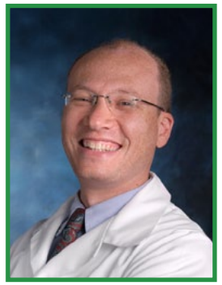
Robotic Surgery



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Background

Robots, taken from the Czech word robota, meaning forced labor, are in full evolution. Although today's robots are still unintelligent machines, great strides have been made in expanding their utility. Today, robots are used to perform highly specific, highly precise, and dangerous tasks in industry and research previously not possible with a human work force. Robots are routinely used to manufacture microprocessors used in computers, explore the deep sea, and work in hazardous environment to name a few. Robotics, however, has been slow to enter the field of medicine.

The current generation of robotic surgical systems started out as a research project by the US Army investigating the possibility of decreasing wartime mortality by "bringing the surgeon to the wounded soldier—through telepresence." With funding from the US 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). Several of the surgeons and engineers working on surgical robotic systems for the Army eventually formed commercial ventures that lead to the introduction of robotics to the civilian surgical community.

Ever since minimally invasive surgery began in 1987 with the first laparoscopic cholecystectomy, the list of procedures performed laparoscopically has grown at a pace consistent with improvements in technology and the technical skill of surgeons. The advantages of minimally invasive surgery are very popular among surgeons and patients. Incisions are smaller, the risk of infection is less, hospital stays are shorter, if necessary at all, and convalescence is significantly reduced. Many studies have shown that laparoscopic procedures result in decreased hospital stays, a quicker return to the workforce, decreased pain, better cosmesis, and better postoperative immune function.

Despite its attractiveness, minimally invasive surgery suffers from several limitations. Some of the more prominent limitations involve the technical and mechanical nature of the equipment. Inherent in current laparoscopic equipment is a loss of haptic feedback (force and tactile), natural hand-eye coordination, and dexterity. Current instruments have restricted degrees of motion; most have 4 degrees of motion, whereas the human wrist and hand have 7 degrees of motion. There is also a decreased sense of touch that makes tissue manipulation more heavily dependent on visualization. Finally, physiologic tremors in the surgeon are readily transmitted through the length of rigid instruments. These limitations make more delicate dissections and anastomoses difficult if not impossible. The motivation to develop surgical robots is rooted in the desire to overcome the limitations of current laparoscopic technologies and to expand the benefits of minimally invasive surgery.

Today, the lack of crossover between industrial robotics and medicine, particularly surgery, is at an end. Surgical robots have entered the field in force. Robotic telesurgical machines have already been used to perform transcontinental cholecystectomy. From their inception, surgical robots have been envisioned to extend the capabilities of human surgeons beyond the limits of conventional laparoscopy. Although there are many commercial robotic systems being developed, the main one on the market worldwide is the Da Vinci robotic surgical system.

Description of Da Vinci robotic surgical system

The *da Vinci* Surgical System consists of several key components: a surgeon console where the surgeon sits used to control the robotic arms and instruments remotely, a patient-side cart which displays essential information, four interactive robotic arms with surgical wristed instruments and a high-definition 3D vision system.

The surgeon sits at the console and operates the arms of the robot while viewing a high definition, 3D image inside the patient's body. The system translates the surgeon's hand, wrist and finger movements into precise, real-time movements of surgical instruments. The patient-side cart includes four robotic arms that carry out the surgeon's commands. The precision and surgical ability of the surgeon is further increased by the fully wristed instruments which offer 7 degrees of motion allowing for precise movements and suturing that mimic the surgeons' natural movements in open surgery to be done in a very precise manner and in a very narrow space.

Advantages and disadvantages of robotic surgical systems

The robotic surgical systems are designed to offset the classical disadvantages of laparoscopic surgery while maintaining its benefits. They enhance dexterity by providing instruments with increased degrees and eliminate surgeons' tremor through appropriate hardware and software filters. In addition, these systems can scale movements so that large movements of the control grips can be transformed into micro-motions inside the patient.

Another important advantage is the restoration of proper hand-eye coordination and an ergonomic position. With the surgeon sitting at a remote, ergonomically designed workstation, current systems also eliminate the need to twist and turn in awkward positions to move the instruments and visualize the monitor.

The enhanced vision afforded by these systems is remarkable. The 3-dimensional view with depth perception is a marked improvement over the conventional laparoscopic camera views. Also to one's advantage is the surgeon's ability to directly control a stable visual field with increased magnification and maneuverability. All of this creates images with increased resolution that, combined with the increased degrees of freedom and enhanced dexterity, greatly enhances the surgeon's ability to identify and dissect anatomic structures as well as to construct microanastomoses.

TABLE 1. Advantages and Disadvantages of Conventional Laparoscopic Surgery Versus Robot-Assisted Surgery

	Conventional Laparoscopic surgery	Robot-assisted surgery
Advantages	Well-developed technology	3-D visualization
	Affordable and ubiquitous	Improved dexterity
	Proven efficacy	Seven degrees of freedom
		Elimination of fulcrum effect
		Elimination of physiologic tremors
		Ability to scale motions
		Micro-anastomoses possible
		Tele-surgery
		Ergonomic position
Disadvantages	Loss of touch sensation	Absence of touch sensation
	Loss of 3-D visualization	Very expensive
	Compromised dexterity	High start-up cost
	Limited degrees of motion	May require extra staff to operate
	The fulcrum effect	New technology
	Amplification of physiologic tremors	Unproven benefit

Despite the above listed benefits, current robotic surgical systems are not without fault. First of all, robotic surgery is a new technology and its uses and efficacy have not yet been fully established and is currently the subject of intense scrutiny and research. The systems are expensive with a price tag of millions of dollars making their cost nearly prohibitive. The systems are large and bulky making them relatively cumbersome to use. This is an important disadvantage in today's already crowded-operating rooms. They also suffer from lack of haptic feedback which means that the surgeons have to rely purely on visual clues and feedback while performing operations. Most of the disadvantages identified will be remedied with time and improvements in technology.

