The History of Robotics In Urology

Sutchin R. Patel, MD, and Gyan Pareek, MD

In 1921 the playwright Karel Capek coined the word "robot" in his play, "Rossum's Universal Robots". The word is derived from the Czechoslovakian term "robota" which means forced work. Capek's play dealt with a world in which robots help humans with everyday tasks but eventually turn on their masters.[1] Isaac Asimov wrote numerous science fiction stories on robots and was the first to use the term "robotics." His works centered on robots' interactions with society and inspired many of today's fictional books and movies. However, over the past decades the bridge between science fiction and reality has closed. The first digitally operated and programmable robot, the Unimate, was installed in 1961 to lift hot pieces of metal from a die casting machine and stack them. This was the beginning of the use of robotics in industry. Robots have since been used in manufacturing, assembly, packing, transport, space exploration, laboratory research, weaponry and surgery.

A surgical robot has been defined as "a computer-controlled manipulator with artificial sensing that can be reprogrammed to move and position tools to carry out a range of surgical tasks."[2] The field of urology has become increasingly technology driven and thus has been on the forefront of surgical robotics.

Modern surgical robotic systems can be categorized into off-line (fixed-path) and on-line systems. Off-line systems are automated robots that execute precise movements based on pre-programmed imaging studies obtained before surgery, without active input from the surgeon. These include robots for prostate access such as the ProBot (Imperial College, London), an endoscopic robotic resection device for the prostate and renal access systems such as the PAKY device (Johns Hopkins Medical Institute).[3,4]

On-line robotic systems (also known as master-slave systems) were designed to replicate the surgeon's movements in real time within the operative field. In the 1980s, the National Aeronautics and Space Administration Ames Research Center investigating virtual reality systems collaborated with mechanical engineers at the **Stanford Research Institute (SRI)** interested in robotic technologies to develop a "telepresence" surgical system to improve dexterity in microscopic hand surgery.[5,6]

Leonardo da Vinci... is credited for having drawn and built the world's first robot in 1495.

The focus then shifted from microsurgical to macroscopic general surgical applications, largely driven by the demonstration of laparoscopic cholecystectomy in 1989 by Perissat and colleagues.[7] A revised telepresence system including a surgeon's console and remotely controlled telemanipulators was developed with funding from the US Department of Defense. However, rather than using a laparoscopic approach this system was used initially to perform open surgery and was intended to be a battlefield surgical system for combat casualty care. The concept included a mobile, armored, operating room vehicle equipped with robotic surgical manipulators that were controlled remotely by a surgeon at a rear-area mobile surgical hospital unit.[8] The licensed commercial rights to the SRI Green Teleprescence Surgery Systems were then used to found Intuitive Surgical Systems in 1995. After further development, a renovated master-slave clinical system was released in April 1997 as the da Vinci surgical system. In July 2000 the **Food and Drug Administration (FDA)** approved the da Vinci surgical system. Unlike its predecessor, the da Vinci system was intended solely for laparoscopic surgery as opposed to open surgery.[6]

Intuitive Surgical Systems named its robotic system after Leonardo da Vinci because he is credited for having drawn and built the world's first robot in 1495. Leonardo's robot wore a suit of armor, typical of 15th century German-Italian design. It had a flexible neck and a jaw that could open and close. It could sit up, turn its head, wave its arms and make sounds to the accompaniment of automated drums. The hips, knees and ankles operated with 3 degrees of freedom, while the shoulders, elbows, wrists and hands operated with 4 degrees of freedom. Da Vinci's detailed anatomical drawings allowed him to design pulley systems to emulate the complex joints and muscles of the human body.[9] The range of motion of the wrist presented challenges to robot design but, using da Vinci's principles, engineers were able to construct a suitable model. Although the name da Vinci has become synonymous with the robotic prostatectomy, ironically, in all of his anatomical drawings, Leonardo da Vinci never identified the prostate. This was thought to be due to the fact that his anatomical dissections for the genitourinary system were performed on castrated oxen which would thus have atrophic prostates.[10]

The ROBODOC used to mill out precise fittings in the femur for hip replacements was the first robotic surgical device marketed when it was introduced in 1992 by Integrated Medical Systems.[11] The next commercially available device was the **Automated Endoscopic System for Optimal Positioning (AESOP)** created by Computer Motion. Released in 1993, this intern-replacement robot allowed hands-free automated control of the endoscope. The surgeon interacted with the system using a directional microphone thus using both voice and foot controls. Soon after, Computer Motion released its own master-slave system, the Zeus Surgical System which received FDA approval for limited abdominal operations in October 2001.[12] Building on its original AESOP technology, two-surgeon-controlled robotic telemanipulators were added. In June 2003, Intuitive Surgical and Computer Motion merged to combine their intellectual property and market and support product lines from both former companies.[1,13]

