Ultrasound Opens New Doors in Robotic Surgery

Since its introduction more than a decade ago, robotic-assisted surgery has stood out as a game-changer. The robotic console provides a robust platform to enable minimally invasive procedures in urologic, cardiothoracic, gynecologic and general surgical procedures. Today, robotic surgery is witnessing an evolution. The most recent surgical ultrasound systems, specifically Analogic Corporation’s BK Medical Ultrasound Systems Advanced Robotic Technology (ART), are ushering in a new level of precision and diagnostic confidence. Intraoperative robotic-assisted ultrasound helps surgeons to perform more complex procedures robotically with potentially improved outcomes, particularly in radical prostatectomy and partial nephrectomy.

Robotic consoles have experienced tremendous growth. Intuitive Surgery, the undisputed leader in the field, launched its da Vinci Surgical System in 1999, and received FDA clearance for general laparoscopic surgery in 2000. By 2003, the company had installed 210 systems. Throughout the decade, the FDA cleared the platform for additional procedures, including thoracoscopic surgery, cardiac procedures, urologic, gynecologic, pediatric and transoral otolaryngology procedures. Today, the installed base has reached nearly 2,000 da Vinci Surgical Systems.

Indeed, the surgical robot has become a fixture in operating rooms across the country. Pioneers like New York University (NYU) Robotic Surgery Center in New York City have paved the way. And as regional and mid-sized hospitals have entered the field, early adopters have expanded their repertoire and infrastructure. Today, NYU is home to three da Vinci Surgical Systems.

“Robotic surgery is a minimally invasive surgical technique like laparoscopy in that the surgeon places...
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Intraoperative ultrasound images from BK Medical’s Flex Focus 700 system help surgeons identify key landmarks during robotic-assisted radical prostatectomies.

“...instruments and cameras through four or five ¼-inch incisions in the abdomen,” says Michael Stifelman, MD, director of robotic surgery at NYU Langone Medical Center. However, there are critical differences between laparoscopic surgery and robotic-assisted surgery. “With standard laparoscopy, the surgeon does not have a lot of dexterity or fine motor control.” For example, it can be difficult for surgeons to suture in these conditions.

Consequently, laparoscopic procedures had been limited to gross procedures. Surgeons would resort to a conventional open incision for delicate procedures, or those requiring reconstruction or gentle tissue handling. However, the advent of robotic consoles changed the paradigm.

The console’s slender robotic arms return fine motor control to the surgeon and allow him or her to complete more complicated procedures in a minimally invasive environment.

Imaging in evolution

Just as imaging is critical to conventional surgical procedures, it also plays an essential role in robotic-assisted surgery. One of the first-generation solutions is the laparoscopic ultrasound transducer. First-generation probe technology relied on a sonographer or assistant to control the probe.

“The surgeon needs ultrasound for these procedures. Intraoperative ultrasound technology is an exciting new device in the armamentarium of tools available to the urologist,” says Ashok K. Hemal, MD, director of the robotic and minimally invasive surgery program at Wake Forest Baptist Medical Center in Winston-Salem, N.C.

James Porter, MD, medical director of robot-assisted surgery at Swedish Medical Center in Seattle, explains, “A laparoscopic surgeon has to adapt when he or she starts performing robotic procedures. [In the first-generation model], the surgeon is no longer at the bedside and has to depend on the bedside assistant to perform ultrasound.”

It was a bit of a delicate dance that hinged on close communication. The surgeon directed the assistant to maneuver the probe through the incision. With each move, the surgeon assessed positioning of the probe and re-directed the assistant as needed. “It was a bit like watching a tennis match,” says Stifelman. The surgeon would stare at the probe on one screen and then shift to review the imaging data on another screen. “It was cumbersome.”

In March 2011, Analogic introduced a new, leading edge paradigm. The Advanced Robotic Technology solution returns control to the surgeon thanks to intraoperative robotic-assisted ultrasound. ART is comprised of several components: BK Medical’s Flex Focus 700 ultrasound imaging system, its ProART transducer, its 3DART transducer and its RST Robotic Stationary Transducer Arm. Analogic also expanded and improved surgeons’ options with the Flex Focus 800 with Quantum Technology. The premium performance system is ideally suited for robotic surgery. Quantum Technology provides improved contrast resolution, new grayscale maps and image pre-sets, making it easier and quicker to obtain the highest quality images. Its Vector Flow Imaging (VFI®) mode enables angle independent visualization of blood flow, and an advanced color Doppler mode enhances spatial resolution.

