

EVALUATION OF LAPAROSCOPIC TOOLS FOR USABILITY AND COMFORT

Kathryn Doné, Allison DiMartino, Timothy Judkins, Susan Hallbeck
University of Nebraska–Lincoln, Lincoln, NE
and Dmitry Oleynikov
University of Nebraska Medical Center, Omaha, NE

Many problems have been associated with current laparoscopic surgical tools, and work is being done to improve the design of many the tools and devices, but little improvement has resulted. The IDEA Lab at the University of Nebraska-Lincoln, has designed a comfortable and intuitive tool with added function as a result of questionnaire responses from student and expert surgeons. Surgeons were asked to respond to a questionnaire asking about pain and discomfort experienced from use of conventional laparoscopic grasper tools. Analysis of the results shows that more than 25% of all respondents experience problems during or after surgery in the following areas: neck pain and stiffness, shoulder/arm pain and stiffness, hand/wrist pain and stiffness, back pain and stiffness, mental fatigue, awkward manipulation of instruments, and performing precise movements. Eleven out of eighteen surgeons reported experiencing painful areas of the hand during or after laparoscopic surgery, including but not limited to, numbness of the thumb and soreness of the fingers. These results make it clear that the redesigns of the new laparoscopic grasper tool were needed. Further testing will be conducted to compare the new design to conventional tools and determine if all of the needs of surgeons have been met.

INTRODUCTION

The tools used in minimally invasive surgery, specifically laparoscopic surgery, along with the operating room set-up and posture of the surgeon, have been shown to cause fatigue, discomfort, pain, and instances of long term damage to the surgeons' hands, wrists, arms, and shoulders (Berguer, et al. 1997; Berguer 1998a; Berguer, et al. 1998b; Berguer, et al. 1999; Matern and Waller 1999b; Berguer, et al. 2001a; Berguer, et al. 2001b; Emam, et al. 2001; Nguyen, et al. 2001; Van Veelen, et al. 2001a; Van Veelen, et al. 2001b; Matern, et al. 2002). It is a widely accepted fact that laparoscopic surgical tools need to be redesigned to better aid the surgeon in conducting safe procedures; safe for both the surgeon and the patient.

Over the past year, those at the IDEA lab at the University of Nebraska-Lincoln have worked to design and prototype a new laparoscopic surgical grasper. An ergonomically designed handle and a redesigned grasper actuation mechanism will provide a more comfortable and intuitive hand/tool interface. These additional design features will increase patient safety by reducing surgeon's fatigue and decreasing the need for complex cognitive planning.

Surgeons and surgical residents gave feedback on those grasper tools currently being used during laparoscopic surgeries. The results of this preliminary questionnaire drove the improvements leading to an ergonomically designed tool. Surgeons and surgical residents will then be asked to participate once again and give feedback on the redesigned graspers tool because they are the most qualified to compare it to current models. Testing of the new tool will be comprised both of a second questionnaire and analyses of video taken while subjects use multiple current grasper models and the new design to perform a standard task in the lab.

The first questionnaire was designed, seeking information on the location and intensity of discomfort and pain experienced during use of conventional tools. This

questionnaire was distributed to student and expert surgeons at training sessions held at the University of Nebraska Medical Center.

QUESTIONNAIRE

The intent of the first questionnaire was to examine the limitations and problems associated with conventional tools. The answers provided by student and expert surgeons have provided the designers in the IDEA Lab directions for improvement on the prototype tool in order to avoid the same problems. This first questionnaire also gives researchers a benchmark with which to compare opinion of the new tool.

The questionnaire (Figure 1) used a modified five point Likert scale to gather information on such things as the size of the tool handle and fit to the surgeon's hand, ease of use, and the surgeons' overall impression of the tool. The surgeons were also asked about the amount of pain felt (none, slight, substantial) in different parts of the body after use of the tool.

METHOD

Eighteen surgeons completed the questionnaire examining conventional laparoscopic grasper tools. The surgeons (both expert and student) were involved in standard training exercises for half a day (sponsored by UNMC), involving extensive use of various laparoscopic surgical tools, including grasper tools. After the training exercises were complete, the surgeons completed the first questionnaire (Figure 1) asking about use of laparoscopic tools (an overall opinion, including the experiences of both that day and previous procedures).

ANALYSIS

Questionnaires using the Likert scale are especially difficult to analyze. Statisticians debate which test is the most accurate for analyzing such a questionnaire. Likert himself accepted parametric statistics for analysis, but many modern statisticians disagree.

