



News & Highlights

Surgeons Embrace Future with Dr. Robot

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If you need surgery anytime soon, there is an increasing likelihood your surgeon will be assisted by a robot. For many urological procedures, such as prostatectomies for prostate cancer, robot-assisted surgery is now the standard-of-care, said Benjamin Chung, a urologist and director of robot surgery at Stanford University in Palo Alto, CA, USA. Chung estimates that as many as 90% of prostatectomies in the United States are performed with robotic assistance [1]; this fraction surpasses 60% for partial nephrectomies, and 27% for radical nephrectomies [2,3]. “Over the last 20 years, it has progressively become more and more common,” said urologist Andrew Hung, director of robotic simulation and education at the University of Southern California in Los Angeles.

While its adoption has been particularly strong in urology and gynecology, robotic surgery is also making inroads in other surgical sub-specialties. According to the global consulting firm Frost & Sullivan, while only 5%–10% of all open surgical procedures involved robot assistance in 2016, the devices have the potential to penetrate as much as 50% of all surgical procedures [4]. Another recent market intelligence report estimates the size of the global surgical robotics market at \$4.71 billion USD in 2018 and projects it to surpass \$15.43 billion USD by 2029 [5].

Today’s robotic surgery market is dominated by the company Intuitive Surgical in Sunnyvale, CA, USA, whose “da Vinci” robotic surgery system is synonymous with robotic surgery and first received US Food and Drug Administration approval for general laparoscopic surgery in 2000. While initially met by a skeptical surgical community, the da Vinci has now been used to perform more than six million surgeries, with thousands of the systems installed in hospitals around the world [6]. In China, there are at least 102 systems in 84 hospitals [7].

The da Vinci is a complex, general-purpose system (Fig. 1). With surgeons at the controls, it robotically performs laparoscopies, minimally invasive surgeries that use specialized surgical tools and a laparoscope, a slender, fiber-optic probe with a tiny video camera and light on the end, inserted through small incisions in the body. In a traditional laparoscopic procedure, surgeons operate these specialized instruments by hand, visualizing the surgical field through the laparoscope. With the da Vinci, however, the surgical tools are fixed to the ends of three of its four robotic arms, with the laparoscope on the fourth arm. Instead of standing at the operating table, surgeons guide the procedure—sometimes in a room separate from the operating room—sitting at a console that displays a computer-generated three-dimensional image on a

high-definition screen. Sitting at a console means less fatigue, said urologist Benjamin Chung, director of robot surgery at Stanford University in Palo Alto, CA, USA.

But perhaps the robot’s best assets are its maneuverable arms, whose tips can precisely bend, swivel, and rotate. The advantage of robotic surgery is the high level of control it provides, making it easier for more surgeons to perform complex laparoscopic procedures, said Hung. “It enables them to do these complex surgeries that maybe ten years ago or more, only the very talented, pure laparoscopic surgeons could do.” The da Vinci is particularly well suited for procedures like prostatectomies, hysterectomies, and nephrectomies because they involve a relatively small area—so the robot does not have to move around much—and demand a lot of suturing, which the robot is good at, Chung said.

Still, the benefits of robotic surgery are not without costs. A single da Vinci system can cost as much as \$2 million USD, and one recent analysis put the minimum per procedure cost for hospitals at \$3568 USD [8]. The expense is partly due to Intuitive Surgical’s almost 20-year virtual monopoly of the market and is anticipated to drop with new entries to the market. Both the lure of a burgeoning

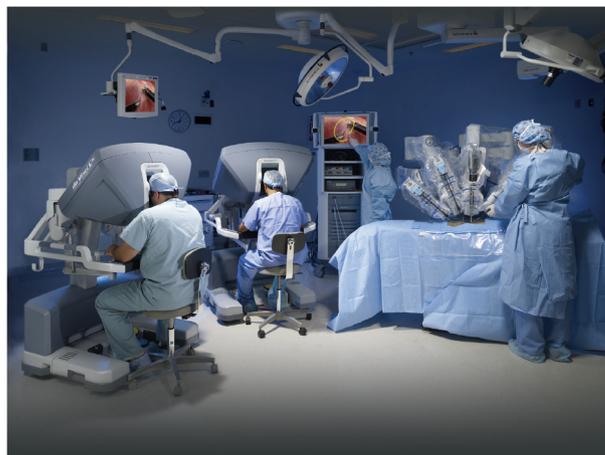


Fig. 1. A simulation of how the da Vinci robotic assisted surgical system is used in the operating room. The system generally includes a cart with a four-armed robot (right) remotely controlled by surgeons utilizing specialized workstation consoles (left). Credit: ©2016 Intuitive Surgery, Inc. (Wikimedia Commons, CC BY-SA 3.0).

