

Novel Laparoscopic Needle Holder

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Abstract. This paper presents a new design of laparoscopic needle holder, which is able to reduce the laparoscopy operating time. Many reports showed that laparoscopic technique provide many benefits to patients, however, it also bring many disadvantages to surgeons. In contrast to conventional surgery, there are several disadvantages to this technique; these include restricted vision, image distortions, difficulty of hand-eye coordination and poor instrument design resulting to a higher probability of getting musculoskeletal disorders compared to conventional surgical procedures. The new design will be the one of solution to improve surgeons' quality of life.

1. Introduction

Laparoscopy (Figure 1), a kind of minimal access surgery technique, is used to reduce the traumatic effect of surgical operations. In contrast to conventional surgery, there are several advantages to this technique; these include decreasing surgical trauma, superiority of surgical care, patients experience less pain, patients can recover quickly and there are economic gains to the whole society. Laparoscopy however, also brings some disadvantages for surgeons [1]. For example surgeons are faced with restricted vision, image distortions, hand-eye coordination difficulty, poor instrument design and musculoskeletal disorder [2]. Surgeons usually complain that they have physical pain after performing laparoscopy [3, 4].



Figure 1. Picture of Performing Laparoscopy

In conventional surgery the surgeon has an unhindered view, which allows the surgeon to explore organs inside the body without a problem. For laparoscopy, an optical image system is needed to provide a view inside the abdomen. Therefore, the

surgeon cannot see directly to control the movement of instruments and he needs to observe intra-abdominal information from the monitor [2].

The image systems, however, can only provide a two-dimensional (2D) enlarged image to the surgeon. Under this situation, the surgeon needs to imagine a normal visual (3D) image and measure monocular distance psychologically in order to identify the object and perform the task accurately [2, 5].

The hand-eye coordination is derived from a sequence of body sensing and control structures. First the image signals are transferred to the visual cortex via the retina. Then the visual cortex identifies the spatial position of the surgical instruments inside the patient's body by the signals sent from the retina. After that, the motor cortex generates stimulation signals to muscles in order to control the movement of arms. Therefore, the surgeon's action will depend on the transformation of visuo-motor signals, which were created during childhood development and enhanced by years of training or experience in their life [6].

The visuo-motor transformation and the real world do not match in the case of laparoscopy, which refers to surgeons do not visuo-motor transformation experience in normal life. Surgeons have been facing a huge challenge to deal with the mapping problem when they cannot look at their hands during the operation. The surgeon is often confused by the indirect method of view and control. Consequently, hand-eye coordination is inconsistent when the surgeon performs laparoscopy [5, 7, 8]. In addition, the surgeon must slow down the movement of the instrument in order to pay attention to the degree of enlargement (Figure 2). The disadvantages of visual problems have limited the adoption of laparoscopy [2, 9, 10].



Figure 2. Posture during Laparoscopic surgery

A user-friendly interface instrument has present in this report, which is able to improve the quality of life of surgeons. The purpose of examination is to find if there are any differences between performing conventional laparoscopic instrument and new laparoscopic instrument. The results show the new concept for laparoscopic needle holder design, which reduces the operation time [2].

2. Observational Study

The problem is demonstrated by looking at a 2D image and attempting to do 3D measurements, for example the surgeon can estimate the distance between Point A and Point B (Figure 3) with the surgeon's eyes (3D).

