

Chapter 21

Biomedical Robotics for Healthcare

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ABSTRACT

Recently, a robotic system was developed in the biomedical field to support minimally invasive surgery. The popularity of minimally invasive surgery has surged rapidly because of endoscopic procedures. In endoscopic surgery, surgical procedures are performed within a body cavity and visualized with laparoscopy or thoracoscopy. Since the initial laparoscopic cholecystectomy was performed in 1987, the implications for endoscopic procedures have continuously expanded, and endoscopic surgery is currently the standard for an increasing number of operations. Advances in laparoscopic surgery have led to less postoperative pain, shorter hospital stays, and an earlier return to work for many patients. However, performing laparoscopic procedures requires several skills that have never been required for conventional open surgery. The surgeon needs to coordinate his/her eyes and hands and acquire a skillful manner using long-shaft instruments as well as mentally interpret a two-dimensional environment as a three-dimensional one. Because learning such skills is stressful for most surgeons, performing a laparoscopic procedure is more physically and mentally demanding than performing an open procedure.

ROBOTIC SURGERY

A robotic system has been developed to resolve the problems related to laparoscopic surgery. The robotic system provides surgeons with technologically advanced vision and hand techniques, which have revolutionized surgery in various

fields (Ballantyne, 2002; Hashizume, Konishi, Tsutsumi, Yamaguchi, & Shimabukuro, 2002). In general, the robotic system consists of three parts: a surgical cart, a vision cart and the surgeon's console. The surgeon's console provides master manipulators, which the surgeon can use to control the movements of the corresponding surgery, and patient-side manipulators that hold the surgical instruments and the endoscopic manipulator used

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for the procedure. The surgeon sits at a control console equipped with a display that presents images obtained by an endoscopic camera inside the patient's body. The surgeon looks down into the viewer in his hands as if looking into the surgical field. The control handles are held with his left and right hands. The surgeon then carefully guides the tool tips inside the patient's body. As the surgeon moves the manipulators on the surgeon's console, the patient-side manipulators closely follow the input motions. This master–slave manipulator allows surgeons to perform more precise surgical procedures than those available in conventional laparoscopic surgery.

The da Vinci™ Surgical System

The da Vinci™ Surgical System was developed by Intuitive Surgical (Mountain View, CA). So far, more than 1900 da Vinci systems have been installed worldwide. Many kinds of surgical operations, such as general surgery (Isogaki et al., 2011; Kakeji et al., 2006), urology, cardiothoracic surgery, pediatric surgery, and other operations (Yoshino, Hashizume, Shimada, Tomikawa, & Sugimachi, 2002), have already been performed using the da Vinci™ Surgical System (Hashizume et al., 2002). The da Vinci™ Surgical system consists of three main parts: The Surgeon Console, the Surgical Cart with one camera arm and three arms directly performing the procedures, and the Vision System. In the Surgeon Console resides the computer system controlling the whole system. One of the features of the da Vinci™ Surgical System are the surgical instruments with the Endo Wrist™ that mimics human hand motion by artificial articulation. Another feature provides visualization through a high-quality 3D endoscope. The da Vinci™ Surgical System provides surgeons with an intuitive translation of the instrument handle to the tip movement, thus eliminating the mirror-image effect. Additionally, this system provides scaling function, tremor filtering, coaxial alignment of the eyes, hand and tooltip

image, and an internal articulated endoscopic wrist providing an additional three degrees of freedom. To date, in the surgical treatment of tumors and cancer, which requires more intricate dissection with oncological approaches, we have successfully performed robotic surgery for esophageal tumors, thymoma, retromediastinal tumor, gastric cancer and colon cancer using the da Vinci™ Surgical System (Hashizume, Shimada, et al., 2002; Kakeji, et al., 2006; Yoshino, et al., 2002).

However, there are several basic problems that remain to be resolved in order for robotic surgery to spread more widely. These problems include the price of surgical robots as well as the lack of training systems for surgeons, medical insurance coverage, downsizing and navigation systems. In the regard to the training systems for surgeons, an excellent testimony to the significance of training has been reported (Amodeo, Linares Quevedo, Joseph, Belgrano, & Patel, 2009) (Suh, Mukherjee, Oleynikov, & Siu, 2011). Furthermore, our group at the Center for Integration of Advanced Medicine, Life Science and Innovative Technology (CAMIT) at Kyushu University started a training course called 'Hands-on Training for Robotic Surgery at Kyushu University' in July 2003. There are two training courses for robotic surgery. One is a one-day inanimate laboratory course and the other is a two-day course with an animate laboratory. Both courses are open, not only to medical doctors, but also to a wider range of engineering researchers in both academia and industry.

Single Port Surgery and Robotic Single Port Surgery

Laparoscopy has several advantages over traditional open surgery, such as a shortened hospital stay, decreased postoperative pain, and effective magnification of the surgical view. In laparoscopic surgery, three to six ports are usually used depending on the difficulty of the procedure. However, the use of multiple ports increases the potential chance of morbidity from bleeding, port site her-

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