Surgical Navigation Pointer Facilitates Identification of Targets in a Simulated Environment

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ABSTRACT

Introduction: The objective of this study was to determine whether or not a navigation pointer (NP) integrated into a laparoscopic camera and projected onto a surgical display might allow instructors to more easily and precisely direct assistants' instruments to specific sites in a simulated laparoscopic field.
Methods: Two hundred forty pins served as targets in a standard laparoscopic box trainer. An instructor guided 24 subjects to locate 5 randomly selected targets each, with verbal instructions alone, or with verbal instructions supplemented by either a navigation grid (NG) or the localizing NP. Each subject performed 15 trials alternating between use of the NP, NG and no navigation tool. The primary outcome measure was the time to target identification.
Results: The mean time to identify each selected target was significantly shorter with the NP (4.53 ± 2.87 seconds) than with the NG (8.59 ± 4.35 seconds, P<0.001) or without any navigation tool (11.16 ± 5.39 seconds, P<0.001).
Conclusion: The use of the NP appears to improve efficiency in guiding an instrument to randomly selected targets within a simulated laparoscopic field. The use of the NP may reduce the time required to move instruments to specific sites during laparoscopic surgery.

1. INTRODUCTION

Laparoscopic surgeons place a high value on the ability of assistants to carry out verbal instructions accurately [1]. This reliance may be especially pronounced in teaching hospitals, where guidance through verbal instructions is an important element in the training of novice surgical trainees [2]. However, accurate communication can be compromised by the inherent challenge of laparoscopic surgery that necessitates indirect observation and manipulation of instruments in a limited two-dimensional working space [3-5]. Given this limitation, assistants can easily misinterpret descriptions of precise anatomical landmarks and instructions of where to interact with tissue [4]. This can lead to critical delay in the procedure and increase the mental strain compared to open surgical procedures [3].

Many recent studies examining the impact of nontechnical skills on surgical performance have found that breakdowns in intraoperative communication often underlie adverse patient events [6, 7]. However, few studies have explored strategies to facilitate communication events between the surgeon and the assistant. Currently, there are few technologies to improve this interaction. The majority of navigation technologies involve robotic instrument holders controlled directly by the operating surgeon [8-11]. However, in a procedure performed by an inexperienced trainee, this may not be beneficial.

We hypothesize that a laparoscopic navigation software consisting of a coordinate grid and pointer that can be integrated into the surgical camera and superimposed on the video monitor image might allow an instructor to provide more precise instructions to assistants to more efficiently position and move laparoscopic instruments to a specific target in a simulated surgical field.

2. MATERIALS AND METHODS

We conducted a randomized, crossover study to evaluate the impact of a surgical navigation pointer (Karl Storz Endoscopy-America Inc.) on the ability of an instructor to provide guidance to students in a target identification task performed in a simulated environment. The study was conducted at the Arizona Simulation Technology and Education Center (ASTEC) at the University of Arizona, College of Medicine and was performed in compliance with regulations and requirements of the Institutional Review Board (IRB) of the University of Arizona.

2.1 Study Participants

A total of 24 medical students (12 male, 12 female) were recruited for this study. None of the students had any prior experience operating laparoscopic instruments. After completing an informed consent form, each participant received a scripted introduction to the use of the laparoscopic instrument and a description of the target identification task. All participants were over 18 years of age.

Each participant completed 15 trials with 5 randomly selected targets, alternating between using the NP, the NG and without using a navigation tool. Participants were randomized into 3 groups, according to whether they began trials with the NP (n=8), the NG (n=8) or without either tool (n=8). No practice trials were allowed prior to data collection.

2.2 Experimental Design

The test bed for the target identification task consisted of 240 colored map pins (1/8 inch diameter), arranged in a repeated pattern of 15, 4x4 quadrants. The targets were embedded in a silicone base plate and placed in a laparoscopic box trainer. Evenly positioned, the pins created a template of many identical targets with a density of 10.25 targets per square inch. The color scheme was designed to allow the instructor to locate and fixate designated targets more easily when guiding participants using the same monitor. The instructor was not permitted to use the color of the pin as an identifying feature of the designated target.

For each participant, a total of 5 targets were randomly selected using a computer number generator. Each target was presented 3 times in the 15 trials, once each with the NP, the NG and without any navigation tool. In order to minimize any impact of the learning effect, we randomized the order of the interventions (NP, NG, and no navigation tool) and the order in which the 5 targets would appear with each intervention over the 15 trials.

