38 Upcoming Robotic Systems

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Introduction

Ever since there was work to do, humans have been endeavoring to use machines to augment and improve our ability to do that work. Surgery, with its need for precise and often repetitive movements, seems particularly well-suited for robotic augmentation or automation. Due to the complex nature of the field, however, robotics has only relatively recently made any inroads, and still in limited settings.

Current-generation robots confer several theoretical advantages compared to traditional open surgical or laparoscopic techniques covered in greater detail elsewhere in this book, including enhanced visualization, improved surgeon ergonomics, increased degrees of freedom with wristed instruments, and the capability to operate remotely. Still, penetrance into surgery has been limited mostly to certain fields – in particular, urology, gynecology, and pelvic colorectal surgery – and has been very modest in other surgical subspecialties. There are several drawbacks to currently available robotic platforms that may account for some of this slow adoption, including increased setup time, significant capital investments, and the requirement to utilize at a high rate to make up for operational costs, bulky equipment, the lack of haptic feedback, and concerns about trainee education.

Since coming to market in the late 1990s and early 2000s, Intuitive Surgical, Inc. (Sunnyvale, CA, USA) has been the dominant force in the field of surgical robotics, and it has seen rapid growth in market penetrance in recent years. In the United States, most patents last 20 years from their earliest effective filing date, and many patents associated with Intuitive's technology are expiring or will be expiring in the coming years. As such, many competitors are expected to attempt to take advantage of the rapidly expanding, multi-billion-dollar market of surgical robotics. With any luck, this will result in increased innovation, reduced costs, and ultimately improved patient outcomes.

There are several forthcoming robot systems and modifications of existing systems that seek to extend upon some of the advantages and ameliorate the disadvantages of robotic surgery. The industry is primed for increased competition, which will ideally result in rapid innovation and ultimately improved patient outcomes in the coming years.

Enhancements to Current Systems

Da Vinci: Single Port

The da Vinci Xi Surgical System (Intuitive Surgical, Inc. Sunnyvale, CA, USA) is the most recent iteration of what is the industry standard robotic surgical platform. Prior to the release of the Xi, Intuitive demonstrated a prototype da Vinci SP (single port), with a deployable 3D camera, and three instruments with wristed motion. Intuitive has continued to develop this platform and is currently in the testing stages.

The currently available generation of the da Vinci single-site platform, compatible with the da Vinci Si, does not feature wristed motion, thus limiting triangulation and retraction. The instruments and camera cross within the port to allow for some degree of triangulation and to minimize interference between the working arms.

As compared to conventional single-incision solutions, robotic platforms eliminate some of the issues with instruments that collide or require the surgeon to manipulate instruments on the opposite side from their hands.

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Haptic Feedback

Intuitive is also developing a mechanism for haptic feedback, utilizing sensors already built in to the hardware of the Xi system, which could be deployed via a software-only update. While directly addressing one of the major drawbacks of robotic platforms in general, the utility of such an update would be greatly dependent upon the quality of its implementation. An ideal haptic feedback system would allow the surgeon to detect arm collisions and problem shoot them with minimal bedside assistance, reduce off screen visceral injuries, and improve feel while performing fine motor tasks such as suturing or manipulating fragile structures.

New Systems

TransEnterix

At the time of the writing of this chapter, Senhance Surgical Robotic System (Fig. 38.1), developed by TransEnterix (Morrisville, NC, USA), is approved by the FDA for colorectal and gynecologic surgery and has been submitted for approval for gallbladder and inguinal hernia surgery. To date, the company has sold a total of three systems, one in the United States [7]. Its key differentiating features include an open console system, utilizing polarized glasses for its three-dimensional display, eye tracking to move the camera, robotic instruments housed in independent arms, and haptic force feedback through controllers that are designed similarly to conventional laparoscopic instrument handles. Most of the instruments do not have increased degrees of freedom, but a wristed needle driver is available. The company claims cost containment is a priority of this system, but quantitative assessments are not available.

