

# THE NONCONVENTIONAL SURGICAL SYSTEM DA VINCI

Gheorghe Tolu<sup>1</sup>, Daniel Ghiculescu<sup>2</sup>, Miron Zapciu<sup>3</sup>

<sup>1</sup> Politehnica University of Bucharest, Romania, georgetolu@gmail.com

<sup>2</sup> Politehnica University of Bucharest, Romania, daniel.ghiculescu@gmail.com

<sup>3</sup> Politehnica University of Bucharest, Romania, zapcium@yahoo.com

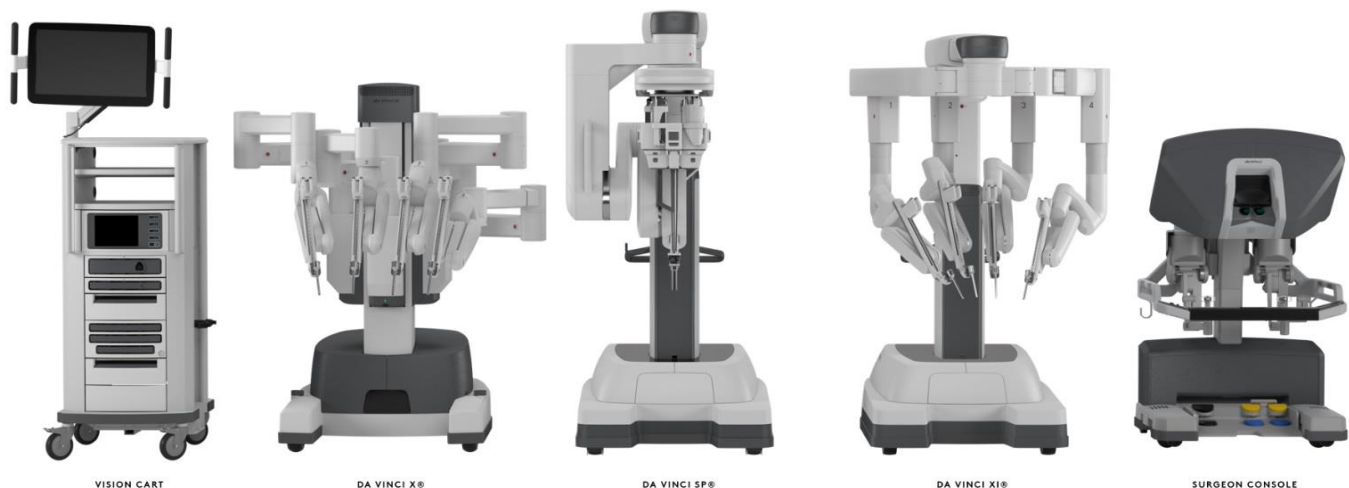
**ABSTRACT:** Intuitive Surgical is the pioneer and a global technology leader in robotic-assisted, minimally invasive surgery. The company develops, manufactures and markets the Surgical System da Vinci, the most complex device used in medical robotics. The product is called "da Vinci" because Leonardo da Vinci invented the first robot, and his works excel in anatomical details. The Surgical System da Vinci is a robotic platform that allows complex surgery through incisions of 1-2 cm. So far, hundreds of thousands of surgeries have been performed. The Surgical System da Vinci reproduces the surgeon's movements in real time. The advantages of using the Surgical System da Vinci, are greater precision, a much better picture and remote surgery. The disadvantages to traditional techniques are that it cannot be programmed and cannot make decisions on its own to make a surgical move or surgery without the surgeon's command. The Surgical System da Vinci is used currently in major medical centers around the world.

**KEY WORDS:** Intuitive Surgical, Robotic Surgery, Surgical System, da Vinci, Monza Hospital, Ponderas Academic Hospital.