The NG consists of a 3x5 coordinate system projected through the camera onto the surgical display. The individual quadrants are designated by number and letter assignation (e.g. A2, C4). The NG can be activated from the camera head and adjusted to 3 sizes, comprising 50%, 70% and 100% of the surgical field. For this study, we used the 70% mode only. The NP consists of a fluorescent green dot that is likewise activated from the camera head and projected through the camera onto the surgical display. It is manipulated to specific targets on the display by physically moving the camera head.

Participants were given a laparoscopic forceps instrument (Karl Storz Endoscopy-America Inc., El Segundo, CA) with which they could contact the designated target within the simulated surgical field. Participants were asked to operate the instrument with their dominant hand. The instructor holding the laparoscope was positioned on the non-dominant side of the participant. The laparoscope was fixed distally by a rubber stopper to prevent it from sliding into the trainer box. This created a stable, invariant point of rotation for the laparoscope to ensure that there would be no change in the size of the displayed field. The same instructor guided all participants. Each trial began with insertion of the instrument into the laparoscopic trainer box. Timing began when the instrument was first seen on the surgical display and ended when the participant successfully closed the forceps around the correct target.

The instructor guided participants either with directional instructions only or with directional instructions supplemented by either the NG or NP. For trials using no navigation tool, the instructor was allowed to use only 4 basic directional commands: “up,” “down,” “right,” and “left” to guide participants to the correct target. With the addition of the NG, the instructor could direct participants to a specific quadrant, per coordinates, followed by the same 4 basic directional commands to identify a specific target within that quadrant. Finally, for trials using the NP, the instructor could manipulate the laparoscope to point directly at the designated target.

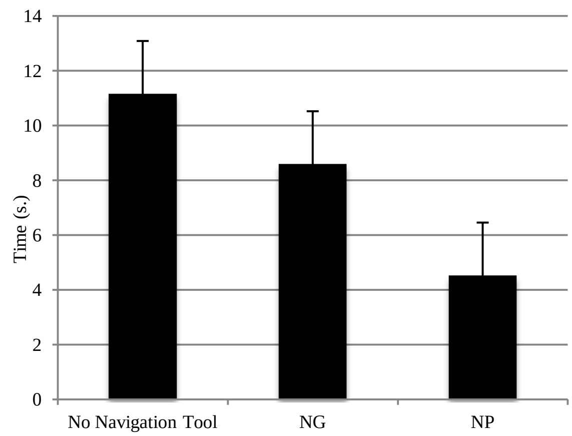
The collected data were analyzed statistically with a series of paired *t* tests, using a *p* value of less than 0.05 to indicate a significant difference between groups. The primary endpoint was the time from introduction of the laparoscopic instrument to grasping the correct target.

3. RESULTS

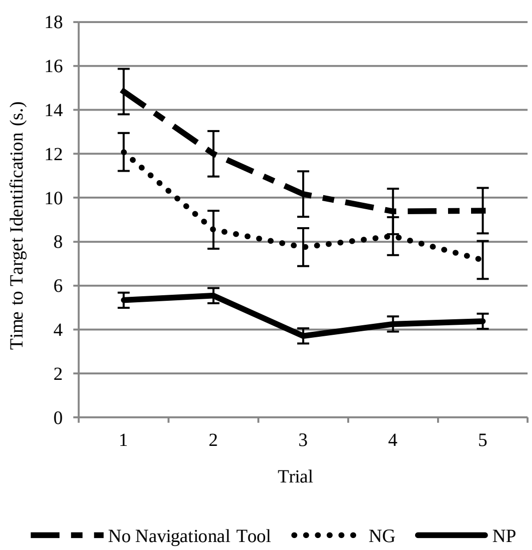
The instructor was able to guide participants to the correct target significantly faster using the NP than using either the NG (4.53 ± 2.87 s. vs. 8.59 ± 4.35 s.; $P<0.001$) or without using any navigation tool (11.16 ± 5.39 s.; $P<0.001$). Additionally, the instructor was able to guide participants significantly faster using the NG than with no navigational tool ($P<0.001$). There was no significant difference in the time required from insertion of the instrument to grasping the correct target by gender, education level, or by the presentation order of the 3 intervention groups.

The learning curve of participant performance was related to the type of navigation tool used by the instructor for guidance (**Graph 2**). In the 5 trials performed without any navigation tool, there was a significant difference in the mean time to target identification between the 1st and the last trial (14.83 vs. 9.41; P<0.01). The same effect was observed when comparing the 1st and last trial using the NG (12.08 vs. 7.167; P<0.01). The NP group showed no significant mean time difference between the 1st and last trial (5.33 vs. 4.38; P=0.168).