AVRA Medical

AVRA Medical Robotics (Orlando, FL, USA), in partnership with the University of Central Florida, is developing a robotic platform with small, light, modular arms that can be attached to the patient bed, bedside cart, or a rail system mounted to the operating room itself. The company hopes to offer increased flexibility, reduced bulk, and reduced cost. The company is developing integrated image guidance combined with machine learning in hopes of creating an autonomous or semiautonomous robotic instrument that could be used in the office as well as the operating room [2]. Their marketing materials generally target the aesthetic surgery market. AVRA's current models and concepts bear more resemblance to robotic manufacturing than robotic surgical instruments, and some utilize instruments from Intuitive's da Vinci robot. Additionally, they hope to integrate their system with operating room lights, patient tables, surgical instruments, and a training platform.

Titan Medical

The SPORT Surgical System (Titan Medical, Inc., Toronto, ON, Canada), being developed by a publically traded Canadian firm, is a single-port surgical robot, with a deployable 3D

Fig. 38.1 Senhance surgical robotic system. (Courtesy of TransEnterix, Inc.)

camera and two replaceable wristed motion instruments. Currently in the prototype phase, the robot is mounted in a single stalk on a mobile tower with a boom. The instruments are controlled from a remote, open configuration workstation [6].

Auris Health

Auris Health (San Carlos, CA, USA), based in Silicon Valley, has recently gained FDA approval for its Monarch Platform (formerly ARES – Auris Robotic Endoscopy System) for use as a bronchoscopy diagnostic and therapeutic platform [1]. It is controlled with a remote design similar to a video gaming console. Although the company has yet to provide many public details, they possess several patents pertaining to endoluminal surgery, and its founder is a veteran of Intuitive Surgical, Mako Surgical, and Hansen Medical. The company's recent purchase of Hansen Medical, which produces robotic catheter-based tools for treating cardiac arrhythmias, suggests an expansion of its market, but it has made no public statements about future plans in that area.

Medrobotics

The Flex Robotic System, developed by Medrobotics (Raynham, MA, USA), is a robotic platform mounted on a flexible endoscope with two articulating 3 mm instruments, such as retractors, scissors, monopolar cautery, or a needle driver [4]. The endoscope has a telescopic inner core stabilizer to maintain the spatial orientation of the proximal scope. It is designed for transoral surgery, particularly oropharyngeal, hypopharyngeal, and laryngeal surgery. The company also produces a colorectal apparatus called the Flex Colorectal Drive, similarly designed for natural orifice surgery in the anus, rectum, and colon. Control of the instruments is via a hand piece directly connected to the instrument at the patient's bedside.

Mazor Robotics

Medtronic (Parsippany, NJ, USA) has been making substantial financial investments in Mazor Robotics (Caesarea, Israel), to distribute its surgical robotic guidance system, the Mazor X and its image-based guidance system, Renaissance. Mazor Robotics has a background in image-based, preplaned robotic guidance for spine and brain surgery. To date, Medtronic has invested $72 million in three separate disbursements in exchange for 10.6% of fully diluted shares of Mazor and distribution rights for Mazor's existing Mazor X Surgical Assurance Platform. As of Q1 2018, the company claimed 33,000 procedures performed with Mazor systems but would not add additional details [5].

Verb Surgical

Ethicon (subsidiary of Johnson and Johnson, New Brunswick, NJ, USA) is invested in a joint venture with Verily Life Sciences (a part of Alphabet, Inc., Mountain View, CA, USA the parent company of Google) called Verb Surgical, which is in the development stages of a surgical robot, or what it terms digital surgery. The company's goal is to democratize surgery, with its stated pillars of robotics, visualization, advanced instrumentation, data analytics, and connectivity, increasing access to technology and information, improving outcomes and reducing cost [8]. Given Alphabet's background in data analytics and machine learning and Ethicon's background in medical device manufacturing, this is an intriguing partnership, but specific details have not been made public at the time of this chapter's writing. The company's goal is to bring a product to market in 2020 [3].

Several truly autonomous robotic surgical devices and implantable remote-controlled instruments currently in various stages of research and development are beyond the scope of this chapter but are described elsewhere in this textbook.

Minimally invasive surgery, and surgical robotics in particular, has always been a rapidly developing field, but the expiration of many of the initial patents for surgical robot technologies and subsequent entrance of several new players to the field is likely to result in accelerated growth in the number of options, ideally leading to improved choice, reduced cost, and ultimately improved patient outcomes.

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