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Research Paper

Reflections on Surgical Robotics

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ABSTRACT : *Surgical robots can be divided into two classes, autonomous or tele-operative robots. The most popular robotic applications in medical services and healthcare are surgery. Everything from organ transplants and gastro-intestinal surgeries to spinal medical procedures and urological operations is performed using some kind of robot. The market is divided into three parts, mainly surgical systems, surgical services and instruments and accessories. The areas of use of robotic surgery include gastrointestinal, general surgery, gynecology, heart, ophthalmology, orthopedics, pediatrics, spine, chest, organ transplant surgery and urology. Robotic surgery market revenue is estimated to exceed $ 13.8 billion by 2027. Features from some robotic surgery companies are described. Hansen Medical pioneered the field of flexible robot technology. Moll had previously co-founded Intuitive Surgical and Auris Health. Its robotic catheter aims to explore the peripheral vascular system and provide a channel for the regulation of therapeutic devices. The catheter works as a component of Hansen's Magellan robotics system. The Sensei X robotic system uses 3D catheter controls and 3D visualization to allow a surgeon to control their robotically orientable catheters to gather electrophysiological information within the heart's Atria. Hansen has produced two robotic systems, the Magellan robotic system and the Sensei robotic system. The company Intuitive Surgical or IntuitiveTM received FDA approval for the first historical robotic system da Vinci ® in 2000, from which point they developed the da Vinci ® framework. The Sensei X robotic system uses 3D catheter controls and 3D visualization to allow a surgeon to control their robotically orientable catheters to gather electrophysiological information in the heart atrium. IntuitiveTM had revenues revenues of $ 4.36 billion in 2020.*

KEYWORDS: *Medical Robotics, Surgical Robots, Robotic Market, Robotic Surgery*

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I. INTRODUCTION

There are many benefits of using robots in surgeries. The use of robotic arms makes surgical procedures easier and more effective. Since the robotic system makes it possible to work with more than one arm at the same time, it allows the application of techniques that are normally very complex or impossible to do. It can be performed through a small incision. Less pain and blood loss occurs after the surgery, the recovery time is accelerated and a smaller scar is formed. Important tissues such as nerves and vessels in the operation area that need to be protected are detected more easily thanks to the high-resolution camera on the robotic arm. The surgeon has the opportunity to examine the operating field more clearly and in depth, in a holistic way. In this way, damage to the surrounding tissues during the surgical procedure is prevented and the possibility of complications in the postoperative period is considerably reduced. In robotic surgery applications, since more geometrically accurate and clear surgical repairs can be made, more satisfactory results are obtained in functional and cosmetic terms. Since robotic arms can be disinfected more effectively than human hands and do not carry biological risks, they ensure that the surgical field is kept more sterile and safe. (Garisto, et al. 2021; Stokes et al. 2021).

Robotic surgery can be performed in primarily three major methods: (a) directly with the surgeon removes the tissue with the fingers, and also the manipulation of surgical instruments using open or minimally invasive approach that interacts through a surgical procedure (b) the interaction with the tissue, prior to surgery (pre-op) and during surgery (during surgery) in conjunction with a surgical robotic system cameras and imaging modalities that provide visual information is mediated by a surgical procedure (c) a surgical procedure performed in a simulation environment where the operating environment may be real or simulated tissue. These three modalities have a common man-machine interface in which information is shared between the surgeon and the operation decency. This information-rich layer can be analyzed to monitor the surgical process at a high level and evaluate the surgeon's operational skills.

Surgical robots can be divided into two classes: autonomous or tele-operative robots (Rosen, 2013). Another less commonly used classification is the classification of the branch of medicine such as urology, general surgery. Classification based on the role of the surgical robot is given as student, resident and specialist. Student robots have small responsibilities and low risk, resident robots have moderate responsibilities and risk, and specialist robots have full responsibility and risk (Graur et al. 2018).