The data collected from a Likert scale is ordinal. If parametric statistics are used on such data, the second assumption of linear regression, validity and accurate measurement of dependent and independent variables, is violated. Since this assumption cannot be met, nonparametric analyses should be used. For all questions using a Likert scale (questions 1-6), generalized results were determined by using a Wilcoxon Signed Rank Test utilizing ranking with zeros for each of the questions. This test looks to see if the median is significantly different than zero, or in this case, two (neutral on the Likert scale). The hypotheses are:

H_0 : The median is equal to two.

H_1 : The median is less than two.

The alternate hypothesis tests for a median less than two because these significances will indicate a serious desire from surgeons for improvement.

Those questions rating the level of pain were analyzed both by quantitative and qualitative measures. A Wilcoxon Signed Rank Test was used to look for significant differences from zero (no pain) for each of the complaints listed. The results were also observed and documented as a percentage (ex. 10% of surgeons report slight pain in their shoulders after laparoscopic surgery).

RESULTS

The Wilcoxon signed rank test showed no differences on any of the first six questions shown in Figure 1.

The data collected on problems experienced during and after surgeries were statistically analyzed, and also calculated as percentages. A Wilcoxon Signed Rank Test revealed medians statistically larger than zero (no pain) on all but two complaints. "Headaches" were not found to be a significant problem and because of too many missing data (surgeon did not answer question), "excessive tachycardia/sweating/tremors" could not be tested.

The percentage of respondents who indicated experiencing either slight or substantial problems in the indicated areas during or after use of the conventional grasper tools are shown in Table 1.

The last question on the questionnaire asked surgeons to identify, on a picture of a hand, where they feel pain during or after laparoscopic surgery. Eleven out of eighteen respondents identified painful areas of the hand. Four surgeons indicated experiencing pain on the lateral side of the wrist. One surgeon indicated experiencing pain on the medial side of the wrist. One surgeon indicated experiencing pain in the entire hand. Three surgeons indicated experiencing numbness of the thumb. One surgeon indicated experiencing soreness on the backs of the fingers (from opening the handle

Table 1: Percent of surgeons experiencing slight or substantial problems

Neck pain	47%
Neck stiffness	47%
Shoulder/arm pain	59%
Shoulder/arm stiffness	50%
Hand/wrist pain	53%
Hand/wrist stiffness	50%
Back pain	29%
Back stiffness	29%
Headaches	7%
Mental fatigue, irritability, exhaustion	47%
Excessive tachycardia/sweating/tremors	0%
Instruments awkward to manipulate	60%
Not able to perform fine or precision motions	47%

with the finger rings). Two surgeons indicated experiencing pain on the skin surrounding the proximal phalanx of the thumb (also a result of pressure from the thumb ring).

DISCUSSION

The lack of significant results in the first six questions tells us that the surgeons feel comfortable using the conventional laparoscopic grasper tools. And should we expect any different? These surgeons perform hundreds of laparoscopic procedures a year; they are willing to adapt to any environmental stressor.

Headache and excessive tachycardia/sweating/tremors were the only two problems not experienced by more than a quarter of the respondents. One may conclude that after extensive training, surgeons are not severely affected by the cognitive load of laparoscopic surgery. They are also willing to endure personal pain to perform their job as shown by the high frequencies of pain and discomfort reported in the questionnaire.

Awkward manipulation of instruments was the most frequently indicated problem, with 60% of respondents indicating this problem. This is interesting, considering the first six questions did not reveal significant complaints.

These results confirm the initial concerns of designers: surgeons experience discomfort and pain during and after laparoscopic surgery that is caused by factors that include tool design. The current prototype has been designed to address many of the concerns raised in this questionnaire. Neck pain and stiffness is most likely an effect of operative room design and not tool design. Shoulder/arm and hand/wrist discomfort has been addressed by novel hand positioning options on the new tool handle. Mental fatigue may be a factor of multiple variables, but intuitive control of the handle may help. Awkward manipulation and inability to

perform precision motions are most likely factors of handle design, shaft length and function control.

Now designed and with first prototype in hand, this tool must be compared to currently used tools. Evaluation of the new tool design is expected to reveal reduced response for pain and discomfort in the shoulder, arm, wrist and hand as well as awkward manipulation and inability to perform precise motions. Even small decreases in these percentages would be a great leap forward for laparoscopic surgeons.