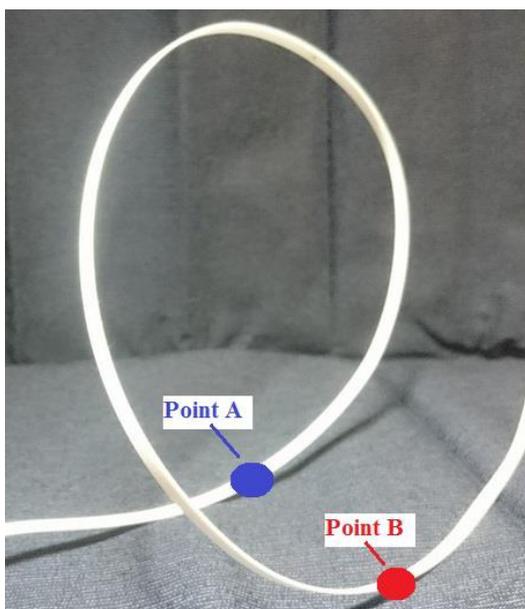


Figure 3. The Loop with 45 Degree Obliquity

However, it is not easy to guess the distance in front of the loop when the surgeon closes one of his/her eyes (2D). From another angle it seems that there is a complete loop from the front side of the loop (Figure 4), however, if the surgeon looks laterally then the two ends of the loop could be either quite close or widely separated.

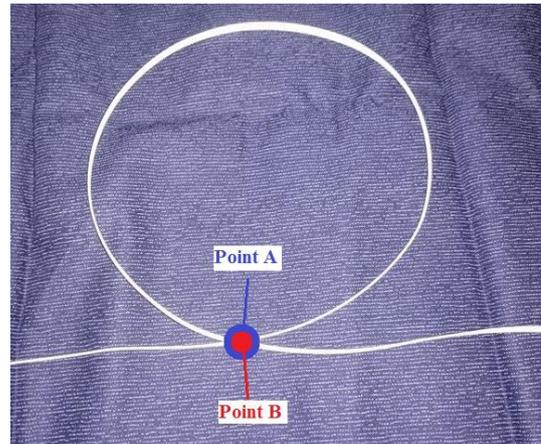


Figure 4. Front View of the Loop in 2D Picture

During the data collection for Investigation, it was found that surgeons move their arms in six DOF with four DOF vision. In this case, the surgeon finds it very difficult to make sure that the knot has been made, which could be the major problem with laparoscopic suturing. 3D imaging is one of the best ways to solve this problem. Otherwise it can only be solved though the surgeon's experience and increased operating time.

The aim here is to design a novel laparoscopic instrument to reduce the hand-eye coordination problem. The idea behind the proposition for a new needle holder is that if we cannot improve the surgeon's vision then we may need to limit the degree of movement required by the surgeon.

3. The New Concept of Design

In the new idea of laparoscopic needle holder, a "Thread Holder" is installed on the instrument stem, which is used to fix the suture thread behind the main jaw (Figure 5).

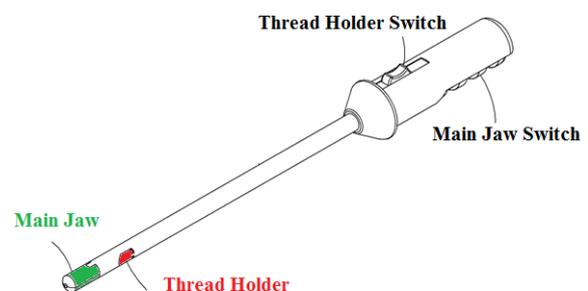


Figure 5. Proposed New Instrument Design

The structure of the new needle holder is shown in Figure 6. The instrument has to have as simple a construction as possible so that it may be sterilised

repeatedly. For example, it can contain no electrical components. The handle will be similar to original laparoscopic instrument. The only difference is to install an innerspring switch on the top on the holder to control the “Thread Holder”. The user can easily pull the switch with his thumb to open the “Thread Holder” or release to close it.

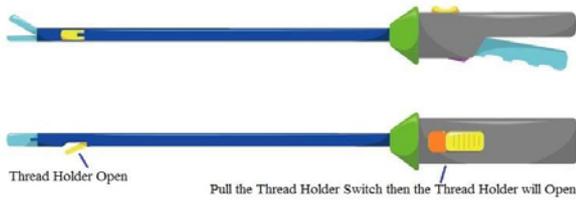


Figure 6. Demo of the New Laparoscopic Instrument Operating

The function of “Thread Holder” is to fix the position of the suture thread and let the surgeon make laparoscopic circular movements more simply and quickly (Figure 7). In this case, the suture line cannot be moved without turning the instrument, since the two ends have been held by the instrument jaw and the “Thread Holder”.