The recent introduction of robotic surgery into the operating room offers a significant breakthrough in the way the operation is performed. It combines technological and clinical breakthroughs in developing new robotic systems and surgical techniques to improve the quality and outcome of surgery. These breakthroughs are based on innovation in robotics, both in academia and industry. The promise of surgical robotics is to minimize impact and trauma to the tissue surrounding the surgical site at the same time, while providing a high level of dexterity and vision to anatomical structures that cannot be approached with the surgeon's fingers and seen directly with the surgeon's eyes. Various imaging modalities of robotic surgery, respectively, it acts as an intermediary between the area of surgery with the surgeon's hands and eyes; however, these two elements will continue to evolve, and that will affect every aspect of health care in general surgery and is part of a larger Information System. Understanding the clinical information accumulated through the use of these new systems and their potential capabilities is likely to lead to the development of new and more capable surgical robotic systems in the future (Rosen, 2013).

Hidden Markov Models are used for real-time gaze motion recognition, allowing the robotic camera to scroll, tilt and zoom while being immune to eye movements. An online calibration method has been proposed that overcomes the calibration shift for the viewpoint viewer and simplifies its clinical application (Fujii et al 2017).

According to a study conducted in China on 276 people, including 153 robot-assisted surgery and 123 conventional, post-operative complications are similar to conventional methods with robot-assisted surgery (Wang et al. 2020).

A study of different types of gynecological surgery reports that the Senhance ® robotic system is viable and safe (Siaulysa et al. 2021). In some cases, minimally invasive surgery provides reduced high-risk complications and a shorter hospital stay compared to laparotomy (Matsuo et al. 2021).

A training course about prospective, single-center observational study, one of da Vinci © skill simulator that includes simulation exercises, and equipment that is controlled by a dual console with two robot-assisted procedures in both the result of the application of the training course has been shown to be feasible and safe in both in vivo surgery simulation. Again, it was found

that none of the in vivo operations required conversion for laparoscopic surgery, no transfusions or re-operations were required for any patient within 30 days of surgery (Marguerritte et al. 2020). The term in vivo is often used to refer to experiments conducted in an entire organism rather than living isolated cells.

In terms of Environmental Impact Assessment, annual laparoscopic surgery 1.6 million procedures, robot-assisted surgery 1.4 million procedures and packaged carbon dioxide gas sales increased to 0.4 million procedures in the United States. The main gas used for insufflation in Minimal invasive surgery is carbon dioxide. The total operation time is calculated as 3,233,917 hours, in which this gas contributes 9% to 26% of the greenhouse effect (Power, et al. 2012).

II. ROBOTIC SURGERY COMPANIES

Medical robots constitute a rapidly growing sector of the medical device industry. Whether they are used for home help, Crisis Intervention, negligibly invasive medical surgery, targeted therapy, or prosthetics, they are increasingly being used these days and are transforming medical care around the world (Dialani, 2021).

As innovative advances have steadily evolved, medical surgery has established itself as a refined discipline suitable for treating many diseases and conditions. Therefore, as computer hardware and software have evolved over time, these developments have also been integrated into the operating room.

The most popular robotic applications in medical services and healthcare are surgery. Everything from organ transplants and gastro-intestinal surgeries to spinal medical procedures and urological operations is performed using some kind of robot.

The market is divided into three parts, mainly surgical systems, surgical services and instruments and accessories. The areas of use of robotic surgery include gastrointestinal, general surgery, gynecology, heart, ophthalmology, orthopedics, pediatrics, spine, chest, organ transplant surgery and urology. Robotic surgery market revenue is estimated to exceed $ 13.8 billion by 2027 (Surgical-Robot, 2021) and $ 16.8 billion by 2031 (Research and Markets, 2021) (figure 1).

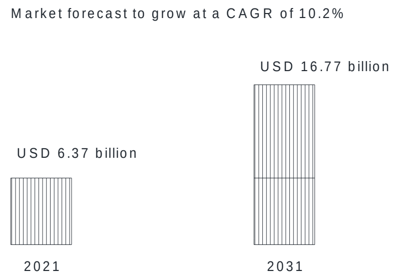

Figure 1: Surgical robot market growth forecast (Research and Markets, 2021).