REFERENCES

- Berguer, R., G. T. Rab, et al. (1997). "A comparison of surgeons' posture during laparoscopic and open surgical procedures." *Surgical Endoscopy* **11**(2): 139-142.
- Berguer, R. (1998a). "Surgical technology and the ergonomics of laparoscopic instruments." *Surgical Endoscopy* **12**: 458-462.
- Berguer, R., S. Gerber, et al. (1998b). "An ergonomic comparison of in-line vs. pistol-grip handle configuration in a laparoscopic grasper." *Surgical Endoscopy* **12**: 805-808.
- Berguer, R., D. L. Forkey, et al. (1999). "Ergonomic problems associated with laparoscopic surgery." *Surgical Endoscopy* **13**(5): 466-468.
- Berguer, R., D. L. Forkey, et al. (2001a). "The effect of laparoscopic instrument working angle on surgeons' upper extremity workload." *Surgical Endoscopy* **15**: 1027-1029.
- Berguer, R., W. D. Smith, et al. (2001b). "Performing laparoscopic surgery is significantly more stressful for the surgeon than open surgery." *Surgical Endoscopy* **15**(10): 1204-1207.
- Emam, T. A., T. G. Frank, et al. (2001). "Influence of handle design on the surgeon's upper limb movements, muscle recruitment, and fatigue during endoscopic suturing." *Surgical Endoscopy* **15**: 667-672.
- Gupta, V., and Reddy, N. P. (1997). "Forces in laparoscopic surgical tools." *Presence: Teleoperators & Virtual Environments*, **6**(2), 218-229.
- Lewis, W. G. and C. V. Narayan (1993). "Design and sizing of ergonomic handles for hand tools." *Applied Ergonomics* **24**(5): 351-356.
- Matern, U., M. Eichenlaub, et al. (1999a). "MIS instruments: An experimental comparison of various ergonomic handles and their design." *Surgical Endoscopy* **13**: 756-762.
- Matern, U. and P. Waller (1999b). "Instruments for minimally invasive surgery." *Surgical Endoscopy* **13**: 174-182.
- Matern, U., C. Giebmeier, et al. (2002). "Ergonomic aspects of four different types of laparoscopic instrument handles with respect to elbow angle: An electromyogram-based study." *Surgical Endoscopy* **10**.
- Nguyen, M. D., N.T., M. D. H. S. Ho, et al. (2001). "An ergonomic evaluation of surgeons' axial skeletal and upper extremity movements during laparoscopic and open surgery." *The American Journal of Surgery* **182**(6): 720-724.
- Patkin, M. (1997). A checklist for handle design, Ergonomics Australia On-Line. **2003**.
- Van Veelen, M. A., D. W. Meijer, et al. (2001a). "Improved usability of a new handle design for laparoscopic dissection forceps." *Surgical Endoscopy* **16**(1): 201-207.
- Van Veelen, M. A., D. W. Meijer, et al. (2001b). "New Ergonomic Design Criteria for Handles of Laparoscopic Dissection Forceps." *Journal of Laparoendoscopic & Advanced Surgical Techniques* **11**(1): 17-26.

Figure 1:

Grasp/grip tool used _____
 Hand used to control tool _____
 Is this your dominant hand? ? YES ? NO

The following questions are adapted from Van Veenen et al. (2001c), Adams et al. (1999) and Berger (1996a).
 The rating scales have been modified.

1. Regarding the force required to open and close the grasper, what is the experience of comfort/discomfort during use?
 0 _____ 1 _____ 2 _____ 3 _____ 4 _____
 uncomfortable comfortable

2. Regarding the rotation function of the instrument tip, what is the experience of comfort/discomfort during use?
 0 _____ 1 _____ 2 _____ 3 _____ 4 _____
 uncomfortable comfortable

3. To what extent do the dimensions of the handles agree with your hand dimensions?
 0 _____ 1 _____ 2 _____ 3 _____ 4 _____
 uncomfortable comfortable

4. How comfortable is the handle in your hand?
 0 _____ 1 _____ 2 _____ 3 _____ 4 _____
 uncomfortable comfortable

5. How precisely can you work with the handle?
 0 _____ 1 _____ 2 _____ 3 _____ 4 _____
 not precisely very precisely


6. What is your general impression of the handle?
 0 _____ 1 _____ 2 _____ 3 _____ 4 _____
 not preferable preferable

7. Do you normally experience any of the following problems during or following laparoscopic surgery?

AREA/SUBJECT	NO	SLIGHT	SUBSTANTIAL
Neck pain			
Neck stiffness			
Shoulder arm pain			
Shoulder arm stiffness			
Hand/wrist pain			
Hand/wrist stiffness			
Back pain			
Back stiffness			
Headache			
Mental fatigue, irritability, exhaustion			
Excessive tachycardia/sweating/tremors			

8. Please identify on Drawing 2 where on your hand you feel pain during/after laparoscopic surgery.

AREA/SUBJECT	NO	SLIGHT	SUBSTANTIAL
Instruments awkward to manipulate			
Not able to perform fine or precision motions			

Drawing 1 

Drawing 2 