Chapter 3
Operating Platforms for Surgical Endoscopy

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Introduction

The field of surgical endoscopy has experienced a sharp rise and adoption of technology, and evolved significantly over the last four decades. From the introduction of the first digital endoscope to the implementation and utilization of operating platforms for surgical endoscopy, the field as a whole has seen an influx of ground-breaking technology and innovative solutions to provide minimally invasive treatments for a variety of gastrointestinal pathologies. While traditional endoscopes provide access to the gastrointestinal tract, more novel task-specific operating platforms have been developed out of necessity to assist the surgeon or endoscopist in the treatment of multiple conditions. These platforms may include fully integrated optics and visualization platforms or rely upon visualization from traditional endoscopes (Table 3.1).

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Table 3.1 Summary of operating platforms

Available Surgical Endoscopy Platforms	Company	Pre-Clinical Data	Clinical Studies	FDA Approval	Commercially Available in US	Number of Instrument Channels	Platform Length (cm)	Outer Diameter (mm)
Endoscopic-Assisted Platforms								
Direct Drive Endoscopic System (DDES)	Boston Scientific (Marlborough, MA, US)	Yes	No	No	No	3	55	22
Incisionless Operating Platform (IOP)	USGI (San Clemente, CA, US)	Yes	Yes	Yes	Yes	4	110	18
Endomina System	Endo Tools Therapeutics (Gosselies, Belgium)	Yes	Yes	No	No	1	–	20
DiLumen C2	Lumendi (Westport, CT, US)	Yes	Yes	Yes	Yes	–	125	11.8

LumenR	Boston Scientific (Marlborough, MA, US)	Yes	Yes	No	No			
Integrated Visual Platforms								
EndoSamurai	Olympus (Tokyo, Japan)	Yes	No	No	No	3	103	18
ANUBIScope	IRCAD and Karl Storz (Strasbourg, France and Tuttlingen, Germany)	Yes	Yes	No	No	3	103	16
Flex Robotic System	Medrobotics (Raynham, MA, US)	Yes	Yes	Yes	No	2	28	18
Robotic Platforms								
ViaCath System	Auris Health (Redwood City, CA, US)	Yes	No	No	No	–	90	16

(continued)

Table 3.1 (continued)

Available Surgical Endoscopy Platforms	Company	Pre-Clinical Data	Clinical Studies	FDA Approval	Commercially Available in US	Number of Instrument Channels	Platform Length (cm)	Outer Diameter (mm)
Master and Slave Endoscopic Robot (MASTER)	Nanyang University (Singapore)	Yes	Yes	No	No	2	154	22
Endoluminal Surgical (ESL)	ColubrisMX (Houston, TX, US)	Yes	Yes	No	No	–	–	–
Other Gastrointestinal Platforms								
Invendoscopy E200 System	Invendo Medical (Kissing, Germany)	Yes	Yes	Yes	No	1	200	
NeoGuide Endoscopy System	Intuitive Surgical (Sunnyvale, CA, US)	Yes	Yes	Yes	No	1	161	20

Aer-O-Scope System	GI View (Ramat Gan, Israel)	Yes	Yes	Yes	No	2	230	13
Sightline ColonoSight	Stryker GI (Haifa, Israel),	Yes	Yes	Yes	No	3	–	–
Endotics System	ERA Endoscopy Srl (Pisa, Italy)	Yes	Yes	Yes	No	–	180	17
Bronchoscopy Platforms								
Monarch	Auris Health (Redwood City, CA, US)	Yes	Yes	Yes	Yes	1	–	6
Ion Endoluminal Platform (IEP)	Intuitive Surgical (Sunnyvale, CA, US)	Yes	Yes	Yes	Yes	1	–	3.5