In addition to returning the probe, and its control, to the surgeon, BK Medical’s ART system provides enhanced probe flexibility. “The [first-generation] flexible probe is a nice instrument, but the user is entering [the body] through a fixed port and not always...
able to gain the optimal angles on the kidney or tumor,” says Porter. These instruments were limited to four degrees of flexion: up, down, right and left.

“With the robotically-controlled probe, the surgeon gains angles because of the wristed capability of the robotic instrument,” Porter explains. The transducer is on a wire that can be dropped in at any angle the surgeon needs.

The advanced capabilities of the ProART transducer are ideally suited for the anatomic contours that surgeons must contend with. “The kidney is a complex 3D structure that does not follow geometrical rules. I can position the drop-in probe at any angle in the kidney to obtain the image I need,” says Monish Aron, MD, co-director of robotic surgery and advanced laparoscopy at University of Southern California (USC) in Los Angeles.

**Early apps**

Radical prostatectomy surgery is a prime robotic procedure, with more than 75 percent of prostate surgeries performed with robotic assistance. The goal of radical prostatectomy is to remove the cancerous prostate, spare the sphincteric mechanism for control of urine and preserve the neurovascular bundles, which helps in recovery and preservation of sexual function after surgery, says Hemal.

“At our center, we are using BK ultrasound probe intracorporally through one of the ports to delineate the neurovascular bundles. The neurovascular bundles, which are rich in blood vessels, nerves and adipose tissue and a conglomerate of these tissue structures, serve as an imaging landmark during intracorporeal ultrasound to locate and spare these structures during surgery,” explains Hemal.

Ultrasound plays a critical role in the identification of key landmarks, particularly areas of the prostate that are not clear or with indistinct margins. “There is no clear plane of dissection on the bladder neck while we are dissecting the prostate. It is often difficult for novice surgeons, and even experienced surgeons, to find these planes,” says Vipul Patel, MD, medical director of the Global Robotic Institute at Florida Hospital in Orlando. “Ultrasound allows the surgeon to visualize the plane in real-time.”

Another problem area in prostate procedures is the apex of the prostate; the apex often is distal and under the pubic bone, which may be impossible to see. However, ultrasound provides the surgeon with an image of the tip of the prostate.

The implications for patients are significant. “Visualization of the apex reduces the risk of a miscalculation and allows a cleaner dissection. The surgeon has to know where the organ starts and ends, because the dissection affects tumor margins, continence and sexual function,” says Patel. Other relatively indistinct areas in the prostate where ultrasound lends guidance for dissection are the femoral vesicle and posterior rectum.

Another plus for patients may be shorter procedures times. “We see very clearly that our trainee surgeons are able to dissect the area faster with ultrasound. They know what the anatomy looks like and where the endpoint is. They can perform faster because they know where they are going; they don’t have to dissect and see where they are and dissect again,” says Patel. In fact, he and his colleagues have observed that bladder neck dissection times may be halved under ultrasound guidance. Total procedure times, which can extend to four to six hours for inexperienced surgeons, are “much faster” with ultrasound guidance, says Patel. He credits the improved surgical turnaround times to ultrasound guidance, which provides the ability to image in real-time and enables surgeons to visualize the anatomy.

Although researchers are just beginning to complete studies to address the impact of intraoperative ultrasound in robotic-assisted radical prostatectomy, the data on the robotic procedure are impressive. According to a study led by Patel and published September 2010, in the British Journal of Urology International, 91 percent of 404 men undergoing the procedure had achieved postoperative continence and potency with no evidence of recurrence at 18 months—with the majority of these achieving the outcomes by six months after surgery.

And as urologic surgeons have mastered intraoperative ultrasound in robotic-assisted prostatectomy, they are able to apply their newly honed skills in other procedures, such as robotic-assisted partial nephrectomy.
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This technology allows us better outcomes, and allows us to tackle more difficult, complex lesions that we would not have considered for a minimally invasive approach in the past.

Michael Stifelman, MD, Director, Robotic Surgery, NYU Langone Medical Center, New York City

Key in kidney care
Partial nephrectomy exemplifies the timeline and impact of the robotic-assisted surgical revolution. Standard laparoscopy may be viewed as the predecessor. The near-microscopic incisions replaced some conventional open procedures and presented a new model, shortening procedure and recovery time. However, there are limits to the surgeon’s ability to perform within the constraints of several minute incisions. Consequently, applications were limited to basic procedures.

Enter first-generation robotic-assisted surgery, which enabled surgeons to regain some dexterity and fine motor control. The slender robotic arms hold instruments, cameras and ultrasound probes and are controlled by the surgeon’s hands. Intraoperative images are ported to the robotic console. Once again, the surgical repertoire expanded to more complex procedures, including partial nephrectomy.