market—and patent expirations [9,10]—are prompting a throng of other companies to develop and offer competing systems.

In late 2019, the global medical device company Medtronic announced that it will join the robot invasion of the operating room with its new general surgery robot system, named Hugo [11]. Hugo will not enter the market until 2021, but it is just one of a coming influx of new surgical robots. The Cambridge, UK, company CMR Surgical recently raised \$240 million USD for commercializing its modular surgical robot system, called Versius, which is planned for launch in Europe and Asia (it is approved in Europe and already in use at one hospital in Pune, India [12]). Pharmaceutical and medical device giant Johnson & Johnson is developing a robotic platform called Verb, a product of collaboration with Google's sister company, Verily. And several companies in Japan [13], Korea, Singapore, Thailand, and China, are building their own robots, such as the TiRobot system from Beijing Jishuitan Hospital and Beijing Tinavi Medical Technologies [14].

Most of these new robots will compete with the da Vinci as one-size-fits-all systems capable of a range of surgeries. But the market is also seeing smaller, more specialized robots being introduced. Intuitive Surgical, for example, has developed its Ion system, a robotically guided, flexible tube that penetrates deep into the lung for bronchoscopies. The Redwood City, CA, USA, startup Auris Health, which was recently acquired by Johnson & Johnson, has created a similar bronchoscopy robot. These more specialized surgical robots add to a number of commercially-available devices designed, for example, to precisely and accurately drill bone in orthopedic surgeries, or to insert needles or electrodes into the body for stereotactic procedures, such as biopsies, said Robert Webster, a roboticist who designs surgical robots at Vanderbilt University in Nashville, TN, USA. “That’s where the field is going,” Webster said. “You will see a lot of purpose-fit systems that I think will one day replace the one-size-fits-all paradigm.”

But robots may not always be better—and might even be worse [15]. In February 2019, the US Food and Drug Administration issued a warning that, at least for some cancers like breast and cervical, there is no evidence that robotic surgery leads to improved outcomes [16]. The warning was based largely on two prominent studies published in 2018 in *The New England Journal of Medicine*, which both showed that women with cervical cancer who underwent minimally invasive surgery, including robotically assisted surgery, had lower rates of survival than those who had the traditional open procedure, possibly due to inadvertent release of tumor cells during the robotic procedure [17,18]. “A robot may not be better for every kind of surgery,” Webster said. “There may be some surgeries that are better by hand.”

In urology, however, a long track record gives surgeons confidence that robotic surgery is safe and beneficial. “If there is something off, it would have already been discovered,” Chung said.

Artificial intelligence (AI) is also part of the robotic surgery revolution. As robots proliferate in the operating room, so will data. As they operate, robots will collect every piece of information about every procedure. AI methods could help analyze that data and help surgeons optimize their techniques for the best patient outcomes, Webster said. AI may also enable robots to automatically perform certain repetitive or mundane surgical tasks, such as tying a knot on a piece of suture [19].

But surgeons—at least for now—need not be concerned about being replaced. The surgical robots of today and tomorrow will likely remain so-called “cobots,” collaborative robots that work side-by-side with humans. Robots are good at repetitive and precise tasks, while humans are better at making the often life-or-death decisions in the operating room. The goal, Webster said,

is a “collaborative system where a robot does what it does well, and a human does what a human does well.”

Still, while semi-autonomous robot surgery is not likely in the near future, it may be on its way. “There’s going to be a constant evolution,” Hung said. “The cost of robots is going to be less, and at the same time they’re going to be smarter with more features. I think those are all good things for surgeons.”

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