Graph 1 Mean time to target identification



Graph 2 Learning curves over 5 trials



4. DISCUSSION

Previous studies have suggested that reducing ambiguity in verbal exchanges in the operating room could improve efficiency, reduce stress and ultimately lead to better patient outcomes [12-15]. Jayaraman et al have demonstrated that a head-mounted infrared signal system with a passive marker can significantly reduce the time required for an instructor to guide an assistant to a designated target [16]. This has significant implications in the interaction between surgical instructors and inexperienced trainees because teaching in laparoscopic surgery relies heavily on mentor guidance [4, 17, 18].

Our results are consistent with these findings. Using the novel NP increased the specificity of directional instructions by decreasing the number of commands necessary to direct an assistant to a specific target. It also eliminated some of the ambiguity that can be present when an instructor has to rely solely on basic directional commands. For example, a trainee may interpret the direction "go down" as a command to move the instrument further into the laparoscopic trainer box instead of moving downwards along the plane of the surgical monitor. The NP was able to directly identify the correct target with a high degree of accuracy.

In laparoscopic surgery, significant learning curves can often be barriers to implementation of new technologies [19, 20]. This is not the case with the NP. As a navigation tool, the NP was an intuitive instructional adjunct for students to follow. This is evidenced by the lack of a significant learning curve: there was no significant difference in the mean time to task completion between the 1st and the last (5th) trial.

However, the NP does have some limitations. Because the fluorescent green pointer is integrated into the video camera, it is fixed to the center of the surgical display. In order to use it for guidance, it requires the instructor to move the entire camera, thereby losing the peripheral field and other potential structures of interest. Moving the camera to identify a structure also rotates the plane of view and changes the angle of approach of the laparoscopic instrument to the designated target. This rotation changes the perceived depth of the surgical field and requires the person manipulating the instrument to adjust the instrument movement to the new spatial distance [21-23].

Changing the plane of view exacerbates an inherent cognitive challenge of laparoscopic surgery – to overcome the decoupling of the visual axis from the motor axis when manipulating instruments in a confined surgical field [24, 25]. The level of handeye coordination necessary to overcome this challenge can prove difficult for an inexperienced trainee [26]. Other studies have shown that changing the monitor display angle relative to the instrument manipulation angle can interfere with optimal task performance [27]. A pointer that could be controlled by a trackball from the camera head might be useful in eliminating these challenges. This technology has been successfully employed in instrument manipulators [28, 29] and could be used with the NP to permit manipulation of the pointer without changing the visual field.

Moving the camera head in the fixed trocar can also present an ergonomic challenge, as the rotational range is limited. Finally, frequent movements of the camera require the instructor to reestablish the ideal surgical view following target identification. Collectively, this introduces a number of extraneous camera movements into the procedure that require consequent readjustments of focus. In our task, which required only a single instrument movement, this was not an issue. However, in a task with multiple steps and consecutive movements, the need to realign the surgical field could become problematic.

The NG eliminates some of these visuospatial problems. Clearly superimposed on the simulated surgical field through the laparoscopic camera, the NG does not require the instructor to move the camera and facilitates identification of targets at the periphery of the surgical field. While not as time efficient as the NP, our results indicate that use of the NG improves guidance significantly compared to trials in which no navigation tool was used.

Other studies have suggested using laser pointers as teaching tools in the operating room [30, 31]. However, such a laser pointer presents potential safety concerns and also requires the instructor to manipulate an additional instrument, which could be cumbersome. The navigation software used in this study offers the benefit of being able to switch easily from one navigation mode to another. Activated directly from the camera head within the sterile field, the surgeon instructor can readily alternate between use of the NG and the NP. For future studies we will analyze the combined impact of the grid with the pointer in a more complex task. We will also test the utility of the NP to center the display image when students are manipulating the camera. Given the fixed nature of the fluorescent green dot, it may prove useful as a way to center and maintain the image of the surgical field during a procedure.

5. CONCLUSION

The NP provides a significant advantage in the time it takes an instructor to guide an assistant to specific targets within a simulated surgical field. However, the current configuration of the NP requires manipulation of the entire laparoscopic camera head, which might create difficulties for novice trainees. Further studies are needed to confirm whether the advantage of the NP can be translated into actual laparoscopic procedures.

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BIOGRAPHY:

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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Dr. Carlos Galvani is an internationally recognized expert in robot-assisted surgery and other minimally invasive surgical techniques. He was a member of the University of Illinois at Chicago (UIC) team that performed the world's first robotic pancreatectomy (removal of the pancreas). He has extensive experience in bariatric surgery, single incision laparoscopic surgery (SILS), robotic surgery of the gastrointestinal tract, robotic surgery for gastroparesis and laparoscopic solid organ surgery. In addition, he performs robotic-assisted surgery for benign and malignant diseases of the esophagus, robotic-assisted living donor nephrectomy and robotic liver resection.

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