Clinical Applications of Robotic Technology

Robotic technology has found its best application in the field of urology and specifically in the performance of robotic assisted radical prostatectomy. The robotic system is uniquely suited for this type of operation for several reasons. First of all the operation itself is complex and difficult to perform laparoscopically except by surgeons with outstanding laparoscopic abilities. The field is narrow, fixed, and relatively small all of which are ideal indications for the use of a robotic assisted procedure. The robot also greatly facilitates the ability of the surgeon to acquire the needed skills to perform this procedure in a minimally invasive fashion using the robotic platform to assist.

The benefits of the robot use in urologic procedures are well established in the literature. Robotic assisted prostatectomies result in improved perioperative outcomes, such as length of stay, bleeding risk, and transfusion prevalence, but also long-term outcomes with respect to side effects of surgery, such as urinary incontinence and erectile dysfunction. The data for partial nephrectomy are also robust in showing that robotic-assisted laparoscopic surgery decreases length of stay, risk of bleeding, and transfusion risk. In addition, because open nephrectomies require very large incisions and a lot of muscle tissue is cut, anecdotally, most surgeons will agree that patients undergoing robotic-assisted laparoscopic partial nephrectomies will recover faster after surgery. In regard to cystectomy, some advantages have been shown with respect to length of stay, bleeding risk, and transfusion risk and, as with partial nephrectomy, these advantages are probably clinically significant. Patients with bladder cancer tend to be older and sicker, so any advantage that can reduce morbidity in these patients can potentially benefit the patient's recovery.

In the field of general surgery, robotic technology has been applied in bariatric surgery to facilitate the performance of a safe anastomosis, to treat achalasia by improving the dexterity of the surgeon during the Heller myotomy, and in solid organ dissections particularly complex hepatobiliary procedures. In the field of colorectal surgery robotic technology has been shown to be both safe and feasible. It could offer potential advantage in resection of rectal cancer as it has a lower conversion rates even in obese individuals, distal rectal tumours and patients who had preoperative chemoradiotherpy. There is also a trend towards better outcome in anastomotic leak rates, circumferential margin positivity and perseveration of autonomic function.

In the field of gynecological surgery, robotic procedures have also been applied to the benefit of patients. In multiple studies, laparoscopic and robotic assisted laparoscopic myomectomies demonstrated shorter hospital stays, less blood loss, and fewer transfusions than abdominal myomectomies. Robotic surgery enables minimally invasive surgery for a larger proportion of patients with malignant and select benign gynecological disorders with low rates of conversions and intraoperative complications. In addition to the above named applications, robotic technology has been used in the field of cardiac surgery to allow the performance of complex revascularization procedures using the beating heart technology when the robot is synced to the patient's electrical rhythm to allow for placement of the sutures. It is also now being progressively applied in the field of otolaryngology by extending the ability of the surgeons to perform tests oral robotic assisted surgery on the larynx the oropharynx and the base of the tongue.

The Multidisciplinary Robotic Surgery Program at AUBMC

In keeping with AUBMC 's mission of improving the health of the community in Lebanon and the region through the delivery of exceptional and comprehensive quality care to our patients, AUBMC is proud to have introduced one of the first surgical robotic systems to Lebanon. In July of 2013, the da Vinci SI dual console state of the art robotic system was installed and the first procedure performed successfully. Since that time we have successfully completed no less than 20 robotic procedures in the specialties of urology, gynecology and general surgery with an excellent outcome and safety record.

The robot was purchased to ensure that AUBMC remains at the forefront of technology in Lebanon and the region. Because of our mission as an academic medical center, we went through a long process of preparation before the initiation of this multidisciplinary robotic surgery program. We defined the training that is needed for every surgeon to acquire the robotic skills, identified competency based objectives and set up a regular and ongoing monitoring process to ensure good selection of cases and excellent outcomes. More importantly we decided to approach robotic surgery as a team approach. Because of this AUBMC has purchased and deployed the dual console SI system. This system is unique in that it has two operating consoles which can be used simultaneously by two surgeons to perform the surgical robotic assisted procedure. This is essential in order to allow for training of faculty and residents, as well as to allow for proctoring of complex cases. We have also made in the requirement that all robotic surgical cases performed at AUBMC are to be performed by a team consisting of a minimum of two surgeons in order to ensure proper selection of cases and excellent outcomes.

In keeping also with our education and training mission, AUBMC has purchased the robotic simulator as well. This simulator is installed on one of the consoles and allows surgeons and residents in training to perform simulator robotic tasks to acquire expertise, refine skills and shorten the learning curve in acquiring and learning how to perform complex robotic procedures.

Conclusion

Robotic surgical systems have entered the operating room in full force. The use of robotic systems seems to be capable of addressing most of the shortcomings of the standard laparoscopic surgery. They also hold the promise of allowing more surgeons to perform more complex operations in a minimally invasive manner. If appropriately managed, the utilization of robotic services by trained multi-specialty teams may enhance patient care, lead to improved outcomes and reduced length of stay.
The future of robotic surgical systems is bright, keeping in mind that robotic systems are very much linked to modern computer technology. With computers rapidly expanding in terms of their capabilities, the robot follows right along. Its potential is unlimited. It's only bound by imagination and the limitations of computer processing. Laparoscopy has completed its evolution; innovation in that technology is pretty much done. The future of innovation lies with the robotic surgical systems.