The global minimally invasive surgery market is estimated to reach 90.4 billion dollars by 2027 (Global Minimally Invasive, 2020).

III. SURGICAL ROBOT COMPANIES

There are many surgical robot companies in the world, some of which are given in Table 1 (Dialani, 2021, Research and Markets, 2021).

Table 1: Robotic surgery companies.

Order	Robot company	Order	Robot company
1	Asensus Surgical, Inc.	22	Medtronic plc
2	Avatera Medical GmbH	23	Meerecompany Inc.
3	B. Braun Melsungen AG	24	Monteris Medical Corporation
4	Boston Scientific Corporation	25	Myomo
5	CMR Surgical Limited	26	Neocis, Inc.
6	Conmed Corporation	27	Novartis International AG
7	Corindus Vascular Robotics	28	Peters Surgical SASU
8	Cousin-Biotech	29	PROCEPT BioRobotics
9	Curexo, Inc.	30	Renishaw plc
10	Dextera Surgical	31	SIM Surgical
11	Diligent Robotics	32	Siemens Healthineers AG
12	Enthrall Medical GmbH	33	Smith & Nephew plc
13	Fuhrmann GmbH	34	Stereotaxis, Inc.
14	Globus Medical, Inc.	35	Stryker Corporation
15	Hansen Medical	36	THINK Surgical, Inc.
16	Hospira	37	Titan Medical, Inc.
17	Integral Lifesciences Holding	38	Venus Concept, Inc.
18	Intuitive Surgical, Inc.	39	Verb Surgical
18	KLS martin Group	40	Vicarious Surgical, Inc.
20	Medicaroid Corporation	41	Virtual Incision Corporation
21	Medrobotics Corporation	42	Zimmer Biomet Robotics

Features from some robotic surgery companies are described below (Dialani, 2021).

CMR Surgical Limited: CMR Surgical is a British company that has built the state-of-the- art surgical robotic system Versius for minimal access medical surgery. Their vision is to make minimally invasive medical surgery easily accessible and affordable. Founded in 2014, CMR Surgical is headquartered in Cambridge and received the European CE mark in March 2019 for its Versius Surgical robotics system.

Corindus Vascular Robotics: The CorPath 200 device from Corindus Vascular Robotics is designed for percutaneous coronary mediation. The CorPath 200 comes with a radiation- protected "cockpit" for the surgeon. CorPath 200 is the first and only robot-assisted procedure to account for the controlled insertion of coronary guide wires and stent/swelling catheters from an optimized interventional cockpit. When using the frame, the surgeon operates CorPath 200 from behind a radiation-protected “cockpit". Instead of being with a patient dressed in a lead apron, the surgeon is located behind an operating station and controls surgical devices with a set of touch screens and joystick controls.

Dextera Surgical: Dextera Surgical, formerly known as Cardica, manufactures proprietary punching devices for minimally invasive surgical procedures. Based in Redwood, California, USA, the company works in manufacturing, healthcare, minimally invasive surgery, robot assisted, test and measurement equipment, medical devices and equipment. Surgical staples are routinely used in more than one million minimally invasive laparoscopic, video-assisted or robot-assisted surgical procedures per year. The MicroCutter 5/80, the company's signature proprietary technology, is the world's first and only five-millimeter surgical stapler that articulates up to 80 degrees in each direction. The MicroCutter 5/80, the smallest profile articulated stapler available today, provides access to hard-to-reach anatomy by reducing the amount of dissection and tissue processing required to place the stapler in tight spaces. The cartridge-based device's small size and wide articulation December are designed to improve the surgeon's access to and visualization of the surgical field and reduce limitations in the advancement of minimally invasive surgical approaches created by larger punching devices.

