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The future of robotic instruments in colon and rectal surgery

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ABSTRACT

Robotic surgery began approximately 30 years ago, growing steadily, and has now become one of the mainstream topics within the surgical literature across multiple surgical disciplines. More recently, robotic use has expanded to colorectal surgery, demonstrating increased usage in the more difficult operations involved. As competition in the marketplace and technology increase and improve, the size and cost of these systems may progressively decrease, and their presence will likely grow. With that, innovative and novel concepts are being introduced at a rapid pace. The enhanced performance gained by the surgeon with these devices will hopefully enable the difficult operations to become more feasible and potentially even safer. We present a brief history of the instruments related to robotic colorectal surgery and discuss some of the robotic instruments that may be seen in a future robotic-enabled operating room.

History

From their inception, robots have been envisioned to extend the capabilities of human beings. Relative to surgery, robotic use helps to extend surgeon's capabilities beyond the limits of conventional laparoscopy. The history of robotics in surgery began with the Programmable Universal Machine for Assembly or PUMA 560, a robot used in 1985 by Kwoh et al.[1] to perform neurosurgical biopsies with greater precision. This system eventually led to the development of PROBOT, a robot designed specifically for transurethral resection of the prostate. While PROBOT was being developed, Integrated Surgical Supplies Ltd. of Sacramento, CA, was developing ROBODOC, a robotic system designed to machine the femur with greater precision in hip replacement surgeries. In fact, ROBODOC was the first surgical robot approved by the FDA.[2] Yet, the profession remained a long way from a model that would be capable of expanding the use in everyday surgical procedures that spanned a wide breadth of surgical disciplines.

The U.S. Army became interested in the possibility of decreasing wartime mortality by “bringing the surgeon to the wounded soldier-through telepresence.”[3] With funding from the U.S. Army, a system was devised whereby a wounded soldier could be loaded into a vehicle with robotic surgical equipment and be operated on remotely by a surgeon at a nearby Mobile Advanced Surgical Hospital (MASH). This system, it was hoped, would decrease wartime mortality by preventing wounded soldiers from exsanguinating before they reached the hospital.[4] To date, this system has been successfully demonstrated on animal models, but has not yet been tested or implemented for actual battlefield casualty care.[5]

Computer Motion Inc. of Santa Barbara, CA, used seed money provided by the Army to develop the Automated Endoscopic System for Optimal Positioning (AESOP), a robotic arm controlled by surgeon voice commands to manipulate an endoscopic camera.[4] Shortly after AESOP was marketed, Integrated Surgical Systems (now Intuitive Surgical Inc., Sunnyvale, CA), licensed the SRI Green Telepresence Surgery system. This system underwent extensive redesign and was reintroduced as the da Vinci® Surgical system by Intuitive Surgical Inc. Intuitive Surgical is not the only player within this growing field. Companies such as SOFAR, Transenterix, and Virtual Incision are systems with robotic instruments that are dramatically changing the landscape of robotics (Table).

Systems and the instruments

Intuitive Surgical is presently the dominant player in robotic surgery, having developed the da Vinci® System. The FDA approved the use of the system 14 years ago for endoscopic procedures and more the 2500 Da Vinci® systems have been installed in over 2000 hospitals around the world.[6] Regarding the instruments themselves, the newest set of tools available are the EndoWrist® instruments (Fig. 1).

Part of the allure of the system is the ability to perform maneuvers that are not possible using traditional laparoscopic

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Table
Surgical instruments discussed and their current status.

Category	Instrument trade name	Company	Status
Dissection instruments	EndoWrist	Intuitive	Available on Xi system
	Alf-X Telelap	SOFAR	Available in Europe
Surgical staplers	Endostapler	Intuitive	Available on Xi System
Single port surgery	Surgibot	Transenterix	In progress/development
	da Vinci SP	Intuitive surgical	Available on Xi at end of 2015
	Virtual Incision Robotic	Virtual Incision	In progress/development

equipment. These instruments bend and rotate far greater than the human wrist. A full range of EndoWrist® instruments are available to the surgeon while operating. The instruments are designed with 7 degrees of motion, with each instrument having a specific surgical mission such as clamping, suturing, and tissue manipulation. EndoWrist® instruments also provide dexterity, precision, and control: in total, 90° of articulation and fingertip control. In addition, retracting instruments allow the surgeon to provide exposure of the surgical field crucial to colorectal surgical procedures deep within the pelvis. This minimizes dependency on the patient-bedside assistant, providing the surgeon using the da Vinci® surgical system full control of the operative field.