Despite multiple platforms having been designed for surgical endoscopy, few of these systems have successfully navigated the regulatory process and become commercially available in the United States (US). Mechanistically, perhaps the most important aspect in surgical endoscopy includes the issue of hysteresis—the phenomenon of a degradation in task performance due to tendon-sheath mechanisms (i.e., decreased responsiveness or control with increasing flexibility) [1]. Ensuring ideal responsiveness within the angulated gastrointestinal tract is critical. Furthermore, distal tip stability and the ability to deliver adequate and precise force in tortuous configurations continues to be challenging within the gastrointestinal tract. Other key technical aspects to platform design include the ability to create an effective space to perform the procedure (i.e., therapeutic zone), as well as ensuring visibility of end effector instruments. Each platform has attempted to address these barriers and improve upon perceived shortcomings in design. In this review, we will highlight the history of operating platforms within the field, describe current approaches and systems in practice currently, as well as preview the future of surgical endoscopy via robotic platforms.

History of Surgical Endoscopy

One of the most influential aspects of surgical endoscopy that led to the development of multiple operating platforms was the introduction of natural orifice trans-luminal endoscopic surgery (NOTES). NOTES was a technique that allowed access to the intra-abdominal cavity via the trans-oral, trans-vesicular, trans-colonic, or trans-vaginal route. This technique provided the realization that apposition of tissues, closure of transmural defects, and multiple other procedures could be successfully achieved in a minimally invasive fashion through natural orifices and thus avoid the associated morbidity of surgery [2–4]. This NOTES concept of flexible trans-luminal endoscopy was initially conceived in the early 2000s and grew to become a revolution in endoscopy—blurring the boundaries of endoscopy and surgery and igniting a paradigm shift in what was possible within the realm of gastroenterology [4, 5].

While these results were promising and ushered in a generation of forward thinking proceduralists and modernization, the NOTES technique was limited by the reproducibility of results and a lack of available endoscopic tools and platforms. In fact, in 2005, the American Society for Gastrointestinal Endoscopy (ASGE) and the Society of American Gastrointestinal and Endoscopic Surgeons (SAGES) created a working group called the Natural Orifice Surgery Consortium for Assessment and Research (NOSCAR) to discuss the state of NOTES and review several challenges of the technique [6, 7]. One of the fundamental barriers and critical areas of need to the expansion of NOTES was the development of multi-tasking operating platforms and need for instrumentation to help perform these minimally invasive procedures and manage potential complications.

These limitations, as well the lack of consistent reimbursement, rapidly decreased the use of NOTES and stifled its early popularity, with many surgeons opting instead for minimally invasive laparoscopic techniques [8]. Within the field of laparoscopy, robotic platforms, perhaps the most commonly utilized da Vinci Surgical System (Intuitive Surgical, Sunnyvale, CA, US), have seen a tremendous adoption. However, endoscopic platforms have not yet experienced this same success in translation to the patient and widespread adoption. Yet, despite this limitation in adoption and non-sustained momentum, the principles and concepts of surgical endoscopy sparked a revolution of innovation and development to produce future operating platforms within surgical endoscopy.

Traditional Endoscope-Assisted Visualization Platforms

Direct Drive Endoscopic System (DDES)

In effort to expand upon the concepts of NOTES and improve associated outcomes, a novel operating platform called the Direct Drive Endoscopic System (DDES, Boston Scientific, Marlborough, MA, US) was created. This DDES was a flexible multi-tasking laparoscopic platform that consisted of an overtube-like sheath which housed three channels [1, 3, 9]. These channels allowed for the interchange of multiple, separately-controlled articulating instruments through a single, flexible, access system [10]. This access system was composed of a 16 mm diameter sheath [9]. The platform was comprised of two articulating arms fitted to the tip of an overtube. An ultra-slim upper endoscope was then inserted through this overtube to provide visualization for the procedure, possessing the advantage of articulating instruments that were not synchronized with that of the endoscope [11]. A rail-based system was used to stabilize the platform and guide manipulation of the end effectors along with two drive handles, which allowed for seven degrees of freedom: surge, pitch, yaw, roll, tool action, heave, and sway (Fig. 3.1) [3].

