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TOPIC PAPER

Robotic surgery: new robots and finally some real competition!

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Abstract

Purpose For the last 20 years, the predominant robot used in laparoscopic surgery has been Da Vinci by Intuitive Surgical. This monopoly situation has led to rising costs and relatively slow innovation. This article aims to discuss the two new robotic devices for laparoscopic surgery which have received regulatory approval for human use in different parts of the world.

Materials A short description of the Senhance Surgical Robotic System and the REVO-I Robot Platform and their pros and cons compared to the Da Vinci system is presented.

Summary A discussion about the differences between the three robotic systems now in the market is presented, as well as a short review of the present state of robotic assistance in surgery and where we are headed.

Keywords Robotics · Robotic surgery · REVO-I, ALF-X, Senhance · New robots · Minimally invasive surgery · Laparoscopy · Korean robot · Da Vinci · Competition · Robotic urology

Introduction

This article aims to discuss the two new robotic devices for laparoscopic surgery, which have received regulatory approval for human use in different parts of the world. This finally brings an element of competition into a market dominated by one product for the last 15 years. Various companies have attempted to develop a competing product, but have failed to actually bring one to the market. The failure has been at various stages including patent violations, making a viable product or inability to obtain regulatory approval.

Robotic surgery was introduced at the turn of the last century by devices from two companies which came from the West Coast of the United States. Intuitive Surgical, USA with its Da Vinci Surgical Robot and Computer Motion with its Zeus robotic device and Aesop voice-controlled camera holding device [1]. Both systems used a master slave system where the surgeon sits at a console and operates a cart with instruments at the side of the OR table where the patient lies. The two companies fought patent infringement suits against each other and finally merged in 2003. This led to a single device, the Da Vinci Surgical Robot, which remained in the market.

There have also been robotic systems developed for orthopedic surgery, cochlear implants, transoral surgery, transurethral surgery, stereotactic brain surgery and transrectal biopsy among others. For the purposes of this article, we will be confining ourselves to robots used for laparoscopic surgery.

Current situation

The Da Vinci Surgical Robot and its various iterations (the S, Si and Xi) have been the only surgical robots used across most of the world over the last 14 years. The rise of Intuitive Surgical has been meteoric with more than 750,000 procedures performed worldwide last year using one of their robots [2]. However, there are still a significant number of open surgical procedures performed outside the USA such as for prostate cancer [3].

The reasons for the rapid uptake of the Da Vinci are clear. It has a 360 degree endowrist and high-definition 3D vision which helps in lessening the learning curve for surgeons to perform complex reconstructive minimally invasive surgery. The entire ecosystem surrounding the Da Vinci, including integrated imaging like intraoperative ultrasonography (USG), infrared imaging with indocyanine green (IR ICG)

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and availability of ultrasonic shears and tissue sealers, has been developed over the last 20 years to a point where it is a comprehensive tool for surgeons to perform the most minimal invasive surgery.

However, there continue to be issues with the use of the Da Vinci system. The cost of the equipment as well as recurring costs is significant and insurers in most countries will not reimburse any extra amount for robotic surgery over the costs for other minimally invasive surgery like pure laparoscopy. The lack of competition for the Da Vinci has precluded any control on costs. Technically, lack of haptic feedback remains a concern and due to the nature of the technology, the instrument sizes have remained at 8 mm [4]. The whole setup is cumbersome and docking and undocking the robot for use is a fairly time-consuming procedure. The operation cart is bulky and takes up a lot of space limiting access to the patient.

Over the years, many companies have tried to develop and bring systems to market which would challenge the hegemony of the Da Vinci Surgical Robot. These include the Surgibot from Transenterix and Single Port Orifice Robotic Technology (SPORT) from Titan Medical. Most have failed, either at getting regulatory approvals or at developing a product which would suit the purposes of minimal access surgeons to actually improve their techniques. Others like Auris Robotics, Cambridge Medical Robotics (UK), Verb Surgical (a collaboration between Johnson & Johnson and Google) and Vecna Technologies are still in the process of developing a product for laparoscopic surgery.

In the last year, we have two products which have received regulatory approval in some countries for routine clinical use. We refer here to the Telelap Alf-X [5] (now renamed the Senhance Surgical Robot) which has the CE mark for use in Europe and recently US FDA approval and the REVO-I Robot Platform from South Korea which has received Korean FDA approval for use in Korea [6]. These two products are now in clinical use in the respective areas where they have approval, but are still improving instrumentation.

