The Comparison Of High Definition Versus Stereoscopic Display On Standardized Fundamental Laparoscopic Skill Procedures

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Abstract

The objective of this study was to determine whether or not a standard definition stereoscopic, 3D display could improve trainees' performance on a standard Fundamentals of Laparoscopy (FLS) task. Thirty-two procedurally naïve volunteers were recruited for the study. Subjects were randomized to begin the trials on either the 3D or 2D display and performed 10 trials on a peg transfer task (SAGES). Subjects alternated between 3D and 2D displays for each trial. Time to completion of task, and the number of dropped objects were recorded for each trial, and a subjective evaluation of the subjects' preference in display monitor was collected. Mean time for peg transfer was significantly faster with the 3D monitor than the 2D monitor (114.22 s. versus 133.05 s.; SE: 3.82; $P < 0.0001$). The number of dropped objects was significantly reduced in trials using the 3D monitor (3.09 versus 4.25; SE: 0.34 $P = 0.035$). Complaints related to the stereoscopic display monitor included teary eyes (18.75%) and dizziness (12.5%). Nevertheless, 81.25% of subjects preferred the 3D display monitor. The 3D stereoscopic monitor display significantly improves performance of laparoscopic surgery skills on a standardized FLS peg transfer task.

1. INTRODUCTION

Performing laparoscopy in a two-dimensional vision system without stereoscopic depth perception can be challenging for the operator and can require substantial training and experience to overcome [1, 2]. The loss of depth perception is a product of the indirect way of viewing the anatomy that is necessitated by the laparoscopic technique. Given the misalignment of the visual axis from the manipulation of laparoscopic instruments, the surgeon relies almost exclusively on the video monitor display for visualization [3]. This condition makes hand-eye coordination and precise manipulation of instruments challenging.

To optimize the efficiency of the laparoscopic technique, efforts have been made to improve the quality of the video monitor display [4-7]. Several studies have found that three-dimensional (3D) monitor displays may enhance laparoscopic skills by providing stereoscopic depth perception [8-17]. The advantages of such technology have been extensively researched for robotic laparoscopic systems [5, 8, 18-20]. However, far fever studies have looked at the potential benefits for standard laparoscopy. While some previous studies have shown advantages of 3D endoscopes related to movement efficiency, task completion time and error reduction, others have found no significant improvement compared to standard or high-definition 2D camera systems [21-25]. Stereoscopic, three dimensional video monitors have improved significantly in display quality and come down substantially in cost, making their utilization in standard laparoscopic surgery more feasible.

We hypothesize that a standard definition, stereoscopic 3D display might improve performance times of procedurally naïve medical students on a standard Fundamentals of Laparoscopic Surgery (FLS) peg transfer task compared to a high-definition 2D display.

2. MATERIALS AND METHODS

We conducted a randomized, crossover study to evaluate the difference in efficacy between a stereoscopic 3D and high-definition 2D monitor display.

2.1 Study Design

Standard laparoscopic box trainers were used to simulate the surgical working space. For the high-definition (HD) 2D system, we used a Karl Storz Endoscopy HD camera, a 24-inch 1080p HD liquid-crystal display (LCD) monitor, a 0° telescope, and a standard light source. For the 3D system, we used a prototype Karl Storz stereovision camera, a Sony 24-inch LCD monitor and a pair of 3D goggles. Trocar sites for insertion of the laparoscopic instruments and endoscopes were fixed and the same Maryland graspers were used for both stations. We aligned both monitors to the same height and adjusted the endoscopes and cameras to standardize the size of the viewing space on the 2D and 3D monitors [21].

2.2 Laparoscopic Task

Participants performed the Fundamentals of Laparoscopic Surgery (FLS) peg transfer task (SAGES). The task includes 3 skills that require substantial depth perception, ambidexterity and hand-eye coordination: (1) lifting a triangular object with the non-dominant hand, (2) transferring the object mid-air to the dominant hand, and (3) placing the object on a corresponding peg on the other side of a pegboard. Once all 6 objects are transferred, the process is reversed. The task is complete when all objects are returned to their original position.

