FEATURE ARTICLE

Robotic Surgery

How are we training future operators?

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BACKGROUND

Since 1921 when Czech playwright Karel Capek introduced the notion of and coined the term “robot” in his play *Rossum’s Universal Robots*, robots have taken on increasing importance in society in sectors from industry to military and now, medicine.¹ First introduced in 2000 by Binder and Kramer, robotic surgery has revolutionized the field of minimally invasive surgery and has been rapidly adopted for various procedures.² Perhaps the most renowned surgical robot nowadays is the da Vinci Surgical System (dVSS) (Intuitive Surgical, Inc.).

Urologists, cardiac surgeons and general surgeons have swiftly adopted this technology and have been instrumental in its growth. Today, robotic-assisted laparoscopic radical prostatectomy (RALRP) is the most commonly performed robotic procedure worldwide. In 2002, only 766 RALRPs were performed in the United States. By 2007, this number had swelled to 48 000, and represented 68% of all radical prostatectomies.^{3,4} Other urological procedures performed with robotic assistance include pyeloplasty, nephrectomy, radical cystectomy and urinary diversion.⁴ Cardiac surgeons further refined this technology. Mohr et al used dVSS to perform CABG on 131 patients and mitral valve repair on 17 patients, and discovered that robotic systems could be used safely in select patients to perform endoscopic cardiac surgery.⁵ Gynecology and general surgery have also adopted this system for certain procedures including hysterectomy, myomectomy, sacro-colpopexy, Roux-en-Y gastric bypass and Nissen fundoplication.³

Despite the growing popularity of this technology, education of residents and fellows has not kept pace with this new era of surgery. Duchene et al conducted a survey of urology residents training in laparoscopic and robotic surgery. They determined that robotic procedures were being performed at 54% of respondent hospitals and residents were involved in the majority of these cases, but only 38% of residents considered their expertise satisfactory.⁶ A more recent survey of obstetrics and gynecology residents showed that 79% of them felt robotics training should be included in their residency program and 69% felt that their training was inadequate.⁷ The Dutch Healthcare Inspectorate has also published a report stating that 50% of the hospital lacked a standardized method for assessing surgeons’ competence before allowing them to operate with robotics.⁸ In an attempt to address these shortcomings, this article highlights the challenges of establishing a robotics training program and the need for a standardized training curriculum.

ROBOTIC SURGICAL SYSTEM

Figure 1 depicts the four components of dVSS, which consists of surgeon console, patient-side cart, EndoWrist instruments, and vision system. The console allows the surgeon to manipulate the robotic arms. The patient-side cart is where the patient and robotic arms are positioned. EndoWrist instruments are a set of specialized

Figure 1. The da Vinci Surgical System. From left to right: surgeon console, vision system, patient-side cart and EndoWrist instruments.⁹ Image ©[2013] Intuitive Surgical, Inc.

tools that allows for clamping, suturing and tissue manipulation. The vision system provides the entire OR team with the live feed of the operating field.⁹

The surgeons see a 3-D image of the surgical field through an integrated stereoscopic viewer attached to the console. The image shows the intraoperative area and the surgical instruments at the ends of the robotic arms. The surgeon controls the arms with a joystick and pedals. The movement of the surgeon’s hands are transmitted electronically and reproduced by the robotic arms. These arms have joints that allow free movement comparable to that of human arms and hands. They also filter physiologic tremors, which allows for more stable arm motions. Since the robotic arms mimic the movements of the surgeon, the experience, proficiency and judgment of the surgeon influence the surgical results.¹⁰ Nonetheless, when operated by a skilled user, it can yield tremendous benefits. **Table 1** highlights its notable advantages and disadvantages.

ADVANTAGES	DISADVANTAGES
Minimally invasive	Long set-up time
Fewer complications	Limited console time for training
Better postoperative quality-of-life	No tactile feedback
Shorter recovery period	Expensive capital and running costs
3-D visualization	Long and steep learning curve
Tele-surgery	Trainer cannot teach trainees using the system
Improved dexterity and freedom of motion	
Better ergonomics	
Filtering of tremors	

Table 1. Advantages and disadvantages of robotic surgery.¹

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CHALLENGES

The cost of robotic surgery can be a huge impediment to establishing a robotics surgery program. This cost includes that of the robot, annual maintenance, disposable surgical instruments, operating room time, medication, hospitalization and health professionals. With a purchase price of \$1.2 million and an annual maintenance fee of \$100 000, the dVSS poses a significant financial challenge for many hospitals. Furthermore, Steinberg et al estimate that it would cost an additional \$217 000 to train a single resident to proficiency.¹²

More problematic is the steep learning curve associated with the dVSS. Menon et al reported an initial operation time of 360 min for RALRP.¹¹ Similarly, it has been demonstrated that an average of 74 cases are required to achieve competency.¹² Heightened expectations from patients and medico-legal implications, as well as demands from hospital administrators to maximize results, mean that there is a limited opportunity for residents to train with the system.¹³ Even more significant is the lack of any standardized competence-based training curriculum, which has been consistently underlined in successive literature.^{14,15}

THE NEW TRAINING CURRICULUM

Guzzo et al and Shah et al proposed three essential phases in a structured robotics training program: preclinical phase, bedside assistant phase and operative console phase. During the preclinical phase, trainees receive information training delivered through didactics, videos and live surgeries. They also receive hands-on experience through inanimate teaching modules, cadaver dissection and animal laboratories. In the bedside assistant phase, the trainees function as co-surgeons, learning more advanced skills such as trochar and robot placement, instrumentation and troubleshooting. In the console phase, the trainees begin performing parts of the robotic procedures. They will be introduced to cases of increasing difficulty and evaluated objectively along the way. Live feedback will be provided to facilitate immediate skill enhancement.^{16,17}

Simulation technology has been developed to address problems relating to cost and exposure time. Several virtual reality (VR) simulators for dVSS have been marketed. These include ProMIS (CAE Healthcare), SEP-Robot (SimSurgery AS) and dV-Trainer (Mimic Technologies).¹⁸ Each of these simulators is comprised of a master console with finger cuff telemanipulators and a binocular 3-D visual output. Simulation exercises include EndoWrist manipulation, cameral control, object transfer, needle targeting, etc. The VR simulators allow for deliberate practice in a safe and controlled environment. Additionally, they allow for real-time assessment of trainee skill.⁸ A systematic review demonstrated that VR simulators are effective training tools for junior trainees and can be used as adjuncts to traditional training methods.⁴ Multiple studies have also demonstrated face, content and construct validity for this hardware.¹⁸

The concept of mastery learning has also garnered considerable attention in recent years for simulation-based training. Mastery learning is an extreme form of competency-based education and requires learners to acquire the clinical knowledge and skill to a degree measured against fixed proficiency standards.¹⁹ In mastery learning, the educational results are uniform with varying educational time. This is in contrast to the current educational paradigm

where students are given limited hours of lecture or practice time and assessed at the end, resulting in varying performance. The efficacy of this approach has been demonstrated for simulation-based central venous catheter insertion and advanced cardiac life support trainings.^{20,21} Residents trained with a mastery learning approach improved their skills compared to those trained with more traditional methods. It is possible to integrate this training paradigm with da Vinci simulators to address shortfalls in robotic surgery training and establish a competency-based training curriculum.

CONCLUSION

With the rapid proliferation of robotic surgery in various specialties, there needs to be a standardized competence-based training curriculum for trainees. While there are foreseeable challenges, technologies and training paradigms are also evolving concurrently. With increasing quality of VR simulators and growing evidence supporting mastery learning, applications of robotic surgery will surely expand in the next decade and beyond.

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