## 1. INTRODUCTION

From 1995, Intuitive Surgical company, designs, manufactures and markets Surgical System da Vinci, which utilizes computational, robotic and imaging technologies. The company focuses on minimally invasive surgery (MIS) including: General Surgery, Cardiology, Gynecology, Urology. The Surgical System provides its operating surgeons with control, range of motion, tissue manipulation capability and three-dimensional (3D), high-definition (HD) vision. It allows surgeons to work through the small ports enabled by minimally invasive surgery (MIS) procedures. The systems provide immersive 3D visualization, precise and Tremor-Free Endoscope Control, intuitive Instrument Movements, Endo-Wrist Instruments, Scaled, Tremor Filtered Instrument Movement, Surgeon Ergonomics, Multi-Specialty Surgical Platform, and Training Tools. In 2017, the company had four generations of Surgical

System: da Vinci standard, S, Si, Xi (Figure 1). The Surgical Systems consists of Surgeon's Console, Patient-Side Cart, 3D Vision System, Skills Simulator, da Vinci Xi Integrated Table Motion, Firefly Fluorescence Imaging and Standard da Vinci System. The vision system includes its InSite 3D endoscope with two separate vision channels linked to two separate color monitors through video cameras and specialized image processing hardware. The accessories include Endo-Wrist Instruments, da Vinci Single-Site, Endo-Wrist One Vessel Sealer, Endo-Wrist Stapler and Accessory Products. Intuitive Surgical manufactures a range of instruments, which incorporate wrist joints with tips customized for various surgical procedures. Accessory products include sterile drapes used to help ensure a sterile field during surgery, vision products, such as replacement 3D stereo endoscopes, camera heads, light guides, and other items that facilitate use of the Surgical System, da Vinci [10].



**Figure 1.** The Surgical System da Vinci [1].

## 2. ACTUAL STAGE

At present, there are only a few surgical robots in the hospitals and clinics in Romania, but the trend of acquiring new appliances, especially in the private environment, is increasing. Annually, over 150 surgeries are performed through this surgical technique. Robotic Assisted Surgery, also called Robotic Surgery, involves the use of a revolutionary system that includes an arm equipped with a high-resolution camera and several mechanical arms with surgical instruments. They are particularly flexible and are connected to a computer console that is operated by the surgeon. The surgeon's surgeon controls the robot's arms with increased safety, enjoying high-resolution 3D imaging. The first private Robotic Surgery Center in Romania operates in Brasov, at Saint Constantine Hospital, with the installation of the Surgical Robot, da Vinci Si, acquired through an investment of 2 million euros [2]. Monza Hospital in Bucharest, the largest hospital for cardiovascular surgery and interventional cardiology in the country, has invested over 2 million euros for the purchase of the Surgical System da Vinci. Robotic surgery is used in interventions that treat a wide range of conditions: coronary diseases, renal and biliary disorders, colon cancer, gynecological, thyroid, prostate, bladder, obesity, uterine fibroids, major uterine bleeding [6]. The development strategy of Monza Hospital includes the development objectives of hospital. It sets out the priority measures and actions to achieve these objectives. Monza Hospital, is specialized in performing complex surgery interventions and in providing high performance integrated medical services. The hospital is equipped with the highest quality equipment, produced by world leaders in medical technology [3]. Ponderas Academic Hospital is the only private hospital in Romania with 5 international accreditations, providing complete, integrated medical services (hospital, polyclinic, imaging) and covering all medical and surgical specialties. Ponderas Academic Hospital launched the first integrated minimal invasive and robotic surgery program in Romania. Using the world's most advanced robotic surgery system, the Surgical System da Vinci Xi offers an extensive range of robotic minimally invasive surgical interventions for: oncologic surgery, cardiology, digestive surgery, urology, gynecology and thoracic surgery. The team of professionals at Ponderas Academic Hospital has performed over 30.000 minimally invasive operations and over 1.000 robotic surgeries so far. The last two robots installed at the Ponderas Academic Hospital (one for the surgery room and the other for the surgeon training)

are from the latest model (the Surgical System, da Vinci Xi) and are a premiere for the Romanian private health system (Figure 2)[5].



Figure 2. Robotic Surgery Center in Romania [2].