The pegs were color-coded to standardize the motion path of each participant. If the participant dropped the object within the field of view, the participant was required to pick it up with the same grasper and continue the task. If the object fell outside the field of view, the research assistant placed the object into the out-of-field dish for the participant to continue the task. (**Figure 1**)

In-field drops and out-of- field-drops were treated equally and counted as one error respectively. Total time and the number of drops were recorded for each trial.

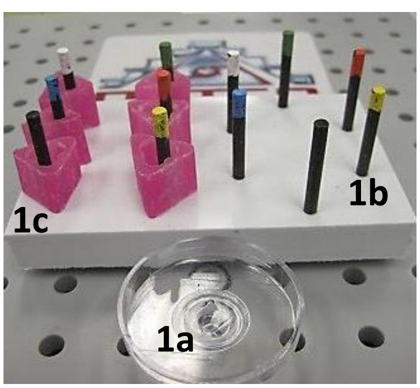

Figure 1 Peg transfer pegboard under 2D monitor: **1a**. out of field dish, **1b**. color coded pegs, **1c**. triangular objects

2.3 Participants

This study was performed under the supervision of the Institutional Review Board of the University of Arizona and in compliance with its regulations and requirements. All participants volunteered to participate after completing an informed consent. A total of 32 procedurally naïve participants (12 male, 20 females) were recruited to the study. The participants consisted of both medical students (MS; n = 6) and non-medical students (NMS; n = 26) with no previous laparoscopic surgery training. Because the study was designed to evaluate the impact of the monitor display system on laparoscopic skill, any previous training was considered a bias to the study. The MS included first- and second-year medical students from the University of Arizona, College of Medicine. The NMS consisted of undergraduate students from the University of Arizona.

Table 1 Subjects Characteristics

	Group A (3D First) (n = 15)		Group B (2D First) (n = 17)	
	Male	Female	Male	Female
Medical Students	2	0	2	2
Non-Medical Students	4	9	4	9

Participants were randomized to begin the experiment with either the 2D or 3D display and performed 10 trials of the peg transfer task, alternating between 2D and 3D displays for each trial. Each participant was provided with a video demonstration of the task and instructions on how to use the laparoscopic instruments. To reduce the learning curve effect, practice was not permitted prior to the collection of data. Performances were supervised and timed.

2.4 Questionnaire

Participants were asked to complete a questionnaire concerning their experience with the stereoscopic imaging system following completion of the trials. We asked them to rate their level of comfort with the 3D vision and to identify any complaints related to it. Finally, we asked participants to identify their preference of the imaging systems, 2D or 3D.

2.5 Statistical Analysis

A linear mixed-effect model using SAS® Proc Mixed was conducted to examine the main effect of monitor condition (2D, 3D), presentation order (2D vs. 3D presented first), and trial (trials 1-10) on time consumed to complete the task. In each of the models, the independent variables were treated as class variables, with person as the random effect. A repeated measures general linear model was conducted on the number of drops in each condition (2D, 3D) with presentation order (2D first, 3D first) as the between group variable. We used a *P* value of less than 0.05 to define statistical significance.

3. RESULTS

3.1 Time to task completion

The mean time to complete the peg transfer task was significantly faster with the 3D monitor than the 2D monitor ($P < 0.0001$, Figure 1). Presentation order was not found to be statistically significant with respect to average time ($P = 0.73$). Beginning the trials with 3D versus 2D did not impact the average time of the ensuing 3D or 2D trial times respectively.

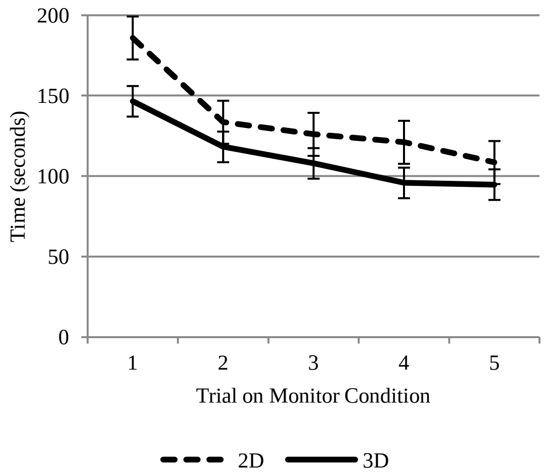

Figure 1 Mean time to complete ten trials of the peg transfer task.

