New Robotic Platforms

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Ludovica Baldari, Luigi Boni, and Elisa Cassinotti

25.1 Background

25.1.1 Limits of Endoscopic Surgery

Minimally invasive surgery has been performed for over 30 years leading to a new era, but improvements in instrumentation lagged behind the clinical developments. Standard laparoscopic instruments are rigid and can be opened and closed in order to catch or cut, allowing five degrees of freedom (DoF): in/out, up/down, left/right, rotation, open and close of the jaw [1]. Specific tasks are difficult to perform with standard laparoscopic instruments, including suturing in a horizontal direction or reaching some abdominal regions and organs, especially when a lateral approach to tissue is necessary [2].

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/978-3-031-33020-9_25.

L. Baldari (✉)
Department of General and Minimally Invasive Surgery, Fondazione IRCCS Ca' Granda Ospedale Maggiore Policlinico, Milan, Italy
e-mail: ludovica.baldari@policlinico.mi.it

L. Boni · E. Cassinotti
Department of General and Minimally Invasive Surgery, Fondazione IRCCS Ca' Granda Ospedale Maggiore Policlinico, Milan, Italy
Department of Clinical Sciences and Community Health, University of Milan, Milan, Italy
e-mail: luigi.boni@unimi.it; elisa.cassinotti@policlinico.mi.it

G. Ceccarelli, A. Coratti (eds.), *Robotic Surgery of Colon and Rectum*, Updates in Surgery, https://doi.org/10.1007/978-3-031-33020-9_25

25.1.2 From Endoscopic Surgery to Robotic Surgery

Robotic surgery provides the same patient benefits as laparoscopy without the limits of traditional tools. Indeed, the end effector of robotic instruments is equipped with a miniaturized wrist achieving seven DoF: in/out, up/down, left/right, rotation, flexion/extension of the wrist, abduction/adduction of the wrist, open and close of the jaw [3]. Nevertheless, these benefits are associated with substantial financial costs.

As several key patents expired in 2019, competing companies are now allowed to adopt these technologies. Thus, in the last few years, many companies have developed new robotic platforms, applying for Food and Drug Administration (FDA) approval in the United States and for CE marking in the European Union for clinical use. This chapter will provide an overview of new robotic platforms already approved for clinical use.

25.2 New Robotic Platforms

New Robotic Platforms can be classified according to some of their features:

- *Console, closed or open*: the closed console allows the operator to fix her or his head in position without any alteration of the field of view during the procedure. By contrast, in the open console the operator is free to move her or his head, can achieve a better communication with the operating room team and has a view of the operating room.
- *Operating units*: the operating units can be boom-mounted, units mounted on multiple carts, or table-mounted.
- *Kinematics*: remote center of motion kinematics, or general serial kinematics.
- *Haptic feedback*: some robotic platforms are equipped with haptic feedback from the robot to the operating surgeon, which can result in a reduction of the force applied [4].
- *Augmented intelligence*: some systems can be provided with software that enables camera movement according to instrument movements [5].

25.2.1 Senhance Surgical Robotic System

Originally developed by SOFAR SpA (Milan, Italy) and called TeleLap Alf-X, this system was renamed after being acquired by TransEnterix (Morrisville, North Carolina, USA). Apart from the da Vinci by Intuitive, it is the only new robotic platform that has both the CE mark and FDA approval for general surgery. The Senhance surgical system has a seated-open console with 2D or 3D monitor, according to surgeon preference, keyboard and touch pad and a single pedal. The robot can control up to four detached and independent robotic arms. The platform provides advanced eye-sensing camera control, enabling the surgeon to maneuver the camera through eye movement and forward and backward head movement for zooming. The system has haptic feedback integrated in it, allowing surgeons to feel tissue consistency and force applied. One of the main advantages of the Senhance system is the reduced cost, as it utilizes a set of reusable non-wristed 5-mm laparoscopic instruments. However, this also represents a limit, because lack of articulation implies a decrease in dexterity: one of the main features of any robotic system [6].

In 2019, the TransEnterix's Senhance Ultrasonic System received FDA approval. It is an advanced energy device that couples with the Senhance robotic platform, allowing a better hemostasis through high-frequency vibration that denatures proteins with minimal thermal spread. Moreover, the system offers 3-mm instruments for microlaparoscopy. The Senhance includes a "machine vision system", which is a form of augmented intelligence that moves the camera according to instrument movements. This tool will learn procedure steps and how the surgeon approaches the cases [7].

McKechnie et al. published a systematic review on six observational studies including 223 patients who underwent colorectal procedures with the Senhance Surgical Robotic System. The authors concluded that the system has an acceptable safety profile, reasonable docking and console times, low conversion rates, and an affordable case cost across a variety of colorectal surgeries [8].