## 3. IDENTIFICATION

The Surgical System da Vinci has three parts:

- The vision cart video system where the surgeon follows surgery on a 3D HD screen
- The patient cart the patient-connected robotic assembly of Endo-Wrist instruments
- The surgeon console, where the surgeon manages surgical instruments with joysticks and pedals.

Although similar to standard laparoscopic instruments, robotic instruments have the added advantage of being articulated. This allows instruments not only to close and open, but to perform complete twists and turns, allowing for a more faithful mimicking of the human hand and wrist. But unlike the human hand, these tools are much smaller. Many of the jaws of the instruments are similar or shorter in length than the nail. This allows very small and precise incisions. The robot also allows the surgeon to measure hand movements. A hand movement on the consoles can be translated a precise microdissection. The robot can also filter the shaking of the hand, increasing accuracy. Another advantage of this system is that it significantly reduces the fatigue of the surgeon associated with traditional laparoscopic surgery, allowing the surgeon to remain in a natural, comfortable position during surgery. During a laparoscopic operation, the vision is of a single room, which limits the surgeon to a 2D view similar to watching television. The robotic video camera is made up of two high-resolution cameras connected by optical fiber. This room reproduces a 3D color image to the surgeon sitting at the da Vinci console. With these cameras, the image can be enlarged up to 10-12 times. A central robotic arm places the camera and illuminates exactly where the surgeon wants it because it is maneuvered using foot pedals while the doctor is comfortable sitting in front of the console. Also, two different rooms are

available one right and one oblique, 30 degrees. The oblique room allows the surgeon to see around the corners. These components are one of the most advanced visualization systems available [6]. Intuitive Surgical company released a new version of the Surgical System, da Vinci, the Xi (Figure 3), which is optimized for complex procedures:

- a new overhead instrument arm architecture designed to facilitate anatomical access from virtually any position.
- an ability to attach the endoscope to any arm, providing flexibility for visualizing the surgical site.
- a new endoscope digital architecture that creates a simpler design with improved visual definition and clarity.
- smaller, thinner arms with newly designed joints that offer a greater range of motion than ever before.
- longer instrument shafts designed to give surgeons greater operative reach [7].



**Figure 3.** The Surgical System da Vinci Xi [1].

#### 4. CHARACTERISTICS

The Surgical System da Vinci is the only available technology, that gives the surgeon the precision, dexterity and control of open surgery, using incisions of only 1-2 cm. The Surgical System da Vinci consists of the ergonomically designed surgeon's console, the patient's cart with three or four robotic arms, a high-performance video system and Endo-Wrist instruments. The robotic arms move around the pivot points. One arm holds the video camera and the others hold Endo-Wrist instruments that are designed with seven degrees of freedom. This type of instruments presents advantages over conventional laparoscopic instruments such as: reduction of physiological human tremor, finger-tip control, motion scaling. There is a great variety of Endo-Wrist instruments that allow a quite large variety of surgical procedures such as monopolar and bipolar cautery

instruments [9]. As the manipulator surgeon handles, the Surgical System da Vinci responds in real time to the signals received from the console, transmitting the movements of the hands, the joint of the fist and its fingers, in precise movements of the miniaturized instruments from the card next to the patient. Clinical studies show that the facilities provided by the Surgical System da Vinci help the surgeon to achieve better clinical results than conventional open or minimally invasive techniques allow. During the operation, the Surgical System da Vinci, will perform millions of safety checks. The system is designed to be protected from errors, which means that in the event of a voltage drop or in the event of an error in the self-tests performed, the system will stop safely, allowing the surgeon to keep control over the operation [4]. The technical specifications of the da Vinci Robot are described in Table 1.