The data began to demonstrate the superiority of the model. In the September 2009 issue of The Journal of Urology, Stifelman and colleagues published a study demonstrating that robotic-assisted partial nephrectomy is as effective as laparoscopy in removing lesions, and also results in less blood loss and a shorter warm ischemia time. The robotic-assisted procedure also was associated with a shorter hospital stay than laparoscopic surgery.

The average length of stay for 102 robotic-assisted partial nephrectomies at NYU was 2.47 days.

However, there was room for improvement. "Proprioception has been an important part of the surgeon’s toolkit. If the surgeon is working on an organ, he or she can palpate the area with a finger to determine where the artery is. One of the challenges with robotics is that the surgeon no longer feels the tissue," says Stifelman. Much like the robotic arms allow surgeons to compensate for the reduced dexterity associated with operating through minute incisions, ultrasound enables surgeons to compensate for the lack of proprioception.

"Ultrasound overcomes this challenge and augments what the surgeon can do robotically," says Stifelman. The surgeon can bring the ultrasound probe into the abdomen any time there is difficulty palpating an organ. In addition to providing clearer visualization and guidance via Doppler imaging, ultrasound also compensates for the loss of proprioception by allowing the surgeon to hear the vessels.

Robotic-assisted partial nephrectomy illustrates these advantages. In fact, in 2010, NYU switched from laparoscopic partial nephrectomies to robotic-assisted procedures. Comparing 120 cases in each group, Stifelman and his team found the robotic procedure was associated with:

- Less blood loss;
- Shorter length of stay; and
- An average 33 percent reduction in the warm ischemia time.
This probe brings major advantages in that the surgeon no longer relies on an assistant for ultrasound imaging. Imaging capability and flexibility are improved. If an organization is serious and planning on a high volume of robotic-assisted surgery, investing in this technology is the right move."

James Porter, MD, Medical Director, Robot-assisted Surgery, Swedish Medical Center, Seattle
and embolize distally thereby blocking blood supply to the entire kidney. The surgeon might be completing a partial nephrectomy and reconstructing the kidney, but unbeknownst to him or her, by virtue of the plaque rupture, the entire kidney may be dying.” Intraoperative ultrasound after the partial nephrectomy is complete can be very useful to assess blood flow in the remnant kidney and can assuage any doubts about the perfusion of the remaining kidney.

Another smaller patient subset that can benefit from the enhanced visualization afforded by the system is patients who have undergone previous kidney surgeries. “They tend to have lots of adhesions around the renal hilum and it can be difficult to dissect out the vessels if there is dense fibrous scar tissue around them,” says Aron. The surgeon can place the probe on the vena cava, or aorta, and move it laterally toward the kidney to image the renal artery and help direct the surgical dissection appropriately.

Hemal also has leveraged BK technology infrequently in patients undergoing robotic pyelolithotomy to identify and remove secondary kidney stones. Without ultrasound, the surgeon’s imaging toolkit would be limited to pre-operative CT or MR imaging, which cannot be used intracorporeally during surgery.

Peering into the future

Robotic-assisted surgery has experienced a decade of dramatic growth, which is poised to continue and accelerate in the coming years. “BK ProART technology is going to expand into other areas of surgery for a number of reasons. The technology is intuitive and easy to use. It produces clearer images and provides accurate 3D reconstructions,” predicts Patel, who offers that gynecological procedures such as myomectomy may be a future application, as ultrasound can help surgeons localize myomas.

Stifelman agrees that ProART technology will penetrate into other areas of surgery as robotics moves further into the mainstream. “Sites need to understand the question that needs to be answered by the technology,” he says. For example, in gynecological procedures, surgeons need to accurately identify the ureters because they are at risk of being injured during surgeries. “It’s a need that ultrasound could answer.”

Ultrasound is likely to migrate to robotic-assisted surgery in other specialties, including cardiac surgery, pancreatic surgery and general surgery, Stifelman predicts.

Porter points to other pluses of the BK ProART system. “The probe brings major advantages in that the surgeon no longer relies on an assistant for ultrasound imaging. Imaging capability and flexibility are improved. If an organization is serious and planning on a high volume of robotic-assisted surgery, investing in this technology is the right move.”

Medicine occasionally hosts a perfect marriage of technologies, where the combined benefits to the patient and physician are crystal clear. BK Medical’s ART technology, coupled with robotic consoles, exemplifies this type of union and provides a sound platform today and for the future.

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