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Performance of single versus two operators in laparoscopic surgery

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ABSTRACT

Background: To examine the significance of team collaboration in the context of complex laparoscopic surgery, laparoscopic tasks performed by single operators are compared against that of dyad teams.
Methods: The laparoscopic tasks require subjects to reach, grasp and transport a ring through a roller-coaster obstacle using a pair of laparoscopic graspers. The task was performed either bimanually (using both hands) or unimanually (using their preferred hands) in a dyad team.
Results: Twelve participants completed all the tasks. The dyad teams recorded significantly greater number of anticipatory movements than individuals who performed the task bimanually (2 vs 1, $p < 0.05$). However, there is no significant difference in the task completion time ($p = 0.701$) and the number of errors ($p = 0.860$) recorded between the dyad and the bimanual group.
Conclusion: Compared to a single operator, dyad operators performed the task with greater number of anticipatory movements. The increased movement synchronization can help benefit surgical education and team training.

1. Introduction

Laparoscopic surgery or otherwise known as minimally invasive surgery is one of the fastest growing surgical approach. It has become the standard of care for operations involving the thoracic, abdominal and pelvic cavities. Laparoscopic procedures are carried out using a video camera and several long instruments placed through small incisions in the abdomen of the patient. Due to its advantage of shorter hospital stay following surgery, fewer wound associated complications, improved cosmesis and less incisional pain, it is increasingly favored by patients and physicians alike.[1–6] However, the lack of haptic feedback, limited visual information and inflexibility of instruments poses different challenges for the surgeon as the ability to efficiently manipulate tissue is reduced.[7] Additional difficulties with laparoscopic operations results from the utilization of multiple instruments through multiple ports scattered across the abdomen. One solution to facilitate complex laparoscopic operations is for the attending surgeons to collaborate with surgical assistants: residents, medical students and nurses in manipulation of surgical instruments.

To complete everyday complex tasks, individuals often use both hands concordantly, with each hand serving a slightly different purpose. The manipulation of objects through our hands provides the sensation and perception that defines the relationship between the objects and the person. In conjunction with visual feedback, the non-preferred hand provides reference and context information while the preferred hand guide movement.[8,9] This haptic input becomes particularly important when visual information is limited, as is often the case in laparoscopic surgery. However, haptic feedback is reduced as well in laparoscopic surgery since the hands of the surgeon makes contact with the target through the means of a long-shaft instrument. The indirect collection of information about the target may be inadequate for providing the reference and context information that would be useful. Hence, the loss of sensory information in laparoscopic surgery could increase the mental workload and attentional demands of the surgeon, consequently degrading surgical performance. By adding more operators, we have the opportunity of increasing the capacity for information processing thereby share the burden of performing a complexed laparoscopic task amongst two operators.[10] Due to the mentally demanding nature of a laparoscopic approach, we wish to investigate if it would be more efficient for the instruments to be controlled by two operators unimanually or by one operator bimanually.

Within this study, we assessed laparoscopic bimanual performance and compared the performance with that of dyad group. The performance of each group was analyzed and evaluated by

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comparing the task duration, number of errors made and also the number of anticipatory actions. We hypothesize that the performance of the dyad group would be better than that of a single operator, if working in a team facilitates greater efficiency in task completion.

2. Methods

2.1. Participants

A total of 12 subjects (university students) were recruited and randomly assigned to one of two groups forming 12 bimanual groups and 6 dyad groups. All participants are right-handed with 20/20 normal or corrected-to-normal vision who were novices to laparoscopic procedures and tasks. The University of Alberta Health Ethics Review Board approved the study's protocol. Informed consent was obtained from each participant.

2.2. Apparatus

Tasks were completed in a laparoscopic training box measuring 43 cm × 33 cm × 31 cm. The training box is composed of a centrally mounted camera, light source, video monitor and two laparoscopic graspers. The entry ports of the instruments were separated by 9 cm. The subjects were required to perform the task in the dyad team (Fig. 1A) or the individual bimanual setting (Fig. 1B). At the center of the training box was a wire roller coaster with a ring which can be manipulated along the course of the wire requiring the use of both wrist articulation and grasping. The task consists of passing the ring along the tortuous course of the wire, aiming to pass the ring along as fast as possible without touching the wire with the ring. The images were projected on a 19-in color monitor (Fig. 1C).