Diligent Robotics: Diligent Robotics is an Austin-based artificial intelligence company founded in 2017. Its AI-powered robots work with humans in everyday scenarios. The organization's autonomous Moxi robot could be left alone to do tedious logistical tasks, such as setting up patient rooms in hospitals and restocking supply rooms. Suitable for navigating hospital corridors and other confined spaces, Moxi penetrates even the social intelligence that passes through head movements and LED eyes. Diligent Robotics, hospital robot assistant Moxi assists clinical staff in routine, non-patient-face tasks so that they have more time for patient care, focusing on performing and delivering tasks for front-line clinicians. The company has placed Moxi in several U.S. hospitals. Diligent Robotics is working to invent robots that combine mobile manipulation, social intelligence and human-driven learning capabilities.

Hansen Medical: Hansen Medical Company was founded by Dr. Frederic Moll in Mountain View, California. Hansen Medical pioneered the field of flexible robot technology. Fred Moll is a distinguished and prolific medical device entrepreneur, especially in the field of medical robotics. Frederic Moll was raised in Seattle where he attended Lakeside School and was schoolmates with Microsoft cofounders Bill Gates and Paul Allen, graduating in 1969. Frederic Moll then attended the University of California at Berkeley where he earned a B.A. degree, before going to the University of Washington to earn his M.D. degree.

A trocar (Feder, 2008) is a medical device that is made up of an awl, a cannula, and a seal (figure 2). The trocar tip can be of various shapes (figure 3). Conical tipped trocars are supposed to be less traumatic to the tissue. The tip can be pierced without cutting the parietal wall, reducing the risk of herniation or bleeding.

Trocars are placed through the abdomen during laparoscopic surgery (figure 4). Frederic Moll left his residency to develop the safety trocar that made general laparoscopic surgery possible, and funded and later sold. Endotherapeutics was purchased by United States. Surgical. Origin Medsystems was purchased by Eli Lily (figure 5).

Figure 2: Disposable trocars (Mishra, 2021).

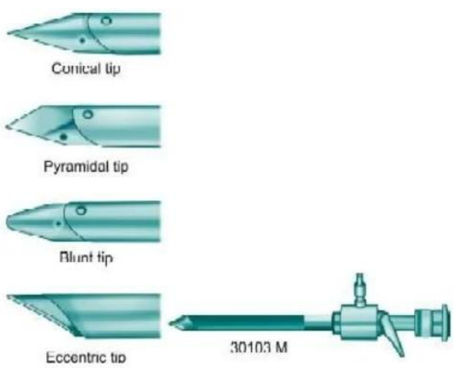

Figure 3: Trocar tip shapes (Mishra, 2021).

Figure: 4 Use of trocars in surgery (Mishra, 2021).

Making important discoveries in surgery, Dr. Frederic Moll is considered the pioneer of robotic surgery (figure 5).

Figure 5: Dr. Frederic Moll.

The trocar functions as a portal for the subsequent placement of other instruments, such as graspers, scissors, staplers, etc. Trocars also allow the escape of gas or fluid from organs within the body.

Moll had previously co-founded Intuitive Surgical and Auris Health. Its robotic catheter aims to explore the peripheral vascular system and provide a channel for the regulation of therapeutic devices. The catheter works as a component of Hansen's Magellan robotics system. The Sensei X robotic system uses 3D catheter controls and 3D visualization to allow a surgeon to control their robotically orientable catheters to gather electrophysiological information within the heart's Atria. Hansen has produced two robotic systems, the Magellan robotic system and the Sensei robotic system. Mag ellan is built for very specific, peripheral vascular robotic procedures and interventional electrophysiology procedures. Along with the Sensei robotics system, Hansen invented the Artisan extended control catheter, a robotically orientable sheath designed to ensure catheter stability, accessibility, and contact force detection when navigating third-party catheters in electrophysiology procedures. In March 2008, Frost & Sullivan presented Hansen Medical with the 2008 Product Innovation Award in the field of U.S. Image- Guided and robotic-assisted surgical devices. Auris Health acquired Hansen Medical in 2016, bringing numerous robotics technologies and patents to the Auris portfolio. Following Hansen integration, in March 2018, Auris Health launched the Monarch ™ Platform, the first FDA- approved robotic platform for diagnostic and therapeutic bronchoscopic procedures. The Monarch Platform is designed to allow doctors to diagnose small, hard-to-reach peripheral lung nodules with greater accuracy than ever before.

