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Abdominal View Expansion by Retractable Camera

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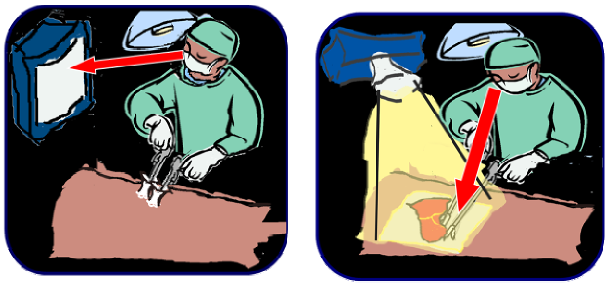
Abstract

Recently, minimally invasive surgery such as laparoscopic surgery is highly recommended to improve the quality of life (QOL) of patients after surgery. However, the laparoscopic surgery could be a mental and/or physical stressor to surgeons. To overcome this problem, we have proposed a computer-assisted laparoscopy system that matches the surgeon's visual axis and the direction of operative field by projecting the laparoscopic image directly onto the abdominal surface of the patient. The final goal of this study is to establish a pseudotransparent laparoscopy system. Therefore, in this study, we propose a novel trocar system with a retractable camera unit, which can provide additional view to surgeons without the need for additional ports. In order to evaluate the efficacy of the proposed system, the proposed trocar system was inserted into a porcine abdominal cavity under laparoscopic guidance and it was confirmed that the retractable action of the camera unit was smooth and safe. We also confirmed that the wide field of view was successfully obtained by a dry box experiment.

1. Introduction

Laparoscopic surgery is performed by inserting a laparoscope and surgical devices through apparatuses that are called 'trocar' while surgeons are looking at the monitor placed at a position different from the patient. As shown in Figure 1(a), laparoscopic surgery imposes, on surgeons, a discordance of the visual axis between the monitor and the operative field, and it could become a mental and/or physical stressor to those surgeons. To overcome this problem, we have proposed a computer-assisted laparoscopy system[1], as shown in Figure 1(b), which matches the surgeon's visual axis and the direction of the operative field by projecting the laparoscopic image directly onto the patient's abdominal surface. The final goal of our project is to establish a pseudotransparent laparoscopy system. Hence, the three-dimensional surface shape of intra-abdominal organs must be obtained in a



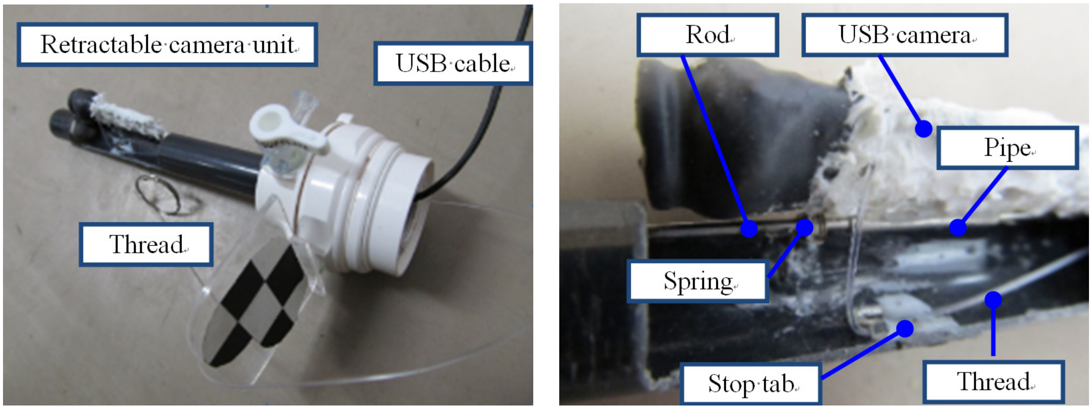
(a) (b)

Figure 1: (a) Conventional laparoscopy, (b) Pseudo-transparent laparoscopy system using projector[1]

real-time manner. In order to obtain organ shapes, Okada *et al.* employed a commercially produced stereo laparoscope and three-dimensional reconstruction of shapes by the hierarchical grid base stereo matching method[2]. However, this method has problems of low reproducible precision of the three-dimensional reconstruction and very high computational cost. Meanwhile, another approach of using a small kaleidoscope that projects structured light directly onto the surface of organs has been developed[3]. It requires an additional port to insert the kaleidoscope; however, such an additional port is unacceptable for minimally invasive surgeries. Therefore, in this study, we propose a novel trocar system with a retractable camera unit, which can provide the additional view to surgeons without the need for additional ports. The efficacy of the proposed device was tested in an animal model and a dry box environment.