2.3. Task and procedure

We designed an experiment requiring participants to reach, grasp, and pass a ring through a wire roller coaster using a pair of laparoscopic grasper. The participants were either asked to perform the task as an individual bimanually or as part of a dyad team to perform the task unimanually (Fig. 1). To start off, the participants were instructed to hold their respective tools such that the tips of the two graspers are both on the start plate. When given the verbal signal to begin, the right grasper will be used to pick up the ring, which will be located at the base of the rightmost loop. The participant controlling the right loop will begin passing the ring along the wire. At the top of each loop of the obstacle, the ring will be transferred from one grasper to the other. Once at the end of the obstacle, the process will be repeated in the opposite direction. Hence, a total of six passes will be completed by the end of the task. The completion of the task will be signaled by the return of the grasper tips to their starting positions at the center plate. This study requires coordination and allows assessments of teamwork capacity. For the given task, the participants in the dyad groups will hold the grasper in each of their dominant hands. To ensure all participants have a good understanding of the task at hand, they were provided with instructions verbally as well as being shown a video demonstration. One practice trial was given to each subject or dyad team for participants to complete one full run of ring transfer.

2.4. Video analysis

2.4.1. Task time

The duration measured in seconds for completion of the task were recorded.

2.4.2. Anticipatory movement

The number of anticipatory movements was obtained for each trial. Anticipatory movement was used in our previous study to indicate movement collaboration between team members.[11] Anticipatory movement is often defined as the preparatory movement performed by one team member toward facilitating the upcoming task step before the other member in the team is finishing the on-going step. In this study, anticipatory movement was defined as the movement of the resting grasper to within 1 cm of the top of the loop (where the ring is passed) and with the grasper open to greater than 30°.

2.4.3. Number of errors

The number of ring drops was recorded as a measure of discoordination between the graspers.

2.5. Data analysis

ANOVA was utilized to compare the task performance between the individual and the dyad team approach to laparoscopic tasks. Results of the study were reported as mean with standard deviation. A *P* value less than 0.05 was considered significant.

3. Results

A total of 12 university students were recruited to the study and completed the tasks. All participants were novices to manipulation of laparoscopic instrumentation. The performances of dyad and bimanual groups were characterized by total task time, number of errors and number anticipatory movements as summarized in Table 1. Significant differences were noted in the number of anticipatory movements ($p < 0.05$, Fig. 2), but not for the total task time ($p = 0.701$) and number of errors ($p = 0.860$). The number of anticipatory movements observed in the dyad team was

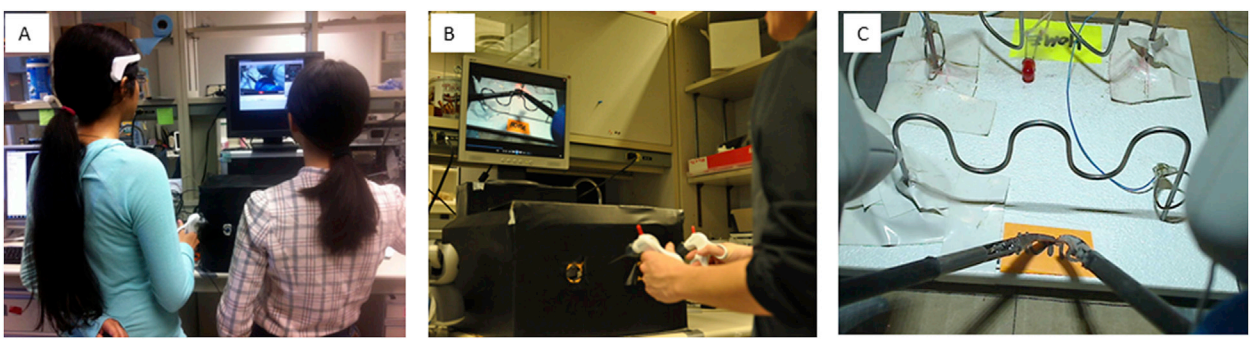

Fig. 1 Participants were asked to perform a laparoscopic task which involves passing a ring through a rollercoaster obstacle either in a dyad group or as an individual

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Table 1
The performance of laparoscopic tasks as compared between individual and dyad teams

Group	Total Task Time (s)	Num. of Anticipations	Num. of Errors
Individual	193 ± 25	1 ± 0.3	3 ± 0.9
Dyad	176 ± 44	2 ± 0.4	2 ± 0.5
p value	0.701	0.038	0.860