25.2.2 Cambridge Medical Robotics Versius System

Developed by Cambridge Medical Robotic Limited (CMR Ltd), the Versius system has obtained the CE mark, while FDA approval is still pending. The platform has an open console that allows both standing and sitting according to operator preference, with an HD-3D monitor. There is no foot pedal control, as all the functions are managed by the joystick controllers, including the camera (Fig. 25.1a). One of the main advantages of the system is the small and modular design of the independent cart-mounted robotic arms providing versatility to the system (Fig. 25.1b). With an arm footprint of 38 cm x 38 cm, the system is intended to be a versatile platform that can be moved between operating rooms and stored outside them. The surgeon can use up to five arms that allow 360° wrist motion thanks to the V-wrist technology with maximum freedom of port placement. The costs are reduced thanks to reusable wristed 5-mm instruments allowing seven DoF [9].

Some case series on colorectal resections using the Versius platform have been published. In all of them, the authors concluded that colorectal resections are feasible and safe even in the case of oncological procedures [10–12]. Moreover, they stated that the system presents dexterity and intuitive movements, allowing oncological safety throughout the procedure [12].

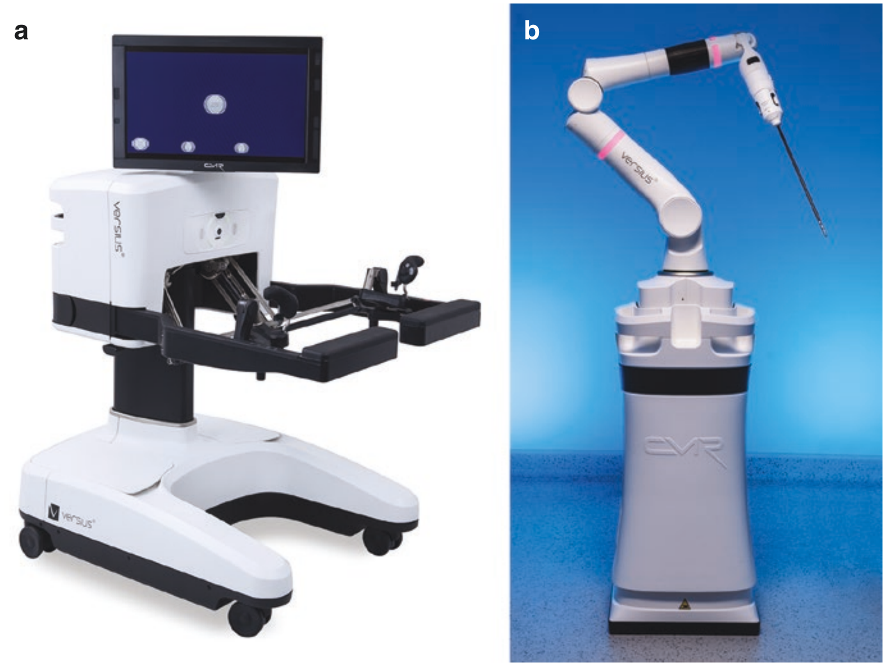

Fig. 25.1 (**a**) CMR Versius system console. (**b**) CMR Versius system operating units. Reproduced with permission from CMR Surgical

25.2.3 Hugo Robotic-Assisted Surgery System

The Hugo system is a robotic platform created by Medtronic, following the acquisition of German-based robotic system MicroSurge as part of the acquisition of Covidien in 2014. The system is a modular platform composed mainly of three elements: the Hugo vision cart, the modular robotic arms and the surgeon control console (Fig. 25.2). The Hugo vision cart is provided with a Karl Storz vision system that allows 2D and 3D visualization with fluorescence-guided surgery capabilities, the Valleylab FT10 energy generator for surgical instruments, a touch surgery video and recording analytics. The surgeon control console has a seated, semi-open design allowing fixed field of view during the procedure and, meanwhile, the possibility of interacting with the patient and operating staff more freely. Each robotic arm is attached to an individualized cart, allowing flexibility of placement and mobility, using seven DoF instruments. The design is more cost-effective than that of the da Vinci robot due to its more durable surgical instruments [13].

The Hugo does not have FDA approval, but it recently obtained CE mark for general abdominal surgery.

Fig. 25.2 Hugo robotic-assisted surgery system. Reproduced with permission from Medtronic

25.2.4 Revo-i Robotic Surgical System

In 2015, the Korean Meere Company developed the Revo-i system, a master-slave platform similar to the da Vinci robot. It is made up of three components: the 3D-HD vision cart, a seated-closed surgeon control console, a four-arm robotic operation cart. The closed console allows fixed position of the head and is provided with handles and pedal control, and precisely transfers the surgeon's hand movements to the robotic arms. The operating cart supports four arms with 12 DoF that can be equipped with instruments that can be reused up to 20 times, reducing the costs of the platform [14, 15].