The competition

Senhance Surgical Robotic System (Transenterix, USA)

This was initially called the ALF-X and developed by an Italian company called Sofar. This company has now been bought over by the US-based Transenterix Company which has renamed this the Senhance Surgical Robotic System.

The system consists of "a remote control unit called the cockpit, a 3D HD Monitor, an infrared Eye Tracking system, foot pedal, keyboard and touch pad, up to four independent robotic arms (instead of the four armed operation cart of the Da Vinci), a connection node and reusable laparoscopic instruments." This system does have some unique features. It can be adapted for use with any 3D system of optics. The eye tracking system allows the camera to be controlled by viewing various parts of the operative field and the handles for manipulating the instruments have haptic feedback, which is an aid to suturing and dissection. The surgeon sits on a fully adjustable seat and the upright position allows others in the room to view the same monitor as the surgeon [7] (Fig. 1).

The optics need a 10 mm trocar for access. All other instruments other than the needle holder need 5 mm ports. The articulating needle holder needs a 10 mm port. This also means that there is no articulating cutting tool at present. The company says that this is in development (personal communication).

The reusable laparoscopic instruments would seem to offer a significant benefit in recurring costs as compared to the Da Vinci device. The eye tracking technology is a unique feature. The haptic feedback is another area where this differs from the currently available robot.

Almost all the publications describing the use of the Senhance Surgical Robot have been in gynecologic or colorectal procedures [8, 9]. The urological studies are in porcine models. They are at present marketing in the USA for use in colorectal or gynecological procedures. It is CE marked for use in Europe in all abdominal and non-cardiac thoracic applications.

REVO-I Robotic Surgical System (Meere Company, South Korea)

The Meere Company in South Korea was selected by the Korean Ministry of Knowledge in 2010 to develop a surgical robotic system for minimally invasive surgery. After multiple models and 20 different animal studies, they developed the current model, the MSR-5000 REVO-I which was introduced in 2015. This particular model has received Korean FDA approval in August 2017 and is now available for human clinical work. There is no published data as yet on human patients [10].

The REVO-I system is a master slave system similar to the Da Vinci system. It consists of a surgeon control console, a four-armed robotic operation cart, an HD vision cart and reusable endoscopic instruments (Fig. 2).

The porcine studies seem to indicate a definite shortening of the learning curve as well as safety of usage. Studies have reported its use in fallopian tube reconstruction, partial nephrectomy and cholecystectomy in porcine models [6, 11].

The instruments are reusable 20 times compared to the 10 uses of Da Vinci instruments. This is claimed to reduce the cost of using the equipment. The latest version incorporates

Fig. 1 The Senhance Surgical Robot seen here with three arms and the cockpit/open console

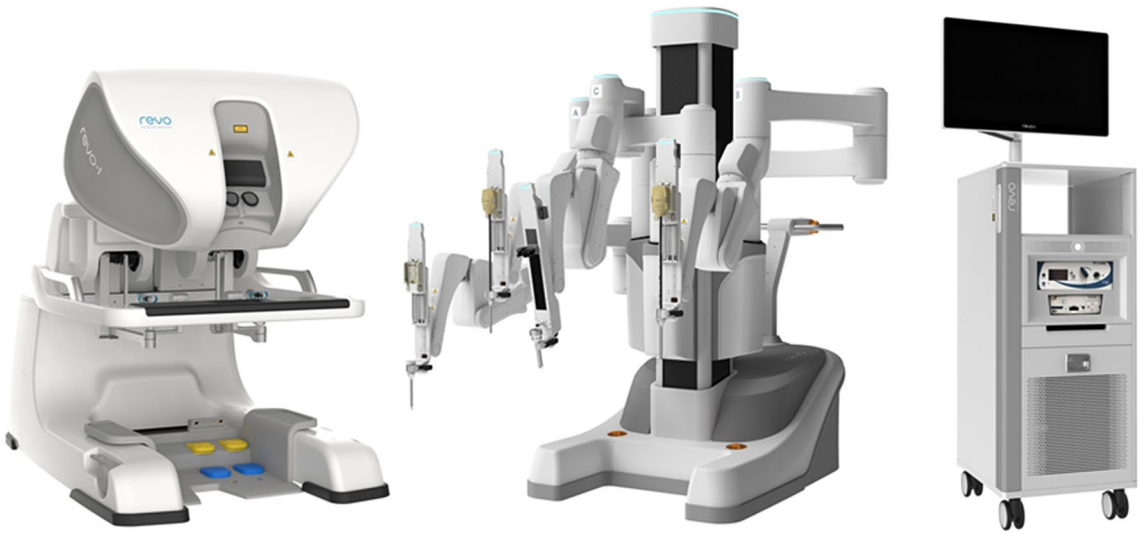

Fig. 2 REVO-I Robot with closed console, operation cart and vision cart

haptic feedback, the lack of which is a significant drawback in the Da Vinci system. The range of motion of the needle driver is not as much as that in the Da Vinci [11].