Robotic systems subsequently have been used to perform a number of urologic procedures including radical prostatectomies, nephrectomies, pyeloplasties, cystectomies, adrenalectomies and pelvic floor procedures. Like all technologies there is a tradeoff between the benefits and drawbacks. General limitations include the high costs involved in acquiring the systems and the set-up times involved. Haptic feedback is lacking, thus the surgeon cannot make decisions based on tension and texture and must compensate with visual cues.[1,6] These drawbacks are not static, however, and will decrease as the technology matures. One of the most prominent benefits of robotic surgery is the increased manual dexterity of the instruments along with motion-scaling and tremor-filtering functions. The robotic systems are ideally suited for constrained spaces such as the pelvis for prostatectomies. The optical capabilities including stereoptic vision along with magnification provide a three-dimensional image. Additional benefit is also derived from the ergonomic control stations used to interface these systems leading to decreased fatigue and strain on the surgeon.[1,6]

Endoscopic and laparoscopic surgery are a large part of urology, thus our field lends itself favorably to advances in technology. Though urologists have been quick to harness the potential of this generation of surgical robotics we should also be meticulous in our evaluation of these new technologies. We are still in the early phases of the robot revolution with advances already occurring in flexible robotics, mobile *in vivo* robots, advances in endoscopic navigation and in haptic feedback and remote robotic surgery.[14] We expect to see exciting developments as technology evolves to suit our surgical needs.

References

1. Murphy D, Challacombe, et. al. Robotic technology in urology. *Postgrad Med J* 2006;82:743-747
2. Dasgupta P, Jones A, Gill IS. Robotic urologic surgery. *BJU Int* 2005;95:20-3.
3. Davies BL, Hibberd RD, et. al. The development of a surgeon robot for prostatectomies. *Proc Inst Mech Eng* 1991;204:35-8.
4. Cadeddu JA, Bzostek A, Schreiner S. A robotic system for percutaneous renal access. *J Urol* 1997;159:1589-93.
5. Hill JW, Holst PA, et. al. Teleprescence interface with applications to microsurgery and surgical simulation. *Stud Health Technol Inform* 1998; 50:96-102.
6. Nguyen MM, Das S. The evolution of robotic urologic surgery. *Urol Clin N Am* 2004; 31:653-8
7. Perissat J, Collet DR, Belliard R. Gallstones:laprascopic treatment, intracorporeal lithotripsy followed by cholecystostomy or cholecystectomy—a personal technique. *Endoscopy* 1989; 21(Suppl 1):373-4.
8. Bowersox JC, Cordts PR, LaPorta AJ. Use of an intuitive telemanipulator system for remote trauma surgery. *J Am Coll Surg* 1998;186:615
9. Moran M. Epochs in endourology. *J Endourol* 2006;20:986-90.
10. Schultheiss D, Laurenza B, et. al. The Weimar anatomical sheet of Leonardo da Vinci (1452-1519). *BJU Int* 1999;84:595-600.
11. Paul HA, Bargar WL, Mittlestadt B. Development of a surgical robot for cementless total hip arthroplasty. *Clin Orthop* 1992;285:57-66.
12. Marescaux J, Leroy J, et. al. Transatlantic robot-assisted telesurgery. *Nature* 2001;413:379-380.
13. Atug F, Castle EP, et. al. Robotics in urologic surgery. *Int J Urol* 2006;13:857-863
14. Tan GY, Goel RK, et. al. Technological advances in robotic-assisted laprascopic surgery. *Urol Clin N Am* 2009;36:237-249.

Sutchin R. Patel, MD, is a Resident in Urology, The Warren Alpert Medical School of Brown University.

Gyan Pareek, MD, is Director of the Section of Minimally Invasive Urologic Surgery, Assistant Professor of Surgery (Urology), The Warren Alpert Medical School of Brown University.

Disclosure of Financial Interests

The authors have no financial interests to disclose.

Correspondence

Gyan Pareek, MD
Division of Urology
2 Dudley Street, Suite 185
Providence RI, 02905
Phone: (401) 444- 8570
e-mail: Gyan_pareek@brown.edu