**Table 1.** Technical Specifications of da Vinci Robot [7].

Length	127 cm
Width	91.5 cm
Height	175.3 cm
Weight	544.3 kg
Power	120 V AC
Actuators	DC motors
Computing	Microcontrollers
Software	Custom OS and control software
Sensors	Infrared sensors and optical encoders

#### 5. EVALUATION

The system reproduces the movements of the surgeon's hand using laparoscopic instruments. Surgical System da Vinci cannot act on its own, nor can it be programmed. It executes the orders the doctor gives in real time [2]. With the robot, the surgeon is no longer standing (but sitting), using the console (which can be in or out of the operating room), and handles the robot arms (with 2 joysticks and 2 pedals). The screens are 3D HD and display a magnified view tens of times and are designed to monitor the intervention. The robot communicates with the equipment in the operating room and accesses the computer system. The surgeon can consult during surgery, radiographs, tomographies or other investigations of the patient. Attached to the robot arms are Endo-Wrist articulated surgical instruments (allowing 7 degrees of freedom movement) with rotation potential at 540 degrees. The operating table can be repositioned during surgery and the system rotates 360 degrees around the patient (Figure 4)[6]. Among the most important indicators of the technical performance of the surgical robot we can mention the following: advanced reliability, high automation degree, complex modularity, increased stiffness, very high accuracy, adapting to the Green concept, immediate recycling.



**Figure 4.** The Surgical System da Vinci SP [1].

Since the introduction of the Surgical System da Vinci over 5 years ago, it has been used successfully in tens of thousands of surgical procedures. Its safety and effectiveness are proven in dozens of specialized articles. The articles that support the da Vinci technique cover an extensive area of surgical interventions, covering all the surgical specialties in which it is used [4]. The advantages and disadvantages of nonconventional over conventional surgery, are described in Table 2 and Table 3.

**Table 2.** The advantages of robotic versus laparoscopic [9].

Nonconventional surgery	Conventional surgery
<ul style="list-style-type: none"> <li>• Tremor filtration</li> <li>• Intuitive movements</li> <li>• Better hand-eye coordination</li> <li>• Improved dexterity</li> <li>• Ability to scale motions</li> <li>• Seven degrees of freedom</li> <li>• Micro-anastomosis possible</li> <li>• Ergonomic position of the Surgeon</li> <li>• 3D view/high definition image</li> </ul>	<ul style="list-style-type: none"> <li>• Easily accessible and affordable</li> <li>• Well established technology</li> <li>• A certain degree of tactile feedback</li> </ul>

**Table 3.** The disadvantages of robotic versus laparoscopic [9].

Nonconventional surgery	Conventional surgery
<ul style="list-style-type: none"> <li>• Absence of the sense of touch</li> <li>• Enlarged team to operate</li> <li>• Longer set-up time</li> <li>• Very expensive</li> </ul>	<ul style="list-style-type: none"> <li>• Enhanced physiological tremor</li> <li>• Limited degrees of freedom</li> <li>• Counterintuitive movements</li> <li>• 2D visualization</li> <li>• Low dexterity</li> </ul>

## 6. SWOT ANALYSIS

### 6.1. Strengths

- The surgeon operates millimeter. The Surgical System da Vinci allows operations in a much more functional way. The surgeon's movements allow for high precision and accuracy.
- The surgeon operates ergonomically. The Surgical System da Vinci is easy to handle,

significantly reducing the surgeon's fatigue. The doctor's position on the console is ergonomic and comfortable. The robot arms are strong and secure.

- The surgeon sees and moves better. The Surgical System da Vinci offers the doctor several degrees of freedom on the move. The robot arms can rotate completely, allowing for natural movement using very small tools.
- The surgeon performs safer movements. The Surgical System da Vinci scans the surgeon's movements. A movement of the surgeon on the console is translated by the robot into a safer movement. The robot filters the inherent tremors of the hand, increasing the precision of the movement.
- The surgeon reaches hard-to-reach areas. The Surgical System da Vinci allows the surgeon to reach narrow and hardly accessible anatomical spaces. Robotic surgery has thus proven its superiority to classical surgical surgery.
- Flexibility and comfort for the patient. With the help of robotic surgery it is possible to perform surgical interventions that would be particularly difficult, risky or even impossible through classical surgery.
- The benefits of using the Surgical System da Vinci are: increased precision, smaller incisions, increased safety, decreased risk of bleeding and infection. In addition, postoperative recovery is much faster and scars are smaller [5].