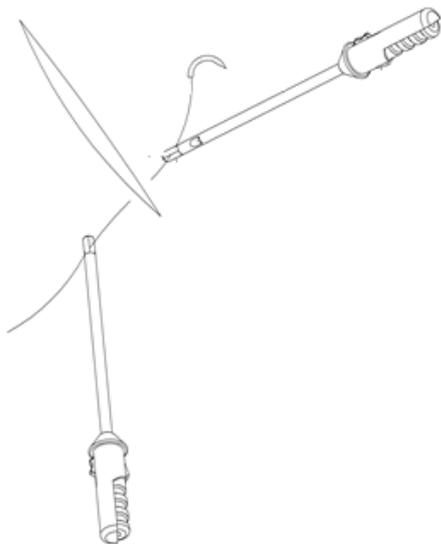


Figure 7. Operating of the New Instrument

The surgeon can mentally figure out the 3D position of the instruments by tactile sensation without 3D vision. The surgeon will find it easier to determine the position of the two ends of the suture knot (Figure 8).

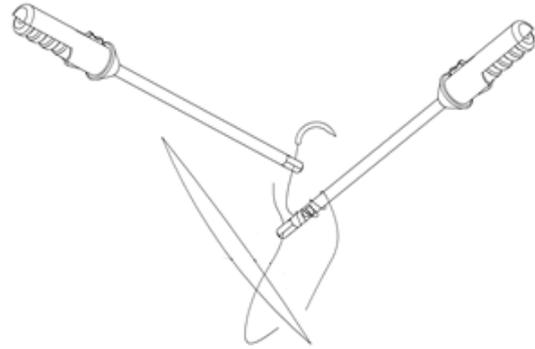


Figure 8. Suture Knot by New Instrument

4. Suturing Procedures by New Laparoscopic Instrument

In order to introduce the operation of the new instrument, the new procedure of laparoscopic suturing is described below step by step. This omits the needle stabbing steps.

- Step 1. Use the left hand instrument to grasp the long end.
- Step2. Place the new needle holder (right hand) under the suture thread. Then push the switch to open the “Thread Holder” (Figure 9).



Figure 9. Place the new needle holder under the suture thread.

- Step 3. Pick up the suture thread by the “Thread Holder” then pull the button to close the “Thread Holder”. (Figure 10).



Figure 10. Pick up the suture thread by the “Thread Holder”

- Step 4. Cycle the suture thread on the stem clockwise twice.
- Step 5. Find the end of suture thread and pick it up by main jaw.
- Step 6. Hold the end of suture thread by main jaw (Figure 11).

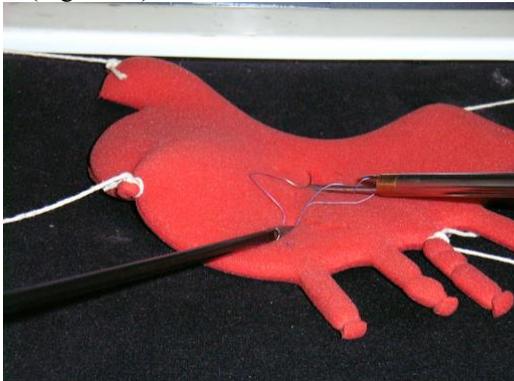


Figure 11. Hold the end of suture thread

- Step 7. Push the switch to open the “Thread Holder” (Figure 12).



Figure 12. Open the “Thread Holder”

- Step 8. Pull both instruments back to tie it well and that will be a single knot.

