Chapter 2
Master and Slave Transluminal Endoscopic Robot (MASTER) for Natural Orifice Transluminal Endoscopic Surgery (NOTES)

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ABSTRACT

Natural Orifice Transluminal Endoscopic Surgery (NOTES) has advantages in reducing postoperative abdominal wall pain, wound infection, hernia formation and adhesions. However, many technical barriers hinder its safe translation into full clinical practice. In this chapter, we proposed a Master and Slave Transluminal Endoscopic Robot (MASTER) with 9 degree of freedom (DOF) end effectors which are long and flexible so as to enhance endoscopic procedures and NOTES. The robotic system consists of a master console, microprocessor, actuator housing and slave manipulators. 15 ex vivo Endoscopic Submucosal Dissections (ESD), 5 in vivo ESDs and 2 in vivo NOTES had been performed successfully on porcine models. An Interventional Navigation System (INS) based on electromagnetic tracking and Computer Tomography (CT) imaging was also proposed for NOTES, with which the surgeons could be provided with integrated and informative visualization of peritoneal organs and the surgical instruments from a registered 3D patient-specific model together with the tracked endoscope.

DOI: 10.4018/978-1-61520-977-4.ch002

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INTRODUCTION

Natural Orifice Transluminal Endoscopic Surgery (NOTES) involves the intentional puncture of the viscera of the stomach, rectum or vagina with an endoscope to access the abdominal cavity to perform an intra-abdominal operation (Pearl & Ponsky, 2008). In the abdominal cavity, the internal organ of interest is operated on endoscopically. When the treatment is completed, the endoscope is used to mend back the incision made on the viscera before being removed from the patient's body. There are several significant advantages for using NOTES. It does not require any percutaneous incisions on the abdominal wall, thereby reducing pain and recovery times. NOTES allows the use of minimally invasive techniques to be used on obese patient whose abdominal wall is too thick to perform laparoscopy on. On top of all these, it would not leave an unsightly scar on the abdominal wall (Farritor et al., 2008).

However, for NOTES to be used on human safely, many technical issues need to be addressed. Out of which tooling for fast and safe access and closure of abdominal cavity and spatial orientation during operation are of paramount importance.

Although the endoscope and conventional tools are useful for simple procedures, many important and complicated procedures are currently not possible due to limitation of degree of freedom (DOF) of the end effectors. If an effective tooling platform is developed, more variety of surgical manipulation could be performed with greater ease via NOTES. Loss of spatial orientation is another challenge during transgastic access to abdominal cavity in NOTES. The endoscopist can only see structures of the stomach wall right in front of the endoscope camera. The exact position of the endoscopic tip, its orientation with respect to the puncture site, and relations of other organs adjacent to the stomach, such as liver, cholecyst, colon and etc, cannot be judged intuitively and accurately. These uncertainties during surgery increase the risk for rupturing the normal organ, tissue and major blood vessels. Therefore, a complete solution for supporting spatial orientation for the surgeon during NOTES will enhance its safety and efficiency, and at the same time, reduce its complication and complexity.

Therefore, we proposed to design and develop a multi DOFs, long and flexible robot to enhance NOTES procedures. The robotic system could also be equipped with effective navigation system to obtain the spatial orientation for the endoscopist. In future version, force feedback could further be integrated into the robot system to enable the surgeons to feel the forces at the two robotic arms as though they are directly operating on the patient. The additional DOFs provided by the two robotic arms allow the surgeon to perform complicated actions such as aggressive grasping and cutting. One of the arms can grasp onto a piece of tissue and pull to expose the site while the other arm moves forward to cauterize neatly at the exposed site. With such a system in place, it is able to provide effective tooling as well as providing additional information on the position, orientation and haptic perception of the endoscope.

Clinical Status of NOTES

NOTES is arguable the most significant, innovation in surgery since Phillipe Mouret (Dubois, Icard, Berthelot, & Levard, 1990) performed the first laparoscopic cholecystectomy using video techniques in 1987. This laparoscopic cholecystectomy is the symbol of revolutionized minimally invasive surgical techniques in general surgery. In 2004, Kalloo et al. (2004) first introduced NOTES to the medical community in a study for the feasibility and safety of an oral transgastric endoscopic approach to the peritoneal cavity with long-term survival in a porcine model, beginning a new era for general surgery. And recently, we saw the first pure NOTES transvaginal cholecystectomy without aid of laparoscopic or needleoscopic assistance performed in humans (Gumbs et al., 2009). A great many pathologies in abdomen,

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