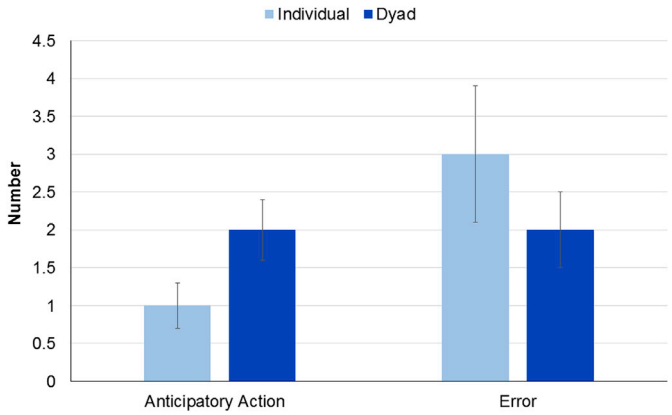

Fig. 2 Number of anticipatory actions and number of errors made by participants as they performed the laparoscopic tasks as an individual compared to a dyad group

significantly higher than that observed in a bimanual approach performed by an individual (2 ± 0.4 vs 1 ± 0.3, $p < 0.05$). The dyad team required less time completing the task in comparison to the bimanual group (176 ± 44 vs 193 ± 25, $p = 0.701$). Lastly, the dyad team also made less errors compared to the bimanual group (2 ± 0.5 vs 3 ± 0.9, $p = 0.860$).

4. Discussion

Our goal in this study is to assess performance of dyads in a laparoscopic simulated task, comparing it with that of the same individuals when they perform the task individually. In the dyad condition, there is an increased synchronized movement that is measured as an increase in anticipatory action between the two graspers. A much earlier study of team performance illustrates that anticipatory movement in laparoscopic surgery is a behavior indicator for team collaboration and movement synchronization.[12] Additionally, the dyad group made less errors compared the individual (Fig. 2). This finding of superior performance in the dyad group is in concordance with a prior published study looking at team performance in an endoscopic cutting task.[11]

In a laparoscopic task performed under dyad conditions, the manipulation of multiple surgical instruments are shared amongst two operators. This collaborative effort creates the opportunity to share the mental burden of performing a complex task. While one operator is occupied with the task at hand, the other operator has the opportunity to analyze the situation and come up with strategies that can facilitate task completion. The ability to share a complexed task with a team member becomes more significant in a laparoscopic surgery. The laparoscopic environment to which surgeon operate is limited in the amount of sensory input they receive, resulting in a greater cognitive burden. With a long-shafted instrument, it is difficult to extract the target's frame of reference through remote contact. The diminished tactile feedback makes it difficult to rebuild context information and guide performance. To accommodate for the increased cognitive workload, when the same task is shared by two operators in a dyad team, the workload is divided amongst the operators and hence more manageable. Many dyads developed a strategy that was rarely seen in the participants when they were working alone. The dyads worked together such that one operator moved grasper to the vicinity of the location where the ring will be passed while the other operator was still moving the ring along the obstacle. This advanced preparation and anticipation for future action contributed to the enhanced performance of the dyad group.

Nonetheless, for teams to perform coherently, there needs to be a shared understanding of the overall process of performing the task.[13] It may be argued that coordinating with another operator in a team requires additional workload in the form of team load. Team load can be described as a barrier to superior performance in a novice team when the partner's motions can be expected to complicate motor planning and efficient task execution. In addition to the task at hand, the operators must also be able to exchange information and coordinate actions with each other. For a newly formed team performing their first several trials, the learning curve is steep. However, when the knowledge of task, environment and role is clearly defined for each of the team members, it facilitates better collaboration. In this study, the participants in each dyad team were clearly informed of the task goal and understood their specific role in the task. With additional training, it is possible that the performance gap between the dyad and individual could be more pronounced. The collaborative efforts coupled with the utilization of their dominant hand are likely the main reasons that performance is better for the dyad than with an individual. This study provides a quantitative measurement of the collaboration seen in a dyad team graphically represented in Fig. 2.

Limitation of this study includes that the participants are all novices and had only a single training session to manipulate the instruments. Hence, this study evaluates the initial difference in performance between the individual and dyad groups when the operator is at the beginning of the learning curve. From the results of this study, it would not be possible to ascertain how performance will be impacted if the operators had more practice and experience manipulating the instruments. As well, we are aware that the laboratory grasping and cutting task in this study differs from the surgical tasks performed in laparoscopic procedures. The object transportation task is too overly simplified to represent true laparoscopic procedure. However, laparoscopic procedures can be hierarchically decomposed to basic surgical tasks and motions such as the one simulated in the current study. The result of this study helps to shed light on the structure of the intra-operator coordination in the surgical context. We plan to study team collaboration in a more realistic laparoscopic setting. This study is also limited in that there is a small cohort and has limited power due to the small sample size.

In performing a laparoscopic task, the ability to share the task load between two operators in a dyad team produced superior performance in terms of anticipatory movements as compared to a single operator performing the task bimanually. Hence, there is benefit in performing laparoscopic operations as a team and consideration should be made in providing team environment training opportunity for residents and staff.

Conflict of interest

The authors confirm that they have no commercial association or financial interest that would pose a conflict of interest with this manuscript.

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