Maintaining Forward View of the Surgical Site for Best Endoscopic Practice

Bin ZHENGA,1 Maria A. CASSERAB, Lee L. SWANSTRÔM; Adam MENEGHETTI; Neely O. N. PANTON; and Karim A. QAYUMIA

A Department of Surgery, University of British Columbia, CANADA
B Legacy Health System, Portland, Oregon, USA

Abstract. Endoscopic surgery performed through patients’ natural orifices (NOTES procedures) often require some degree of retroflexion of the operating system. This can cause a misalignment between the displayed image and the actual work plane, leading to performance difficulties. This study investigated the impact of retroflexion on task performance in a simulated environment. Surgeons were required to perform an aiming and pointing task under two experimental conditions: forward-view vs. retroflexed-view. Results showed that both expert and novice surgeons required significantly longer time for completing the task when the scope was retroflexed, compared to when the scope faced forwards. Results address the importance of careful selection of the surgical approach to avoid image retroflexion. Further analysis revealed that the novices were more vulnerable than experts to image distortion with the retroflexed view. This addresses the necessity for surgeons to go through extensive endoscopic training to overcome the visual-motor challenges before they can perform NOTES procedures safely and effectively.

Keywords. Endoscopic surgery, NOTES procedure, Vision-motion alignment, Simulation, Evaluation

Introduction

One promising surgical technology that has been developing intensively over the last few years is constructed on the platform of flexible endoscopy [1-4]. With the recent advances in image display and remote manipulation technologies, surgery on the abdominal cavity is feasible via various natural orifices such as the mouth, anus, urethra, and vagina. This novel surgical paradigm is named Natural Orifice Transluminal Endoscopic Surgery (NOTES). In NOTES, a transvisceral incision is made on a hollow organ to gain access to organs in the peritoneal cavity [5]. By eliminating the need for abdominal incisions, NOTES has the potential to reduce the incidence of surgical site hernias, abdominal adhesions, post-operative incisional pain, and eliminates any visible scarring.

1 Corresponding Author. 3602-910 W. 10th Ave. Vancouver, British Columbia, Canada, V5Z 4E3, Canada; Email: bin.zheng@cesei.org
While the minimally invasive and cosmetic benefits of NOTES are desirable for patients, NOTES poses new and greater technical challenges for surgeons compared to open or even laparoscopic surgery[3, 6]. From the human factors standpoint, the most serious challenge of NOTES is the perception-motion integration problem, i.e. how to maintain dexterity in manipulating surgical instruments under an unstable and distorted view of the surgical site.

In the most commonly performed NOTES procedure where the gallbladder is removed through the patient’s mouth (Transgastric Cholecystectomy), the tip of the endoscope is twisted backward after entering the abdominal cavity through a transgastric port. In this situation, the distal portion of the scope is flipped over 135 – 175 degrees with respect to the frontal plane [2, 4]. When displayed on the monitor, the images must be interpreted incompletely upside-down by both the surgeon and assistant controlling the instruments. Previous studies outside healthcare have shown that incomplete image distortion creates the worst scenario for mental calibration in remote manipulation, even worse than 180 degree image reversal [7]. Task performance was jeopardized when the image of the working place was distorted. In this study, we intend to quantify the impact of image distortion caused by endoscope retroflexion on performance in a simulated NOTES task.

We hypothesize that when the surgical site is viewed in the retroflexed fashion, surgeons who perform the task must readjust their movements appropriately to accommodate the retroflexed image, in turn prolonging the overall task time compared to when the site was viewed in the straight forward view. To test our hypothesis, a dry-lab simulated NOTES task was performed by a group of NOTES surgeons under two viewing conditions. We expect that our results will help to provide guidelines for setting which surgical approach to take in a given NOTES operation.

1. Methods & Materials

1.1. Apparatus and task

Data collection was conducted in the surgical skills training laboratory.

Our simulation model for NOTES was comprised of a wooden plate (14.5 inch in height, 14 inch in width, and 0.5 inch in thickness) and a hollow plastic sphere (5-inches in diameter). A small opening placed behind the plate with no direct line of sight to the operator. The plate was fixed to a lab table, and a hole was created on the lower portion of the plate. A single channel therapeutic endoscope (Olympus, Tokyo, Japan) was passed through this hole and then aimed to the entrance of the plastic sphere (Figure 1 A).

There were 4 colored dots located around a central point on the inner surface of the sphere. Each dot was labeled with a number 1-5, including the central point. Each participant was required to visually locate these 4 dots and touch the dots in a predefined order using a grasper inserted through the working channel on the endoscope (Figure 1 B).
1.2. Procedure

This task was performed under two experimental conditions: 1) Forward view condition: where the entrance of the sphere faces the operator; 2) Retroflexed view condition: the entrance of the sphere is opposite to the operator. Under the second condition the participant was required to retroflex the tip of the scope over 150 degrees to capture the image of the dots (Figure 1).

Each participant was allowed to complete a trial once prior to testing in order to verify a correct understanding of the task. No additional task training was given. All participants executed the task five times for each experimental condition. For each trial, the task time was calculated from the moment when the grasper was deployed from the tip of the endoscope and touched the central point, to the moment when the fifth dot was correctly touched.

1.3. Participants

A total of 9 participants were recruited for this study, 8 completed required trials over two experimental conditions and data was included for further analysis. Participants include 3 laparoscopic surgeons with extensive experience in flexible endoscopic procedures, and 5 subjects naïve to laparoscopic or endoscopic procedures. A pre-test questionnaire was given to all participants to assess endoscopic and laparoscopic experience, as well as to record demographic data.