Figure 6: Robotic surgery practice in Sydney, Australia with da Vinci (Crew, 2020).

Medrobotics Corporation: Medrobotics is a Massachusetts-based organization that recently secured US $ 20 million in funding to enter general medical surgery and build state- of-the-art robotic systems. The Flex Robotic System received FDA approval in 2015, allowing doctors to reach anatomical areas such as the ear, nose and throat via its snake-like Plan and 180° path.

Myomo: Myomo company's controlled bracelet MyoPro is designed to help those who experience loss of movement or weakening in their hands and arms due to many conditions. The device studies nerve signals from the surface of the skin, at which point it activates small motors that promote natural arm and hand movements.

Stryker Corporation: Stryker was the second leading contender after it acquired MAKO Surgical Corp for $ 1.65 billion in 2013 and entered the robotic surgery market. MAKOTM market introduced the Rio ® robotic arm interactive orthopedic surgery platform, which was touted by Stryker as the MAKO™ robotic arm. The MAKO™ frame, used for partial knee arthroplasty and Absolute Hip Arthroplasty, has the bulk of the revenue in the orthopedic robotics market.

Verb Surgical: Verb Surgical is one of the innovative robotic surgery organizations and is a strategic partnership between Google Alphabet and Johnson & Johnson's medical. They focus on building a digital surgery platform that integrates robotics technology, advanced visualization, advanced instrumentation and data analytics. Such robotic surgery companies are embracing Google's big data and machine learning expertise to create a digital surgery platform that won't exactly cost existing robots in medicine.

Zimmer Biomet Robotics: The Zimmer Biomet Robotics company was once known as Medtech SA. It is a robotic surgery company founded in 2002 in Montpellier, France. It makes robotic provide for different applications such as surgical procedures of the central nervous system and knee. Its main product is Rosa, a robotic surgical assistant designed for negligibly invasive medical procedures. If Intuition of those companies manages to gain a market share of 25% with da Vinci by 2025, compared with 17% now, there could be increased sales of over $1.4 billion. This is possible given that the da Vinci system has many advantages over regular surgical procedures. Surgical systems not only provide surgeons with a December of motion similar to that of the human wrist in the surgical field, but also eliminate the instability of the human hand. In October, these minimally invasive surgeries have the benefits of reduced surgical complications, faster recovery processes, and lower hospitalization costs. In addition, these surgical systems have been widely adopted for certain procedures, but there are still many things they are not accepted for. Until a few years ago, the most common procedures were prostatectomy and hysterectomies, which accounted for more than 50% of the total procedures using da Vinci systems. However, other procedures are being adopted at an increasing rate and this is expected to continue in the future. A wider range of possible procedures would lead to greater demand for the company's systems. Given these factors, da Vinci can continue to grow strongly in the coming years and gain a higher share in the global robotic surgery market (Forbes, 2019).

IV. CONCLUSION

In the use of robotic surgery, there are many areas such as general surgery, gynecology, heart, orthopedics. Robotic surgery market revenue is estimated to exceed $ 13.8 billion by 2027. Even in the competitive environment of high-tech companies, the profit ratio is high, and the ratio of gross profit to sales can be 69%. Robotic surgery can be performed primarily by three main methods. (a) a surgical procedure in which the surgeon interacts with the tissue directly with his fingers, as well as through manipulation of surgical instruments using an open or minimally invasive approach. (b) The interaction with the tissue before surgery, during surgery and visual cameras and imaging modalities that provide information which is mediated by a surgical robotic system in conjunction with a surgical procedure. (c) The tissue that may be of actual or simulated operational environment is a surgical procedure that is performed in a simulation environment. Due to robotic use, surgery is performed with precision and smaller incisions. There is reduced blood loss, less pain and a shorter recovery time.

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