et al.[5] also concluded that stereoscopic vision improves novice surgeon performance during acquisition of minimally invasive surgical skills in precision and efficiency.

Honeck et al[4] highlighted that the advantage of 3D imaging relies on improved spatial orientation and depth perception.

Alaraimi et al.[6] compared the performance of novices with 3D versus 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.

Furthermore, Lusch et al.[7] tested medical students, residents, and expert surgeons; adjusting the results for the surgical level, the 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 expert laparoscopic surgeons as well may benefit from 3D imaging.

Tanagho et al.[8] 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 impressions of efficiency and accuracy also favoured 3D visualization. The advantage of 3D vision persisted regardless of the participants' level of technical expertise (novice vs intermediate or expert) and participants overwhelmingly preferred 3D visualization.

This was similar to our findings, as most participants (65%) "subjectively" defined 3D laparoscopy easier overall.

Conclusions

The use of 3D imaging seems to quantitatively improve and to subjectively facilitate the surgical performance. Participants felt more confident and comfortable when using a 3D laparoscopic system.

The study is limited by a low number of participants, participants being not experts, and the study's in vitro nature.

Stereoscopic laparoscopy has now been proven superior in a sufficient number of simulator studies, so future research should aim at its clinical application.

Further studies assessing the effect of 3D vision systems on laparoscopic learning curve are warranted to corroborate these findings.

In addition, the question remains open whether these findings translate into faster and safer operations in a clinical setting.

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