Importantly, the instruments attached to the overtube could be grasping or scissor forceps—optimized to complement the specific procedure/task [12]. Furthermore, given the novel design, the platform did allow for suturing and knot tying. However, while these instruments varied to ensure the ideal endoscopic tool, the flexible instruments were traction cable-controlled, and therefore possessed the problem of hysteresis. Additionally, with a working length of 55 cm, the platform was unable to access pathology or perform procedures in the distal stomach or small bowel as well as the proximal colon. Another potential disadvantage of this system was the occasional need for two independent operators: one manipulating the two instruments while another

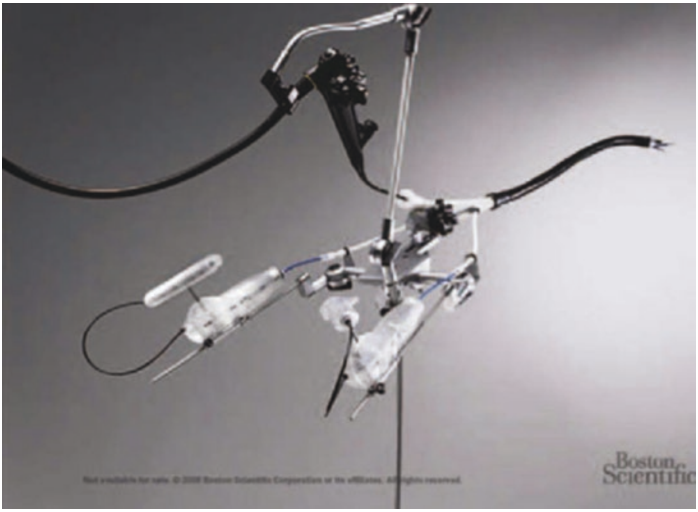

FIGURE 3.1 Direct Drive Endoscopic System (DDES, Boston Scientific, Marlborough, MA, US)

endoscopist performs conventional endoscopy using a standard endoscope through the overtube [10]. However, the endoscope could be parked in a stable position which could allow for a single operator to perform the procedure. Furthermore, given the angle of view and visual limitations, learning curves and challenges existed for surgeons and endoscopists. Perhaps, most importantly, the system did not allow for a channel dedicated to suction or irrigation—further limiting the visibility during complex procedures. At this time, the DDES is not commercially available and its use has been discontinued.

Incisionless Operating Platform (IOP)

Another multi-tasking surgical platform is the Incisionless Operating Platform (IOP, USGI Medical, San Clemente, CA, US). The platform is able to accomplish tissue apposition and possesses a unique market within the field of bariatric endoscopy. This USGI platform has received US Food and Drug Administration (FDA) 510(k) approval for general tissue apposition; however, the IOP itself does not have a specific indication for weight loss [13, 14]. Unlike the Apollo Overstitch device (Apollo Endosurgery, Austin, TX, US) which is an attachment to a traditional single channel, or more commonly double channel upper endoscope, the USGI system is a plication platform. The IOP can be used to perform primary endoscopic weight loss procedures, as well as endoscopic revisional procedures for patients with adverse events or complications from bariatric surgery (i.e., weight regain after sleeve gastrectomy or Roux-en-Y gastric bypass as well as management of gastrogastric fistula formation). There is robust clinical data to support its use for bariatric endoscopy [15–17]. Prior to its adoption within the field of bariatric endoscopy, this multi-functional, flexible surgery platform successfully performed NOTES—including cholecystectomy and appendectomy via trans-vaginal, trans-gastric, and trans-umbilical access [18]. The platform has also been utilized to perform anti-reflux procedures as well given its ease of use in the retroflexed position [19].