### 6.2. Weaknesses

- The system is dependent on the surgeon. The Surgical System da Vinci can not be reprogrammed and can not take decisions alone. The system requires that each maneuver is performed under the surgeon's direct control.
- Doctors have a great time. An advanced surgeon prepares in 15 years. Ponderas Academic Hospital is the only private hospital in Romania that has developed a training center where doctors are trained in robotic operations [5].

### 6.3. Opportunities

- Doctors are involved in the training of other doctors. The training center collaborates with ARCE (Romanian Association for Endoscopic Surgery), SECE (European Society of Endoscopic Surgery) and newly established CRCR (Romanian Club of Robotic Surgery) and is involved in the education and training of doctors, research, exchange of experience with centers of international expertise and standards setting in robotic surgery in Romania [5].

### 6.4. Threats

- Maintenance of robots is extremely expensive. By using robots, hospitals could reduce their costs, but they may not be sufficient to justify system spending. In addition, costs must also be understood in what is gained by this type of robotic surgery: reduced hospitalization, reducing the number of complications that would affect the quality of life [5].

## 7. STATISTICAL ANALYSIS

Intuitive Surgical held the leading position in the United States robotic surgery market in 2018. Intuitive received approval for their first-ever da Vinci robotic system in 2000. Additional da Vinci systems such as the da Vinci S were commercialized in 2006 and the da Vinci Si in 2009, but Intuitive’s flagship product, the da Vinci Xi, was launched in 2014. Intuitive Surgical is expected to remain the market leader, fueled by revenue from procedures and service and maintenance fees [8]. Intuitive Surgical generates revenues from da Vinci products and accessories sales. The company enters into service contracts with customers. The revenues have grown from \$343 million in 2012, to \$582 million in 2017. In the coming years, we expect Intuitive Surgical’s services revenues to grow [12]. The company reported for the fiscal year 2017, earnings of \$660 million, with an annual revenue of \$3.129 billion, an increase of 15.7% over the previous fiscal cycle. The company shares traded at over \$307 per share, and its market capitalization was valued at over \$58 billion [11]. Finances are described in Table 4.

**Table 4.** 2007-2017 Finances of the Intuitive Surgical [11].

Year	Revenue	Net income	Total Assets	Price per Share
2007	mil. \$601	mil. \$145	mil. \$1,040	\$61.82
2008	mil. \$875	mil. \$204	mil. \$1,475	\$85.48
2009	mil. \$1,052	mil. \$233	mil. \$1,810	\$61.58
2010	mil. \$1,413	mil. \$382	mil. \$2,390	\$104.33
2011	mil. \$1,757	mil. \$495	mil. \$3,063	\$122.21
2012	mil. \$2,179	mil. \$657	mil. \$4,059	\$172.93
2013	mil. \$2,265	mil. \$671	mil. \$3,950	\$149.97
2014	mil. \$2,132	mil. \$419	mil. \$3,959	\$147.55
2015	mil. \$2,384	mil. \$589	mil. \$4,907	\$169.00
2106	mil. \$2,704	mil. \$736	mil. \$6,487	\$212.10
2017	mil. \$3,129	mil. \$660	mil. \$5,758	\$307.18

Could your next surgery be done by a robot? With procedure volumes rising, there’s a good chance that this will be the case. Mirroring the quick-paced nature of new technological innovations, the surgical robotics market has experienced significant prosperity recently, which is expected to continue through 2025. Currently valued at over \$3 billion, this market is expected to surpass \$7 billion by 2025 [8].

## 8. CONCLUSIONS

The Surgical System da Vinci is a system based on artificial intelligence, interposed between the surgeon and the patient. Faced with classical open surgery, surgery with the Surgical System da Vinci is a huge technological step, with important advantages for both the patient and the surgeon. In the future, with the help of a very well trained team and remote telementoring, robotic systems with smaller instruments, lower overall costs, shorter set-up time will become available.

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