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Differences in mental workload between traditional and single-incision laparoscopic procedures measured with a secondary task

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A B S T R A C T

Intro: The mental workload associated with laparoscopic suturing can be assessed with a secondary task that requires the same visual-spatial attentional resources. The purpose of this study was to use a secondary task to measure the incremental workload demands of single-incision laparoscopic surgery (SILS) procedures versus traditional laparoscopic procedures.
Method: 12 surgery residents and surgical assistants who had met FLS criteria on an FLS and SILS simulator performed one trial each of peg transfer, cutting, and intracorporeal suturing tasks simultaneously with the secondary task and provided subjective workload ratings using the NASA-TLX.
Results: SILS procedures resulted in lower primary and secondary task scores, $p < 0.001$ and higher workload ratings, $p < 0.0001$. Suturing resulted in lower primary ($p < 0.003$) and secondary task scores ($p < 0.017$) and higher workload ratings ($p < 0.017$) compared to the other tasks.
Conclusions: SILS procedures were significantly more mentally demanding than traditional laparoscopic procedures corroborated by primary and secondary tasks scores and subjective ratings.

1. Background

Single-incision laparoscopic surgery (SILS) is performed with a single incision, usually through the umbilicus, as opposed to the multiple incisions used for traditional laparoscopic procedures.[1,2] The single incision offers patients potential cosmetic benefits due to less scar visibility.[3] Other potential benefits include less post-operative pain and reduced recovery time, but these have not been firmly established.[4,5] SILS procedures do, however, introduce additional challenges to the surgeon beyond those associated with traditional laparoscopic procedures. The instruments are inserted in closer proximity to one another thereby reducing triangulation and restricting movement. There is greater opportunity for extracorporeal and intracorporeal instrument collisions as well as deflections of the laparoscope.[2,6,7] In fact, some surgeons have resorted to intracorporeal or extracorporeal crossing of the instruments to improve triangulation and maneuverability.[8] Further, there are reports that surgeons find these procedures or specific port configurations to be more challenging than traditional laparoscopic procedures, with significantly increased operative time.[4,9–11]

Accordingly, the purpose of the present study was to examine the incremental mental workload associated with SILS procedures over traditional laparoscopic procedures. Mental workload has been described as the attentional demands placed on workers or the demands associated with specific tasks.[12] According to Wickens, there are separate and distinct "pools" of attentional resources dedicated to different aspects of information processing.[13] The encoding of perceptual and cognitive information in working memory uses different attentional resources than those required for the selection and execution of responses. Further, verbal and linguistic activities use different attentional resources than spatial activities and auditory activities use different resources than visual activities. According to Wickens' theory, two tasks that use different pools of attentional resources can be timeshared reasonably well. However, when two tasks that are performed simultaneously draw resources from the same attentional pool, performance on one or both tasks is likely to suffer. Thus, a challenging primary task may use up the attentional resources leaving few or no residual resources for the second task. Hence, performance on the secondary task will decline as the difficulty of the primary task increases.

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Several researchers have recently shown that when individuals perform a laparoscopic surgical task together with a secondary task requiring visual spatial attentional resources, the secondary task is sensitive to differences in laparoscopic demands. Specifically, increases in task difficulty or lower levels of skill resulted in a poorer secondary task performance.[14–16]

Our group has recently developed a secondary task designed specifically for laparoscopic procedures. A visual-spatial task is superimposed directly onto the laparoscopic display resulting in a combined video image in which both tasks are viewed in the same focal field and require the same visual attentional resources. To date, we have shown that this secondary task is sensitive to differences among surgical experience, laparoscopic training tasks, and the transition from FLS to fresh cadavers.[17–19]

The primary goal of this study was to establish the incremental mental workload associated with the more challenging SILS procedures using a visual spatial secondary task as well as subjective ratings. It was hypothesized that compared to FLS tasks, the more challenging SILS tasks would result in lower performance scores and higher mental workload as indexed by higher subjective ratings and lower secondary task scores.

2. Method

2.1. Participants

There were 12 participants (6 surgery residents and 6 students, 7 males and 5 females, in the Master of Surgical Assisting program at Eastern Virginia Medical School) in this IRB-approved study. The residents were trained over a period of 8 weeks in 1–2 h sessions, once per week. The surgical assistants trained for 10 weeks in 1-h sessions, once per week. The residents had passed FLS and the surgical assistants met the FLS criteria described by Ritter and Scott[20] for the tasks examined within 2–3 months of participating in the study.