The IOP, specifically the TransPort system, is similar in appearance to a traditional endoscope; however, the system is larger with multiple ports and directional wheels at the user interface (Fig. 3.2) [3]. The TransPort device consists of a

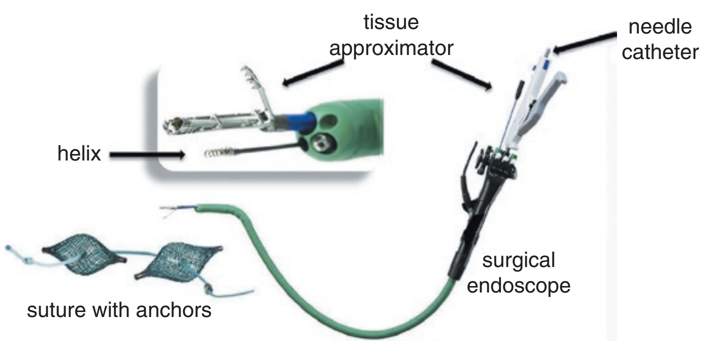

Figure 3.2 Incisionless Operating Platform (IOP, USGI Medical, San Clemente, CA, US)

110 cm by 18 mm overtube-like design with a steerable shaft and four channels (one 7 mm, one 6 mm, and two 4 mm). The 7 mm channel allows for the passage of an ultra-slim upper endoscope down the channel to provide visualization during the procedure. Outside of the TransPort system, the platform is composed of 3 specialized instruments: (1) g-Prox EZ Endoscopic Grasper, (2) g-Lix Tissue Grasper, and (3) g-Cath EZ Suture Anchor Delivery Catheter [15, 16]. The g-Prox is a flexible shaft with a grasper which closes at a 45 degree angle to the axis of the device shaft and allows for approximating full-thickness tissue folds. The g-Lix is a distal helical catheter designed to assist the g-Prox in capturing target tissue while the g-Cath is a catheter system with a hollow needle at its distal tip that, after advancement through the lumen of the gProx, penetrates the gastric wall and creates a plication using polyester mesh snowshoe tissue anchors to create durable serosal fusion [13, 20–22]. At present, the IOP is commercially available in both in the US and worldwide for the treatment of a variety of conditions.

Endomina System

Another bariatric plication platform within the field of surgical endoscopy, the Endomina system (Endo Tools Therapeutics, Gosselies, Belgium), performs tissue apposition and has received a CE mark in Europe. Despite approval in Europe, the device is not commercially available in the US. The Endomina system utilizes an over-the-scope triangulation platform to create transoral anterior-to-posterior greater curvature plications, thereby reducing gastric volume [22]. The platform has two instrument channels with a preloaded needle (TAPES, Endo Tools Therapeutics, Gosselies, Belgium) with suture that is introduced into the platform with a single interrupted suture secured by two T-tags anchors (Fig. 3.3) [23]. The platform is inserted over guidewires into the stomach and can then be opened and tightened around the endoscope which allows the proceduralist to assemble/detach the system when needed without the need for an over-

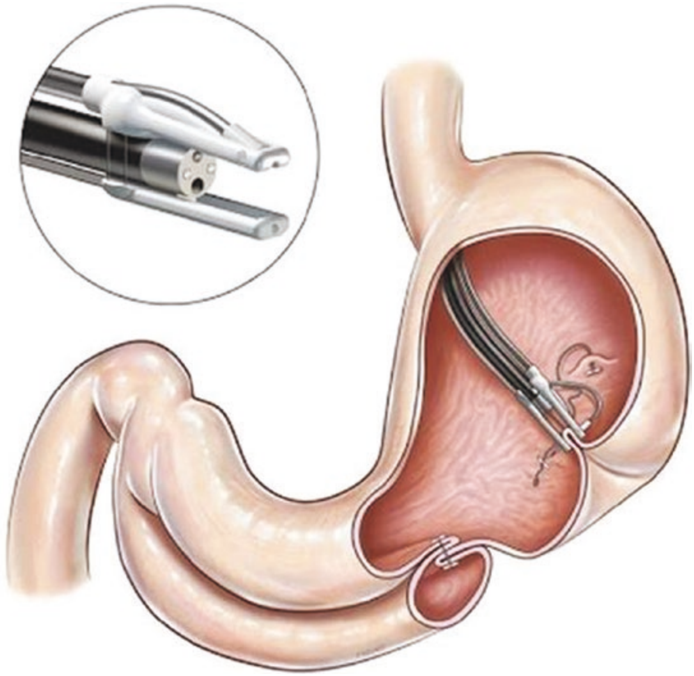

FIGURE 3.3 Endomina system (Endo Tools Therapeutics, Gosselies, Belgium)