1.4. Evaluation and statistical analysis

All tasks were video-recorded. Task performance score was evaluated by task completion time (in seconds). A 2 x 2 ANOVA (two groups of surgeons for two viewing conditions) was performed using SPSS statistical software (SPSS, SPSS Inc, IL, USA) to compare mean times for each group. P < 0.05 was considered significant. Results are reported as mean ± standard deviation unless otherwise stated.
2. Results

Table 1 summarizes the pre-trial characteristics of two groups.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Novice</th>
<th>Expert</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of participants</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Age</td>
<td>26.8 ± 4.2</td>
<td>41.1 ± 7.6</td>
</tr>
<tr>
<td>Years of performing laparoscopic surgery</td>
<td>0–3</td>
<td>5–20</td>
</tr>
<tr>
<td>Number of performing endoscopy procedure/year</td>
<td>0–10</td>
<td>&gt;50</td>
</tr>
</tbody>
</table>

Task performance in the forward-view condition was significantly faster (35 ± 15 sec) than performance in the retroflexed-view condition (51 ± 31 sec, P < .001). On average, the experts finished tasks in shorter time (19 ± 6 sec) than the novices (60 ± 20 sec, P < .001).

Secondary analysis of the interaction between view condition and surgeon’s group revealed that experts and novices responded differently to each image viewing condition. The experts performed slightly worse in the retroflexed view (20 ± 6 sec) than the forward view (18 ± 5 sec) condition. In contrast, the novices were much more vulnerable to image distortion; their performance deteriorated significantly in the retroflexed condition (72 ± 21 sec) compared to the forward condition (47 ± 6 sec, P = .002). (Figure 2).

3. Discussion

Results support our research hypothesis – retroflexed image does impede task performance in NOTES. The reason, we believe, can be attributed to the eye-hand coordination difficulty related to the NOTES procedure.

Unlike laparoscopy which requires one level of mental calibration by changing the viewing perspective from the eyes to the scope, NOTES requires additional mental work...
because the viewing perspective of the endoscope is constantly changing during the procedure [8]. The endoscope must constantly be maneuvered to maintain the horizon and keep track of spatial orientation. The changing perspective of the endoscope also internally changes the configuration of surgical instruments. When performing NOTES procedures with the endoscope retroflexed, another level of mental calibration must be included in the mental adjustment of a surgeon, which can make a surgeon easily lose orientation and dexterity.

Loss of orientation and dexterity brings up significant safety concerns [3, 8]. We argue that when possible, the surgical approach needs to be chosen carefully to avoid using the retroflexed view during any NOTES procedure. Currently both forward and retroflexed view approaches are commonly available for a given NOTES procedure. For example, removing a patient’s gall bladder (cholecystectomy) has been achieved through both transgastric (retroflexed) and transvaginal/transcolon (forward view) approach. Now that we have demonstrated that retroflexion has negative impact on surgical task performance, we argue that surgeons should consider a transvaginal/transcolon approach for cholecystectomy.

It is interesting to observe that experienced surgeons were able to perform tasks in the retroflexed condition with minimal delay in comparison to the novice group. This is mainly due to the fact that experts are already experienced having performed large volume of endoscopic procedures on a daily basis. Extensive endoscopic experience allows experts to develop sophisticated cognitive strategies to deal with misalignment between perception and movement as presented by NOTES procedures [9]. Evidence presented in this study indicates that extensive training is required for a novice surgeon to overcome the difficult vision-motion coordination before they can perform NOTES effectively and safely.

There are a number of limitations related to this study. The first limitation was that successful performance in a true endoscopic surgery requires skills much more complicated than those needed for the aiming and pointing task used in this study. The second limitation was that only a single surgeon was required to perform the pointing task, unlike the more commonly practiced surgical scenario that requires at least two surgeons work in a team for a NOTES procedure. Recently, we have incorporated bimanual coordination tasks into a new NOTES simulation model which was constructed on a double channel endoscopic platform. Two surgeons are allowed to work side-by-side, one to control the scope, the other to manipulate instruments on the surgical site. Replication of the current study with this new model will help to improve the generalization of our findings to a clinical setting.

The third limitation was in the measurement used in the study. We used time to completion to describe the observable impact of visual-motion misalignment on the task performance. In any goal-direct movement such as the task we incorporated in this study, before the observable action, there is a period of cognitive process where environmental information is processed and an appropriate movement is planned[10]. This cognitive process is more sensitive to visual-motion alignment condition, rather than execution of the chosen movement plan. A superior measurement for the cognitive process would be the reaction time, defined as the time from the moment where visual information is presented to an operator, to the moment a movement is performed [11]. Future studies on the human factors of NOTES procedures will integrate the reaction time to measures, to give a comprehensive description of the impact of visual-motion misalignment on surgeons’ performance.
In conclusion, the retroflexed view condition in NOTES procedure built on an endoscopic platform has a negative impact on surgeon’s performance. Careful planning is required for selecting an appropriate approach to avoid retroflexion and subsequent image distortion. To ensure safe performance of NOTES procedure, extensive endoscopic training is recommended for general surgeon before they can perform NOTES effectively and safely.

4. Acknowledgments

This project has been funded by NOSCAR (Natural Orifice Surgery Consortium for Assessment and Research) research grant in 2007. The authors wish to thank the Boston Scientific Corporation for providing experimental devices of this study.

References