The advantages of stapled anastomoses have been well documented.[7–9] Until recently, robotic stapling and anastomoses were performed as they have been for the past 15 years—by using the robotic assistant. However, more recently the da Vinci Si™ and Xi™ Surgical System staplers have been released that allow adaption of the stapling devices to the robotic arms. As such, they are currently the only devices of their type that provide fully wristed articulation and SmartClamp® technology that detects when instrument jaws are adequately closed on target tissue. The design enables control of stapling from the surgeon console. The stapler comes with integrated software that provides feedback to the surgeon regarding tissue compression and a fail-safe mechanism to prevent stapler firing in the event that too much tissue has been included into the stapler jaws (Fig. 2, video supplement 1).[10]

The future

During open surgery, a surgeon can directly palpate tissue, allowing localization of a number of subcutaneous or subserosa lesions based on changes in tissue reaction, palpate organs, distinguish between normal and abnormal tissues, locate lymph nodes, and feel the force needed when tying a good knot. To a certain extent, that force feedback was taken from the surgeon with the advent of laparoscopic surgery, with which skill, the surgeon can interpret through the visualization of the tissue and resistance felt in his/her wrists and not his/her fingers. Robotic surgery completely removed this sense and placed all feedback information on the visual perception of the surgeon. Unfortunately, the lack-of-force perception in robotic surgery has been shown to increase tissue trauma and accidental tissue damage.[11,12] One of the main disadvantages of the da Vinci® system is the high investment and maintenance costs of the system and the lack-of-force feedback. One system has found a way to incorporate force

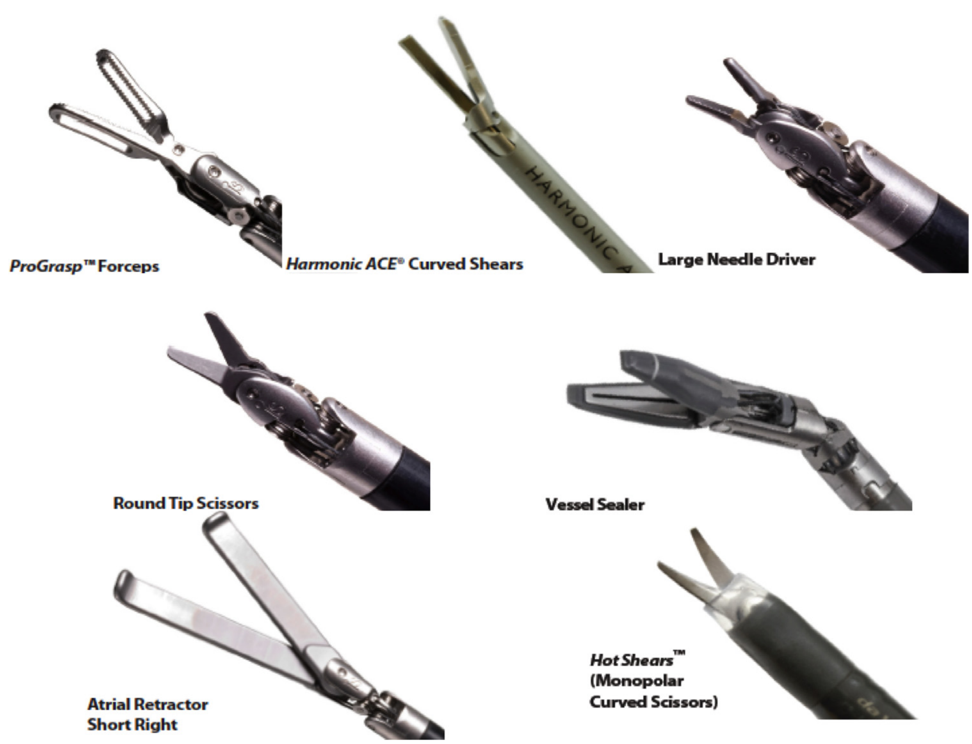

Fig. 1. Endowrist® instruments with the da Vinci Xi Surgical System.