tube nor need to remove the device [24]. Endoscopic forceps utilized through the working channel of the endoscope acquire gastric tissue inside the Endomina platform, and the needle for tissue piercing. Each TAPES needle is pre-loaded with two T-tag anchors which are connected by suture material. The anchors are then tightened using a snare until the formation of a tight serosa-to-serosa apposition [24]. In addition to bariatric endoscopy, the platform has also been studied in proof-of-concept cases performing endoscopic submucosal dissection (ESD) as well as endoscopic full-thickness resection (EFTR) [24, 25].

DiLumen C^2 and the Endolumenal Interventional Platform (EIP)

The DiLumen C^2 system (Lumendi, Westport, CT, US), including the Endolumenal Interventional Platform (EIP) is a multi-tasking non-robotic ESD platform specifically designed for endoluminal therapy. The platform was designed to improve stability and manipulation of tissue throughout the colon to overcome the complexity and technical issues with conventional ESD and to decrease the steep learning curve associated with training. Similar to the IOP, DiLumen C^2 is a single-use, disposable system that has received 510(k) approval by the US FDA. Currently, the DiLumen and DiLumenC^2 platform is commercially available and utilized worldwide. The device has been shown to be safe and effective as well as reduce the substantial learning curve when compared to conventional ESD [26–28]. The first incisionless appendectomy using the DiLumen interventional platform has also been described.

The dual balloon platform can be utilized with endoscope possessing an outer diameter of 8.9 to 11.8 mm and consists of a flexible sheath attached over a standard endoscope. The dual balloon system, one fore (distal) and one aft (proximal) balloon, aims to create a stable, therapeutic zone for endoluminal interventions [29]. The platform also includes two 6-mm working channels at the 3 o'clock and 9 o'clock positions of the hydrophilic sheath which allows for insertion of articulating endoluminal instruments, including interventional graspers, to assist with tissue dissection (Fig. 3.4). Each endoluminal device possesses a wheel and trigger mechanism to allow for rotation, opening, and closing of the device, while the joystick allows providers to control the articulation of the device. The endoluminal DeBakey jaws at the end of the device can be repositioned and can be locked into position at a specific orientation to facilitate visualization and tension on the tissue for dissection. The shaft of the device is 125 cm in length, with a 5 mm outer diameter for use in the 6 mm channel.

FIGURE 3.4 DiLumen C^2 system and Endolumenal Interventional Platform (EIP) [Lumendi, Westport, CT, US]

LumenR Tissue Retractor System

Initially designed by Sergey Kantsevoy and LumenR LLC (Oxford, Connecticut, US) and later acquired by Boston Scientific, the LumenR Tissue Retractor System (Boston Scientific, Marlborough, MA, US) was designed to improve endoscopic intraluminal removal of colorectal lesions and provide an alternative to invasive surgical resection [25]. This innovative platform aimed to improve ESD and endoscopic mucosal resection (EMR) for the removal of superficial neoplasms within the gastrointestinal tract. The system enabled enhanced visualization of lesions and created a stable working environment to perform dissection. The LumenR platform consisted of a flexible, multi-channel tube with an expandable operating chamber on its distal end, and two associated, specially designed, instrument guides [25]. These articulating guides allowed for four degrees of freedom and insertion of flexible endoscopic instruments (both traditional endoscopic tools and more novel instruments) to perform resection (Fig. 3.5).

