The Use of Robotic in GI Surgery

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Background
In the past decade, minimally invasive surgery (MIS) has been proved to be one of the landmark developments in the history of modern surgery. However, its development might be limited by 2-dimensional imaging, unstable camera platform, limited (only 4) instruments’ degrees of freedom, and poor ergonomics. As the complexity of MIS advances, the demand for better instrumentation and surgical platform has also increased. Advancement in technology and mechanical engineering foster the development of robot-assisted MIS in early 1990s.

The Automated Endoscopic System for Optimum Positioning (AESOP; Computer Motion, Inc., Goleta, CA, USA) was the first voice-activated robotic-arm developed for holding and positioning the laparoscopic camera. Investigators had reported the robotic camera holder could perform with less inadvertent camera motion, less frequent camera removal for cleaning or defogging, and could reduce the operating time and outperformed human camera assistant.

Various integrated master-slave telemanipulative robotic systems were then evolved to fulfil the need for more precise, tremor-free surgical operations.

The Zeus robotic system (computer Motion Inc, Goleta, CA, USA) integrates an AESOP unit for laparoscope positioning and two robotic manipulator arms with a surgeon console equipped with manoeuvering handles and a flat viewing monitor.

The da Vinci Surgical System (Intuitive Surgical, Inc., Sunnyvale, CA) is the most technologically advanced robotic surgical platform available for clinical practice. The system comprised of three networked components. The surgeon console, which is located remotely from the operating table; the InSite Vision System that provides 3-dimensional imaging, and the patient cart with 3 to 4 robotic arms that control the endoscope and the other 2 to 3 arms carrying interchangeable EndoWrist® tools. The surgeon seated at the console controls the robotic arms interchangeable instruments by means of the stereoscopic viewer, hand manipulators and foot pedals. The surgeon’s wrist and finger manipulations are transformed, in real-time, to movements of the robotic instruments.

The EndoWrist® instruments are unique in possessing a wrist-like mechanism that allows 7-degrees of freedom, replicating the full range of motion of the surgeon’s hand and in turn eliminating the fulcrum effect observed in conventional laparoscopy. (Figure 2)

Advantages of Robotic Surgery
An ergonomic user interface, co-axial hand-eye alignment, stereoscopic viewer, instruments with seven degrees of freedom, and elimination of fulcrum effect are features of the da Vinci telemannipulator possess to overcome the limitations of conventional laparoscopy. The surgeon working in the console works in a more ergonomic way than in conventional laparoscopy. Precise fingertip control of the fully articulating EndoWrist® instruments allows wrist-like movements that facilitate dissection with...
unparalleled dexterity, precision and control. Computer enhancement provides motion scaling and tremor control that further increases accuracy in control. Complex tasks in a confined space, such as suturing and knot tying can be accomplished with great speed and precision, regardless of individual’s prior level of experience in laparoscopic surgery. Robotic surgery has also the potential to reduce the learning curve for novice surgeons and improve treatment outcomes for some advanced laparoscopic procedures.

**Robotic Gastrointestinal Surgery**

Himpens et al reported the first successful robot-assisted laparoscopic cholecystectomy using a prototype of the da Vinci in 1998. The same group also reported the first telerobotic gastric bypass for morbid obesity, and Nissen fundoplication for gastro-oesophageal reflux in 1999.

Over the ensuing years, robotic surgery has been applied to essentially all types of laparoscopic abdominal procedures. Marescaux et al. reported the safety and feasibility of transcontinental robot-assisted remote telesurgery in 2002.14 Robotic Heller myotomy for achalasia was reported by Melvin et al in 2001.15 The same group also reported RA distal pancreatectomy and splenectomy for the treatment of pancreatic tail neuroendocrine tumour. Ballantyne et al reported their experience of robotic surgery in the management of benign colonic conditions and ventral hernia repair. Young et al then demonstrated the feasibility of robotic left adrenalectomy for an incidentaloma. Hashizume et al successfully performed the first gastric devascularisation and splenectomy for portal hypertension. Various investigator had applied robotic surgery in the treatment of a number of oesophageal, gastric and colonic cancers.