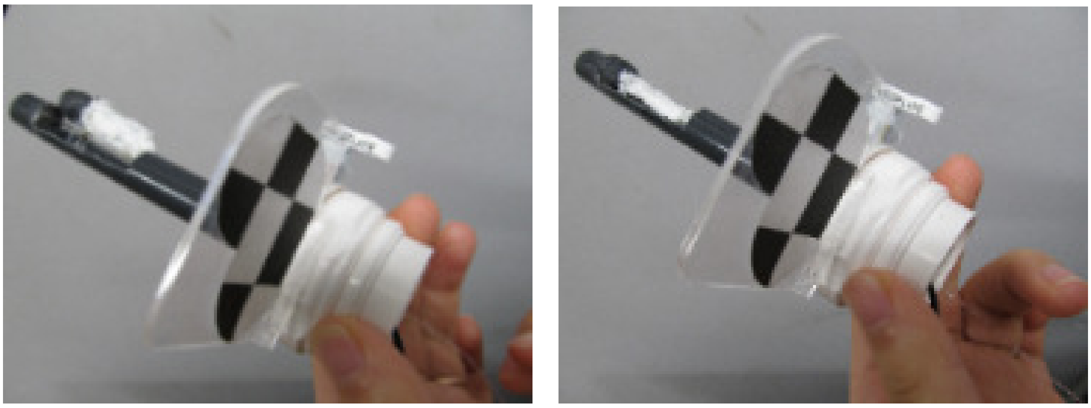
2. Trocar with Retractable Camera

A new trocar device is proposed in this study, which has a retractable camera unit. This device can provide additional views to the surgeon as many as the number of ports on the abdominal surface without making additional holes. This section introduces the details of the mechanism of the proposed device.



(a) (b)

Figure 2: Structure of the proposed trocar device with retractable camera: (a) Overall picture of the trocar device, (b) Detailed structure of the retractable camera



(a) (b)

Figure 3: Retractable action of camera unit: (a) The camera protrudes from of the tube as the normal position, (b) The camera is pulled into the trocar tube when the thread is pulled

In order to attach the retractable camera into the tubular part of the original trocar, the middle part of the trocar tube is cut open. The retractable camera is installed using a stainless-steel pipe and rod to realize the rotation degree of freedom. To adjust the range of rotation, a stop tab is installed. As shown in Figure 2(a), a thin thread is inserted to control the retractable action by hand. One end of the thread is tied to the camera board, as shown in Figure 2(b) and the other end of the thread is drawn out to outside the abdominal cavity through the trocar tube, as shown in Figure 2(a). With the use of a stainless-steel spring, the retractable camera protrudes from the tube as the normal position. When the surgeon pulls the thread, the camera is pulled into the trocar tube to the retracted position. In this study, the image size of the CMOS camera unit is 640x480 pixels, with RGB color channels, 24 bits per pixel, and a frame rate of 30 frames per second. The camera is connected to a Windows PC via a wired USB2.0 cable. The camera was made waterproof using silicon wafer and a cover glass for protection against body fluid inside the abdominal cavity.

When preparing the port for the trocar on the abdominal surface, the surgeon cuts the skin, muscle and membrane layers using an electric scalpel; then the trocar with a spiny core is inserted into the abdominal cavity. Since the proposed trocar with the retractable camera cannot have the spiny core, the surgeon uses an original trocar with a spiny core to form the port, and then the original trocar is replaced with the proposed trocar.

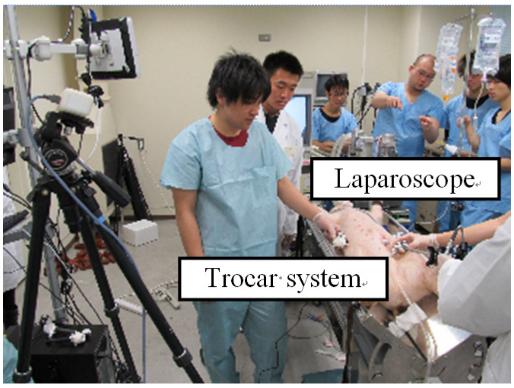
3. Experiments

In order to evaluate the efficacy of the proposed system, the proposed trocar system was inserted into a living porcine abdominal cavity under laparoscopic guidance, and it was confirmed that the retractable action of the camera unit is smooth and safe. In addition, the efficacy of the wider view is evaluated using a mannequin.

3. 1 Feasibility study

Since porcine abdominal organs resemble the human abdominal organs anatomically, it is suitable for confirming the feasibility of the retractable action. The clinical experiment was carried out, as shown in Figure 4(a), where the proposed trocar device was inserted at the red position and a laparoscope was inserted at the blue position, as shown in Figure 4(b).