The device, though associated with limited data in human cases, was designed to be fit over a pediatric colonoscope to perform endoscopic resection. The guides/arms were able to function to provide traction and ESD knives to facilitate easier dissection. While the device theoretically could be used

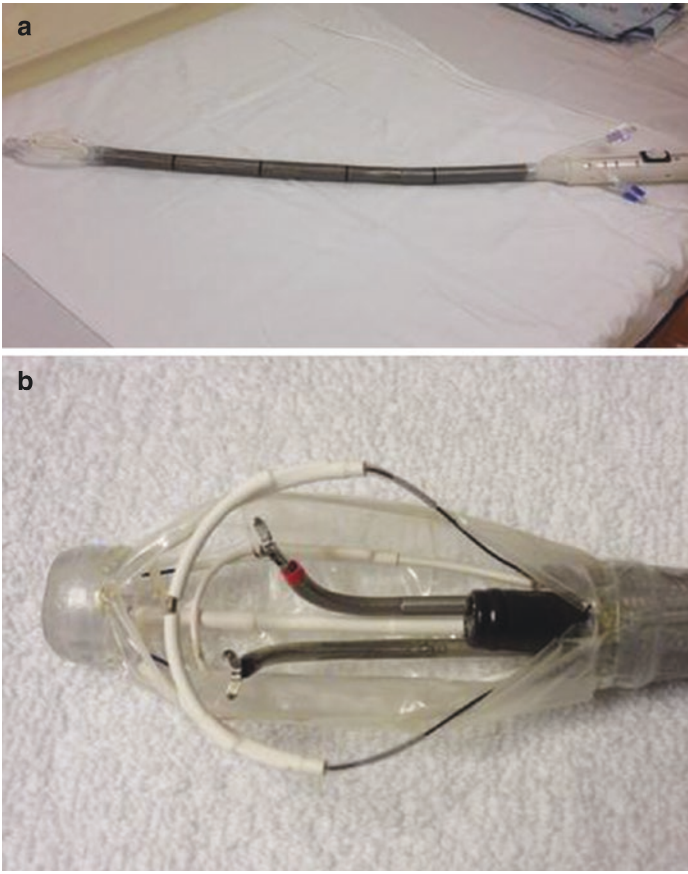

FIGURE 3.5 LumenR Tissue Retractor System. (**a**) Entire device. (**b**) Ebd effector close-up (Boston Scientific, Marlborough, MA, US)

to perform ESD in the upper GI tract as well, it was mostly studied in animal colon models which showed a significant decrease in learning curve and complete, *en-bloc* resection of lesions [30]. One published abstract detailed ESD in human cases [31]. At present, the device is no longer commercially available.

Integrated Visual Function Platforms

EndoSamurai

While we have discussed operating platforms that rely upon conventional endoscopic optics for visualization, the EndoSamurai (Olympus, Tokyo, Japan) is a multi-tasking platform with integrated visual function. The EndoSamurai is comprised of a 15 mm flexible endoscope integrated with lens irrigation function, insufflation/irrigation, two articulating arms, and one conventional operating channel [1]. The overtube-like sheath is similar to that of the DDES system as discussed above though is slightly largely in diameter at 18 mm. This system was designed to operate as a flexible laparoscopic hybrid platform with remote working station to mechanically control the articulating arms (Fig. 3.6) [9]. The working station is similar to robotic or laparoscopic instruments which likely translates to a reduced learning curve for surgeons with this expertise.

One of the main advantages of the EndoSamurai system is the customizability of the platform, allowing for multiple instrument types to assist the proceduralist; including use of standard endoscopic electrosurgical knives, grasper, and forceps—all without the need to remove the endoscope [1]. Again, similar to the DDES system, EndoSamurai requires two individual operators: one for guiding the overtube sheath

Fig. 3.6 EndoSamurai (Olympus, Tokyo, Japan)

and irrigation/suction channel and another to manipulate the articulating instruments [32]. With regard to the articulating arms, the instruments are very long and difficult to maneuver in the retroflexed position, thereby making it perhaps a more ideal platform for intraperitoneal procedures and less intuitive/useful for endoluminal therapies [1, 32]. Overall, data is confined mostly to ex vivo models at this time with limited data translating to human studies [33].