3.2 Dropped object errors

Overall, there was a significant difference between the number of dropped objects in the two monitor conditions ($P = 0.035$), with fewer drops occurring with the 3D monitor than the 2D monitor. Performance results are shown in Table 2.

There was a significant difference in the number of dropped objects between subjects starting with 2D vs. 3D. Participants starting with 3D had significantly fewer dropped objects with 3D versus 2D ($P = 0.003$). Participants starting with 2D showed no significant difference in the number of dropped objects over the course of the 10 trials ($P = 0.86$).

The main effect of gender and medical student status were both insignificant on the mean time and number of dropped objects.

Table 2 Mean performance times (seconds) and number of dropped objects by monitor type

Monitor	Mean	Std error	P-value
Performance time			
2D	133.47	3.82	<0.0001
3D	114.22	3.82	
Dropped objects			
2D	4.25	0.34	0.035
3D	3.09	0.34	

Table 3 Improvements in mean time between subsequent trials by monitor condition

Trials	2D	3D
1 – 2	28 %	19.3%
2 – 3	5.6 %	8.7 %
3 – 4	3.9 %	11.2 %
4 – 5	10.4 %	1.1 %

3.3 Questionnaire

Of the 32 subjects, 75% rated the comfort level of the 3D glasses as either high or very high.
Table 4 summarizes the complaints reported by subjects related to the stereoscopic display monitor. The 3D display monitor was preferred over 2D by 81.25% of the participants. One subject reported no preference between the two monitors.

Table 4 Complaints with the 3D Monitor (n=32)

Complaint	*n*	%
Dizziness	4	12.50
Teary Eyes	6	18.75
Headache	2	6.25
Eye Pain	4	12.50
Out of Focus	4	12.50
None	15	46.88

4. DISCUSSION

Previous studies have evaluated the impact of 3D video monitor display systems on surgeons' laparoscopic performance. Using a passive polarizing stereoscopic display with 3D glasses, Smith et al demonstrated a significant reduction in error rates and improvements in time to task completion [9]. Our results are consistent with these findings. The 3D display facilitated the movement of instruments and provided participants with enhanced visuospatial control within the small simulated surgical space.

Taffinder et al. report that a 3D endoscope reduced the visual handicap of indirectly manipulating instruments by 41-53% compared to 2D endoscopic vision [10]. The authors report that there were no side effects associated with use of the 3D system. In our study, the 3D system did produce some side effects. Common complaints by students included dizziness, teary eyes, and eye pain. One explanation for these reports is that participants were asked to switch monitors between each trial to minimize the impact of the learning effect. Frequent readjustments to the 3D vision could produce the aforementioned side effects.

Some students reported difficulty with the focus of the 3D view. Using polarized glasses has the benefit that users are able to freely move about the operating space. However, the interpretation of 3D shapes in stereoscopic images depends significantly on viewer position [26]. In our study, the endoscope was fixed in the trainer box to prevent it from moving, but students were permitted to stand at any distance from the display. Moving closer to the display could cause the perceived object to compress in depth and reduce the focus of the view. Likewise, moving to the right or left can produce a shearing effect on the image. The visual accommodation that is required in the 3D scene to focus on small moving objects can also be a source of viewer fatigue. Reducing the impact of these challenges is one benefit of the more advanced stereoscopic vision systems employed in surgical robots [27-29]. Nonetheless, our subjective questionnaire results indicated that a majority of students preferred the 3D display over the 2D display.

Shortening the learning curve can have important implications in surgical training [30, 31]. Training under stereoscopic conditions has been shown to reduce the learning curve for novice laparoscopic surgeons [27]. Our study appears to support this finding. Subjects in the 3D-first group (i.e. those who began their 10 trials with the 3D system) had significantly fewer dropped objects with 3D than with 2D. Those who began trials with the 2D system showed no significant difference. This suggests that starting with the 2D system can potentially have a negative impact on performance in subsequent trials. Additionally, the percent improvement between subsequent trials in time to task completion reached a plateau with the 3D system earlier than with the 2D system.