Results of the experiment are shown in Figure 5. Figure 5(a) shows the image of the porcine abdominal cavity obtained using the laparoscope, and Figure 5(b) shows the image obtained using the retractable camera device. It is



(a)

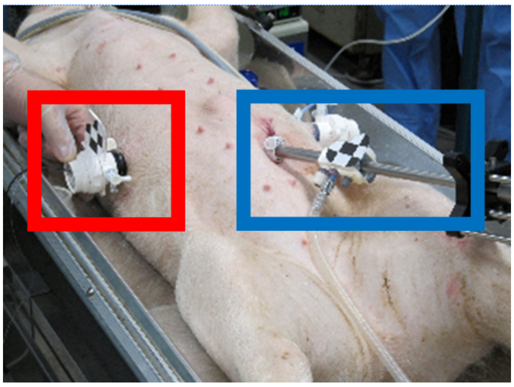
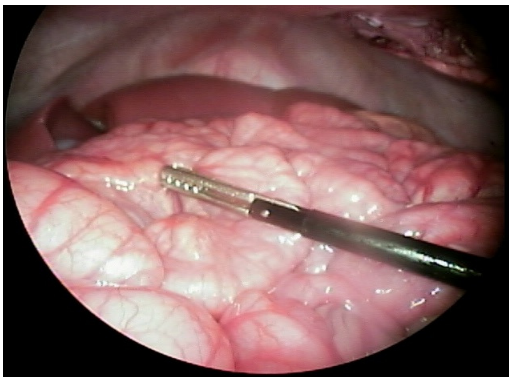

(b)

Figure 4: Porcine clinical experiment: (a) Overall picture of the experiment, (b) Port positions for the laparoscope and the proposed trocar device


(a)

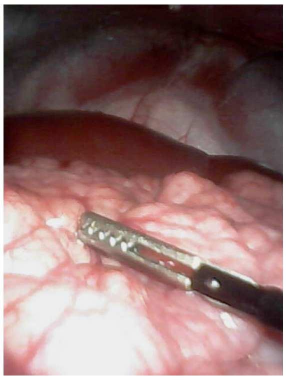

(b)

Figure 5: Images of abdominal cavity: (a) Obtained with the laparoscope, (b) Obtained with the retractable camera device

shown that the retractable camera device successfully captures the abdominal cavity as well as the laparoscope, and abdominal images from different angles were obtained at the same time.

As a result of this experiment, the insertion and extraction of the trocar was operated smoothly and safely by nonexperienced operators. In addition, the retractable action was also successfully achieved by pulling the thread. This device currently has no means of risk aversion, for instance, should the thread break, the camera cannot be retracted and the device cannot be extracted from the cavity. Protection from such trouble will be required in the future.

3. 2 Dry box study

As shown in Figure 6(a), two sets of the proposed trocar device were inserted into the abdominal cavity of the pregnant mannequin. A plastic model was placed inside the cavity, as shown in Figure 6(b) and it was captured with two cameras. Figure 7(a) and (b) show images from the left and right trocar devices, respectively. In this study, in order to evaluate the efficacy of the wider view of the abdominal images, image mosaicing was implemented. The image mosaicing technique consists of the following procedures.

1. Detect robust features using the SURF algorithm[4]
2. Match corresponding features using the nearest neighbor algorithm
3. Calculate the homography between the corresponding features

SURF is a feature detection algorithm that is robust to rotation and scaling. Corresponding features between two images are searched using the nearest neighbor algorithm. Finally, the mosaic image is composed by calculating the homography, which is the projective transform between the corresponding features. The resultant mosaic of the two captured images is shown in Figure 8.

4. Conclusions

In this study, we proposed a novel trocar system with a retractable camera unit, which can provide additional view to surgeons without the need for additional ports. It was confirmed that the retractable action of the camera unit was smooth and safe, by inserting it into a porcine abdominal cavity under laparoscopic guidance. In addition, in order to evaluate the efficacy of the wider view of the abdominal images, image mosaicing was implemented and tested in the dry box experiment.

The proposed device currently has no risk aversion; for instance, if the thread breaks, the camera cannot be retracted and the device cannot be extracted from the cavity. Therefore, it is strongly required to provide a means of protection from such trouble in the future. Also,

(a) (b)

Figure 6: Geometry of dry box experiment: (a) Port positions of two trocar devices, (b) Placement of a plastic model in the cavity

(a) (b)

Figure 7: Image captured by the trocar devices: (a) Left trocar, (b) Right trocar

Figure 8: Resultant mosaic of two captured images from Figure 7(a) and (b)

in order to achieve the final goal of this project, which is to realize pseudotransparent laparoscopic surgery, we must implement 3D surface reconstruction of the abdominal organs in real time using the proposed trocar device.

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