ANUBIScope

Beginning in 2005, the Institut de Recherche contre les Cancers de l'Appareil Digestif (IRCAD) and Karl Storz collaborated on the development of an endoscopic platform to address the need to treat complex endoluminal and transluminal conditions [34]. This collaboration eventually lead to an integrated visual platform called the ANUBIScope (IRCAD, Strasbourg, France, and Karl Storz, Tuttlingen, Germany). This prototype platform consists of a flexible, 110 cm long, four-way articulating endoscope with a 16 mm articulating vertebrae section and an 18 mm tulip-shaped distal tip [34]. The distal tip incorporates two opposing, articulating instruments that contain 4.2 mm working channels and a central 3.4 mm channel which allow for four degrees of freedom to perform dissection or suturing (Fig. 3.7). Unlike the EndoSamurai, an overtube is required for instrument exchange. However, the specialized instrument flaps limited platform maneuverability in narrow spaces with difficulty translating success in ex vivo models to human cases [1]. Similar to DDES and EndoSamurai platforms, the ANUBIScope suffers from difficulty with tip stabilization and articulation making the working arms more difficult to manipulate. Despite these limitations, the ANUBIScope platform received a CE mark. Subsequently a modified robotic system was created using a shortened version of the manual ANUBIScope platform [34, 35]. This newer generation platform has been studied to help providers perform ESD.

FIGURE 3.7 EndoANUBIScope (IRCAD, Strasbourg, France, and Karl Storz, Tuttlingen, Germany)

Flex Robotic System

The original Flex Robotic System (Medrobotics, Raynham, MA, US) was developed for minimally invasive transoral surgery of the oropharynx, hypopharynx, and larynx; however, its use was later expanded to endoluminal interventions and FDA cleared in 2007. This platform possesses the potential to reduce the steep learning curve associated with ESD and broaden the adoption of complex endoscopic procedures [36]. The Flex Robotic System is comprised of four main components: (1) a stable platform, (2) a console with a user interface to control movement of the robot, (3) a drive to execute robotic positioning, and (4) an instrument support assembly. The platform has a flexible and steerable distal end, providing access to lesions up to 25 cm from the anal verge. The dimensions of the flexible robotic scope are 18 mm by 28 mm, including two 4-mm working channels. The system allows for the simultaneous use of two manually controlled flexible instruments, including a complete set of 2.0–4.0 mm articulating instruments for grasping, cutting, and suturing under high-definition visualization. The flexible robotic scope is operated via a joystick which the articulating arms are manually manipulated, similar to flexible laparoscopic instruments (Fig. 3.8) [37, 38]. Despite not being entirely robotic, the platform was shown to improve *en bloc* resection and decrease length of procedures among novice ESD providers in ex vivo animal models [36, 39]. The articulating instruments are analogous to transanal endoscopic microsurgery (TEM) or

Figure 3.8 Flex Robotic System (Medrobotics, Raynham, MA, US)

transanal minimally invasive surgery (TEMIS). However, due to design and length of the device, the Flex Robotic System only allows for access to distal colorectal lesions up to 25 cm from the anal verge [36].

Robotic Platforms

ViaCath System

Initially developed by EndoVia (Norwood, MA, US), the ViaCath System was a first-generation teleoperated robotic platform for endoluminal surgery which utilized a working endoscope for visualization [40]. The system was comprised of a master console and a slave drive system with an instrument channel fixed alongside the endoscope via an overtube [41, 42]. The master console and the slave manipulators have a haptic interface, with seven degrees of freedom (Fig. 3.9) [43]. The system was developed based upon a previously designed laparoscopic surgical platform developed by EndoVia (i.e., Laprotek System) [44]. ViaCath has been shown to be effective in pre-clinical and in vivo animal testing [45]. However, there is limited data in human cases, as the manipulation forces are likely insufficient to navigate luminal folds and successfully perform endoscopic surgery [40]. In 2005, Hansen Medical (Mountain View, CA, US) acquired EndoVia. That same year, Hansen Medical and Intuitive

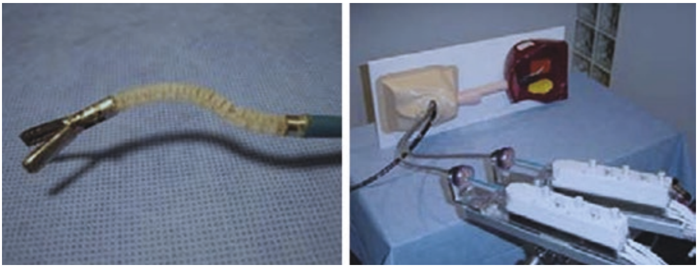

FIGURE 3.9 ViaCath System (Auris Health, Redwood City, CA, US)

Surgical entered into a cross-licensing agreement; however, Hansen was later acquired by Auris Health (Redwood City, CA, US). The ViaCath platform is no longer commercially available at this time.