Repeat these above steps for two more single knots. Turn the thread anti-clockwise in the first repeat cycle and turn the thread clockwise in the second repeat cycle. This process is based on normal suturing, where anti-clockwise and clockwise single-knots are made to increase the overall knot stability, and shows how easy it is to do this with the new tool.

5. Results

In order to measure operating time differences between original and novel laparoscopic instruments, 10 medical students were recruited and taught how to use the new needle holder. Three weeks training was provided to these students. Each participant was asked to perform laparoscopy sutures on a surgical practice kit using the original and the new instruments.

189.41 seconds were spent when these students tying a suture knot using the old instrument on average with the minimum 161.52 seconds and the maximum 210.55 seconds. However, they spent 146.5 seconds on average completing a laparoscopic suture with the new instrument, with the minimum 86 seconds and the maximum 176.53 seconds (Figure 13).

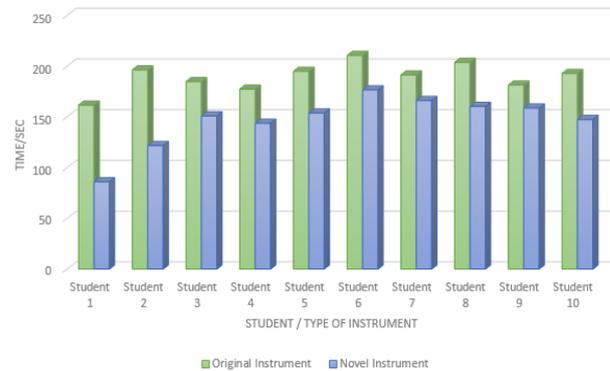


Figure 13. Students' Performances

This indicated that suturing using the updated instrument can reduce performance time by 22.7% compared with the original instrument (Figure 14). These differences between the old and new instrument suturing time were statistically significant ($P = 0.020$) by using a 5% significance level ($P \leq 0.05$) with the Mann-Whitney U-Test.

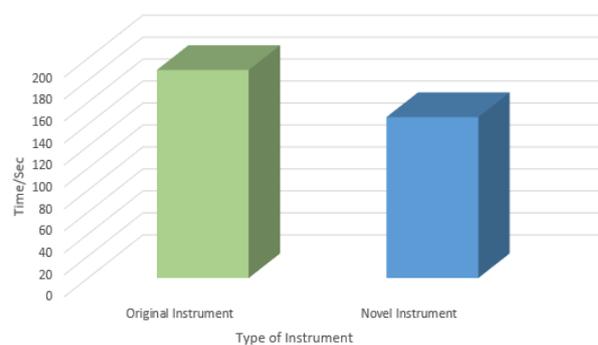


Figure 14. The Mean Value of Operating Time between Original and New Instruments

6. Conclusions

This research only considers the physical problem of the consultant surgeon. However, it is necessary to investigate team-based ergonomic problems by considering how the entire surgical team functions. This involves the participation of the assistant surgeon who is holding the camera and the nursing staff who transfer surgical instruments to surgeons. As a consequence, investigating the ergonomics of the surgical team may provide suggestions on how operating theatres should be designed to suit laparoscopic applications.

The major difficulty and time consuming part of laparoscopy is suturing. The problems of surgeons needing to recognise the position of the 3D thread and then to move their arms in the opposite direction as shown in a 3D image are surmounted with good co-ordination and training. 3D views of the environment are costly to achieve. A solution has been to design a new suture-friendly tool that reduces the need for the hand-eye co-ordination and finding the thread.

In conclusion, most medical engineering research is geared towards designing new equipment and technologies for the benefits of patients. Research by many groups has been carried out and the results demonstrated that most surgeons are not comfortable with laparoscopic instruments. It is important for researchers to find the ergonomic factors and disadvantages in operating with laparoscopic instruments. Ultimately, this will lead to improvements in terms of the quality of equipment for surgeons and other medical professionals.

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