Discussion

Robotic surgery has revolutionised the surgical management of urological cancers over the last 20 years. It has made minimally invasive surgery accessible to many urologists and their patients, especially in the field of prostate

and kidney cancer. The term robotic surgery may be debatable, the robots we use are just remote control tools and the surgery is performed by the surgeon, but it is here to stay.

The development of robots for use in laparoscopy would seem to be going along two clear paths. One set of systems like the Da Vinci system have an instrument cart placed at the bedside that holds the arms with the surgical instruments and optic. The other systems have arms attached to the operating table itself, which would facilitate easier access to the patient under anesthesia and may offer a degree of versatility as compared to the instrument cart. None of these systems, however, have made it to the market yet.

Neither of the two new devices is yet at the level of the Da Vinci system. This is understandable because the Da Vinci has reached its current status after at least four generations in clinical use. The Senhance system lacks an articulating cutting instrument and this is one of the keys to efficient dissection today in any robotic surgery. The REVO-I lacks the range of motion of the Da Vinci in its needle holder and with only limited Korean FDA approval will take time to gain enough clinical volumes at multiple centers to be assessed adequately (Table 1). The biggest hurdle for these two devices and any other new device to be launched will be the huge ecosystem created by Intuitive for its device and the incredibly large database of procedures as well as techniques, which already exists for the Da Vinci. The book has already been written and is being updated each day. It will not be easy to catch up.

Although both the newer robots have haptic feedback, which is a significant lacuna in the Da Vinci, they lag far behind in the other available accessories like energy sources, vessel sealers, imaging and mentoring.

The design of both these robots follows the path set by the Da Vinci robot. The surgeon sits at a remote console which controls the arms of the operation cart that hold the telescope and instruments. In case of the Senhance, there are four separate arms to be positioned as required around the table, which would seem to offer a slight advantage in multiquadrant surgery. But the inherent disadvantage is a bulky system which restricts access to the patient on the OR table in case of an emergency. A few of the other robotic systems including the Cambridge Robotics among others have taken a different approach by doing away with the operation cart and attaching the robotic arms directly to the table. However, none of these are in clinical studies yet.

For the last 20 years, Intuitive Surgical's Da Vinci has been the predominant device used in robotic surgery worldwide and the only one over the last 15 years or so. It is only in the last 2 years that we have seen these two devices, the Senhance and the REVO-I, make an appearance. We are yet to see any significant clinical volumes using either of these two devices. But monopoly breeds complacency as well as a lack of true innovation. It drives prices up for consumers (patients in this case) and retards progress. So we should look forward to any sort of data with these two devices being used over the next few years. In addition, with major players like Medtronics using Covidien instruments and Verb Surgical, both launching a surgical robot in a year or two, we anticipate healthy competition driving innovation as well as lower prices for the end user and the hospitals purchasing the equipment.

Although Google, one of the new entrants to the field, has pioneered a driverless car, the CEO of Verb Surgical has been quoted as saying that the surgeon will always be there to drive the robot they are developing! So we seem to be some way yet from having a true automated robot performing surgery, but the present and shortly available devices will go a long way toward improving minimally invasive surgery and overcoming human limitations.

Table 1 Currently available robots and their features

Device	Da Vinci	Senhance surgical robot	REVO-I
Console	Closed	Open	Closed
Optics	8 mm 3D HD	10 mm 3D HD	10 mm 3D HD
Instruments with articulation	Monopolar/bipolar/needle holder	Bipolar/needle holder	Monopolar/bipolar/needle holder
Instrument size	8 mm	5 mm/needle holder 10 mm	8 mm
Haptic feedback	No	Yes	Yes
Optic control	Handles + foot pedal	Pupil tracking	Handles + foot pedal
Reusability	Ten uses	No restriction	20 uses
Cost per use*	$ 1500	$ 200–500	NA (only in South Korea)
Cost of device*	$ 1.5–2 Million	$ 1–1.2 Million	NA (only in South Korea)
Approvals	Worldwide	US FDA for colorectal and Gyn, CE for all lap applications	Korean FDA for use in South Korea

*Approximate figures which will vary with country

Compliance with ethical standards

Conflict of interest I have no conflicts of interest.

Animal and human participants This article does not contain any studies with human participants or animals performed by the author.

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