2.2. Tasks

The primary tasks were the peg transfer, cutting, and intracorporeal knot tying from the FLS curriculum. A measure of speed and accuracy for each task was calculated so that higher scores would reflect better performance using the following calculations:

- Peg Task Score = 300 (maximum time limit in sec) − (completion time in sec) − 10*(# of drops)
- Cutting Task Score = 300 (maximum time limit in sec) − (completion time in sec) − 10*(accuracy error - distance from inside/outside of circle in mm, if greater than 2 mm)
- Intracorporeal Suture Task Score = 300 (maximum time limit in sec) − (completion time in sec) − 10*(accuracy error - distance (in mm) from the dot on the penrose drain to the suture, with a 1 mm allowance). Also, knot security errors or avulsion of the penrose drain resulted in a score of zero.

Participants performed the three primary tasks on a standard FLS simulator and a 3DMed simulator fitted with a Covidien SILS port and three 5 mm trocars, two for the laparoscopic instruments and one for a 5 mm 35° camera. They used standard laparoscopic instruments on both simulators: Ethicon Maryland graspers and scissors for the peg and cutting tasks, and Ethicon needle drivers for the suturing task.

The secondary task was the visual spatial ball-and-tunnel detection task in which four balls are presented in a representation of a 3D tunnel. Depth is conveyed within the tunnel by small dots that decrease in size and relative distance toward the center of the image. In the standard configuration, balls are located at the 12, 3, 6, and 9 o'clock positions. Participants are presented with successive images and asked to respond when they detect that a ball has changed its position. Targets consist of one ball that appears to shift in depth: either closer (the diameter increases from 26 to 53 mm and shifts 53 mm from the center) or farther (the diameter decreases from 26 mm to 11 mm and shifts 11 mm from the center). Only one ball changes position at any given time and no importance is placed on which ball moves or the direction of movement. Images were presented for 300 ms every 2–4 s with a mean of 3 s. Participants responded to targets using a Savant Elite USB 3 pedal triple action foot switch. Performance in the ball-and-tunnel task was assessed by the proportion of correct detections, false alarms, and response times (RTs).

The ball-and-tunnel task is superimposed onto the video image from the simulator to create a single combined image showing both tasks to the user. Thus, the secondary task appears in the same viewing area as the primary task, but is shown at 50% transparency so that it does not fully obstruct the view of the primary task.

2.3. Subjective workload

Subjective ratings of mental workload were assessed using the NASA–Task Load Index (NASA-TLX).[21] This instrument provides an overall index of mental workload based on the relative contributions of six subscales: mental, physical, and temporal task demands; effort; frustration; and perceived performance. Total workload scores were calculated by summing the ratings across the six subscales (range = 0 to 120). The psychometric characteristics of the NASA-TLX are well documented and Yurko, Scerbo, Prabhu, Acker, and Stefanidis reported that NASA-TLX scores reflected differences in task proficiency due to training and were also positively related to the errors in OR procedures.[22,23]

2.4. Procedure

The participants first performed the ball-and-tunnel by itself to establish baseline performance. Next, they performed one trial each of the peg, cutting and suture tasks (in that order) simultaneously with the ball-and-tunnel task. There were given a maximum of 300 s to perform each task and then completed the NASA-TLX workload scale immediately afterward. They were then transferred to the SILS simulator and performed the same three tasks in the same order. Prior to the experimental trials they were given 5 min of practice to acclimate to the SILS environment.

2.5. Statistical analysis

An a priori power analysis for repeated measures with a power level 0.80, correlation value of 0.5, to detect an effect size of 0.5 at the 0.05 level, required 12 participants for 2-level factors and 10 participants for 3-level factors. All data were analyzed with repeated-measures ANOVAs. Comparisons among the three tasks that did not meet repeated-measures variance requirements were evaluated with Greenhouse-Geisser conservative degrees of freedom and were followed up with Bonferroni post hoc corrected alpha level of 0.017. Comparisons with unequal variances were analyzed with a Wilcoxon Signed Rank Test.

3. Results

3.1. Primary task

The results for the three tasks performed on the FLS and SILS simulators are shown in Table 1. The Wilcoxon Signed Rank Test