The company developed the RevoSim, a virtual reality training system through which surgeons can gain proficiency in using the platform. The Revo-i received approval for commercial use in Korea, but it has not received FDA approval or CE mark.

25.2.5 Avatera Surgical System

The Avatera system is the result of a joint venture between Avateramedical (Jena, Germany) and Force Dimension (Nyon, Switzerland) and it has received the European CE mark. It is provided with a seated and semi-open console with 3D-HD resolution. The four robotic arms are mounted on a single cart, with 5-mm instruments with forceps-like handles and seven DoF. Some of the advantages include the absence of fans, which decreases the noise level, and the space-saving compact design. The company has developed a training program including virtual reality simulator and on-site training [16].

25.2.6 Hinotori Surgical Robot System

The Japanese companies Kawasaki Heavy Industries and Sysmex, through a joint venture, created Medicaroid that developed the Hinotori system. It consists of the surgeon semi-open console, the vision unit and the operation unit. The vision unit provides 3D HD images and supports audio communication between surgeon and assistants. The operation cart is made up of four arms attached to a single cart and instruments with eight DoF [17, 18].

The Hinotori system received Japanese regulatory approval, but it has not received FDA approval or CE mark.

25.2.7 Dexter Robotic System

The Dexter system is produced by the Swiss company Distalmotion. It provides a seated or standing open console, with a single foot pedal controller. The surgeon remains sterile while operating from the console, allowing to readily switch between laparoscopy and robotic surgery (Fig. 25.3a). The two independent cart-mounted

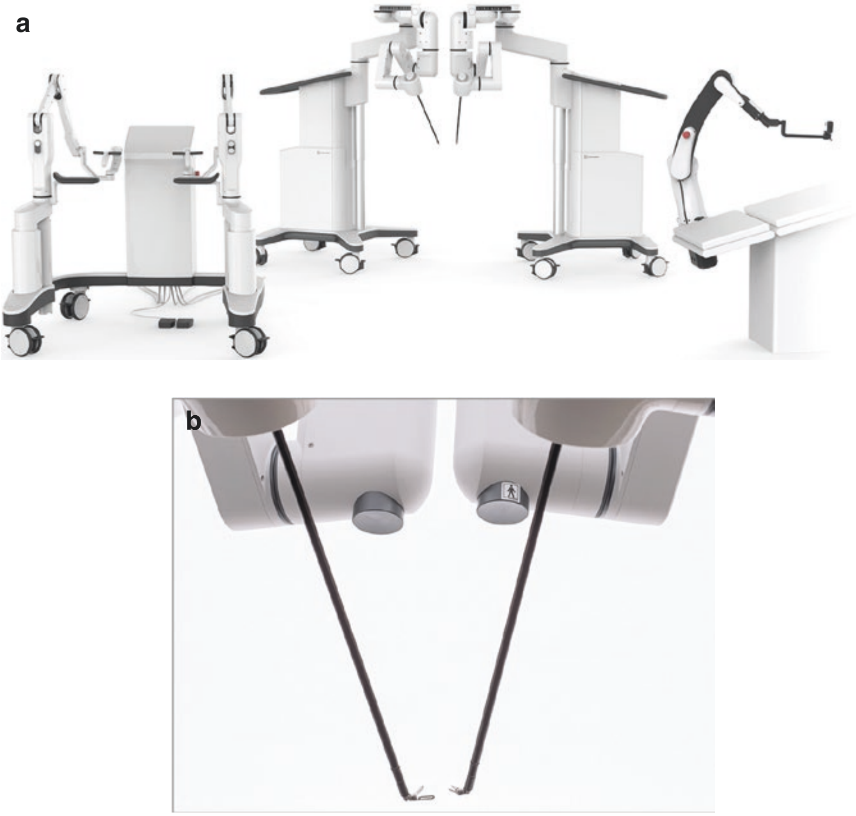

Fig. 25.3 (**a**) Dexter robotic system. (**b**) Dexter robotic system's articulating instruments. Reproduced with permission from Distalmotion

robotic arms are provided with single-use 8-mm instruments for suturing and dissection (Fig. 25.3b). The system integrates into any laparoscopic setup, preserving established laparoscopic trocar position. The platform can be used with any 3D commercial laparoscopic tower and is designed to be able to integrate future imaging technology. The Dexter system comes with an integrated robotic endoscope holder, compatible with all 5-mm and 10-mm endoscopes, that can be mounted on a cart or clipped to the bed and is controlled by the surgeon console [19].

The system has received the European CE mark.

25.3 Conclusion

The current state of the robotic approach in colorectal surgery is still dominated by the da Vinci surgical system. However, the development and the introduction of these new robotic platforms could change the spread of the robotic approach. Despite the increasing use of these platforms in surgery, there are still few literature data comparing the systems. Further data will be necessary to assess costs, clinical outcomes and sustainability.

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