5. CONCLUSION

Hand-eye coordination in laparoscopic surgery is a skill that is difficult to acquire. The task chosen for this study relies heavily on this skill by requiring students to perform smooth, finely controlled instrument movements. Stereoscopic 3D monitor displays appear to facilitate the performance of this skill. In our study, the 3D monitor display conferred a 14.4% difference in performance time compared to 2D. Future studies will need to examine the effect of the polarizing glasses in tasks that require the coordination of multiple operators. The long-term impact of wearing the 3D glasses on surgeons' performance will also need to be explored, especially with respect to ergonomics and ease of use.

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Biographies

Dr. Jerzy W. Rozenblit is University Distinguished Professor, Raymond J. Oglethorpe Endowed Chair in the Electrical and Computer Engineering (ECE) Department, and Professor of Surgery in the College of Medicine at The University of Arizona. From 2003 to 2011 he served as the ECE Department Head. During his tenure at the University of Arizona, he established the Model-Based Design Laboratory with major projects in design and analysis of complex, computer-based systems, hardware/software codesign, and simulation modeling. The projects have been funded by the National Science Foundation, US Army, Siemens, Infineon Technologies, Rockwell, McDonnell Douglas, NASA, Raytheon, and Semiconductor Research Corporation. Dr. Rozenblit has been active in professional service in capacities ranging from editorship of ACM, IEEE, and Society for Computer Simulation Transactions, program and general chairmanship of major conferences, to participation in various university and departmental committees. He had served as a research scientist and visiting professor at Siemens AG and Infineon AG Central Research and Development Laboratories in Munich, where over he was instrumental in the development of design frameworks for complex, computer-based systems. Currently, jointly with the Arizona Surgical Technology and Education Center, he is developing computer guided training methods and systems for minimally invasive surgery. Co-author of several edited monographs and over two hundred publications, Jerzy holds the PhD and MSc degrees in Computer Science from Wayne State University, Michigan, and an MSc degree from the Wroclaw University of Technology. He presently serves as Director of the *Life-Critical Computing Systems* Initiative, a research enterprise intended to improve the reliability and safety of technology in healthcare and life-critical applications.

Dr. Allan Hamilton holds four Professorships at the University of Arizona in Neurosurgery, Radiation Oncology, Psychology, and Electrical and Computer Engineering. He graduated from Harvard Medical School and completed his neurosurgical residency training at the Massachusetts General Hospital in Boston. He has been chosen by his neurosurgical peers as "One of America's Best Doctors" for the last twelve consecutive years. Dr. Hamilton has held the positions of Chief of Neurosurgery and Chairman of the Department of Surgery at the University of Arizona. Dr. Hamilton serves as Executive Director of the Arizona Simulation Technology and Education Center, a multi-disciplinary think-tank at the Arizona Health Sciences Center devoted to developing new technologies and training procedures to reduced preventable medical adverse events. He has authored more than twenty medical textbook chapters, fifty peer-review research articles, and has served on the editorial board of several medical journals. He is also a decorated veteran Army officer who served in Operation Desert Storm. Dr. Hamilton's first book, The Scalpel and the Soul: Encounters with Surgery, the Supernatural, and the Healing Power of Hope (2008, Tarcher/Penguin USA) was awarded the 2009 Nautilus Silver Award, which was conceived to recognize world-changing books. Previous Nautilus Award winners include Deepak Chopra, Eckhart Tolle, and His Holiness the Dalai Lama. Scalpel and Soul has been translated into several languages and is now in a paperback edition. For the last several years Dr. Hamilton has served as medical script consultant to the TV series *Grey's Anatomy*.

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David Biffar is the Director of Operations at the Arizona Simulation Technology and Education Center (ASTEC) at the University of Arizona (ASTEC). He is a leader in the field of medical simulation education and an innovator in the design of high-fidelity artificial tissue models. At ASTEC, he is in charge of designing simulation environments to enhance the educational curriculum for the College of Medicine. With a background in mental health counseling, his research interests include the application of virtual reality exposure therapy for anxiety disorders. He received an MS in mental health counseling from Nova Southwestern University.