One study by Cadiere et al evaluated the results of 146 robotic gastrointestinal procedures. There was no robot related morbidity and they found robot to be most suitable for intra-abdominal microsurgery or for manipulations in very small space. Giulianotti et al reported their series of 207 robotic abdominal, thoracic, and vascular procedures in a community hospital. The results suggested robotic surgery is feasible and safe for daily clinical practice.

The Academic Robotics Group reported a series of 211 robotic-assisted operations in 2003. There were 69 antireflux procedures, 36 cholecystomies, 26 Heller myotomies, 17 bowel resections, 15 donor nephrectomies, 7 gastric bypasses, 7 splenectomies, 6 adrenalectomies, 3 exploratory laparoscopies, 4 pyloroplasties, 2 gastrojejunostomies, and one distal pancreatectomy, duodenal polypectomy, oesophagectomy, gastric mass resection, and lysis of adhesion. There were 8 (4%) technical complications that caused only delay in the procedure and 9 (4%) medical or surgical complications, including 1 unrelated death.

**Comparative Studies**

A retrospective comparison of laparoscopic cholecystectomy (LC) versus robotic cholecystectomy (RC) was performed for 40 patients. The mean operative time of RC (85 minutes) was similar to conventional LC (65 minutes). The conversion rate was higher with LC than RC (3.5% Vs 1.9%). The mean post-operative stay and morbidity rate were comparable in both groups.

Melvin et al prospectively compared 20 robot-assisted procedures with 20 standard laparoscopic antireflux procedures. Outcomes were similar, but operative times were significantly longer in the robotic group.

In a multi-centred study retrospective comparison was studied for robotic-assisted Heller myotomy (59) versus laparoscopic Heller myotomy (62) in the treatment of oesophageal achalasia. Operative time was significantly shorter for the laparoscopic treatment group in the first half of the experience. However, there was no difference in operative time between the groups in the last 30 cases. Oesophageal perforation was more common in the laparoscopic group (16% versus 0%). No oesophageal perforation was found in the robotic group, even in patients who had previous treatment. At short-term follow-up, relief of dysphagia was equally achieved in both groups.

Delaney CP reported a case controlled study of 6 robotic-assisted colorectal procedures (2 right hemicolectomies, 3 sigmoid colectomies, and 1 Wells rectopexy). Safety and feasibility was demonstrated in the robotic group, but operative times were increased in addition to the expenses incurred with the additional instrumentation.

**Limitations of robotic surgery**

The extremely high cost required for procurement and maintenance of the system is a distinct disadvantage. The current robotic system is heavy and bulky, and the initial set-up is particularly cumbersome for inexperienced team.

Experiments confirmed force feedback plays a significant role in minimally invasive surgery. The loss of haptic sense in the robotic system remains one of the major limitations of the system.

Da Vinci was originally designed for cardiac operation and later adapted for other surgical procedures. Abdominal operations require extreme operating table positions and wider movement of robotic arms could lead to collisions between the elbows of robotic arms as well as that of assistant.
Procedures like instrument exchange, aspiration and irrigation, clips and endoscopic staplers application cannot be performed by the robot. An experienced assistant is often required to carry out essential procedures on the operating table.

Discussion

Robotic surgery represents a growing subset of minimally invasive surgery. The da Vinci transcends the limitations of both open surgery and laparoscopy, expanding the surgeon’s capabilities and offering a minimally invasive option for many complex procedures. Robotic technology is continually improving, and surgeons using these systems continue to find new applications and improve on conventional laparoscopic techniques.

Various authors had demonstrated the feasibility and safety of various robot-assisted laparoscopic gastrointestinal procedures. Prospective randomised studies are needed to evaluate the cost-effectiveness of robotic surgery versus conventional laparoscopic surgery. It remains to be seen whether robot-assisted laparoscopic surgery can further improve the standard of patient care.

References


24. Hashizume and co-workers reported the first RA distal gastrectomy for early gastric cancer.