Master and Slave Translumenal Endoscopic Robot (MASTER) System

The Master and Slave Translumenal Endoscopic Robot (MASTER, Nanyang University, Singapore) is a cable-driven flexible robotic platform that allows bimanual steering of two articulating instruments (Fig. 3.10). The MASTER platform also provides dexterity, triangulation, haptic feedback to maintain spatial orientation, and a navigation system that allows a three-dimensional reconstruction that can be utilized to maneuver in real time [46]. Similar to other platforms, MASTER requires two independent operators: the first operator controlling the master interface slave manipulator and the second directing the endoscope to the desired location and controlling suction/insufflation [38]. Despite demonstrating early improvement in training for ESD for treatment of gastric neoplasms, issues with hysteresis and haptic feedback have been noted to occur [47]. Pre-clinical and limited human studies have demonstrated the effectiveness of the MASTER platform when performing ESD for upper gastrointestinal tract lesions [48–51].

FIGURE 3.10 Master and Slave Translumenal Endoscopic Robot (MASTER, Nanyang University, Singapore)

Endoluminal Surgical (ELS) System

The Endoluminal Surgical (ELS) System (ColubrisMX, Houston, TX, US) is a next-generation, advanced flexible robotic system that has the benefit of being the first fully robotic endoscopic platform to be evaluated in US clinical trials (Fig. 3.11). The system is designed for upper and lower endoscopy and consists of a patient cart [including instrument controller, conventional flexible endoscope, flexible overtube (colubriscope), and mobile base cart as well as a surgeon console (including high-definition display, master controller, arm rest, and foot pedals). This innovative platform utilizes a flexible shaft with articulating wrist and elbow joints that have 7 degrees of freedom. There are a variety of instruments, including needle driver, pinching forceps, Cadière forceps, monopolar cautery knife, monopolar curved scissors, and rat tooth forceps. The additional working channel of the endoscope also allows for use of conventional endoscopic instruments. At present, the company is undergoing an investigational device exemption (IDE) clinical study to support FDA clearance.

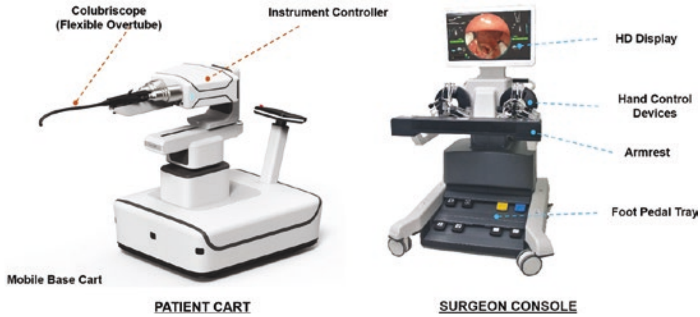

Figure 3.11 Endoluminal Surgical (ELS) System [ColubrisMX, Houston, TX, US]

Additional Gastrointestinal Platforms

Robotic operating platforms have also extended to traditional endoscopy as well. The Invendoscopy E200 system (Invendo Medical, Kissing, Germany) is a robotically assisted colonoscopy system that uses the single-use Invendoscope SC200 as the colonoscope. The handheld controller (ScopeController) is a joystick, which is detachable from the colonoscope (Invendo SC200) and allows for tip deflection, insufflation, suction, and image capture to be completed using only one hand [44, 52]. Similarly designed for diagnostic colonoscopy, the NeoGuide Endoscopy System (NeoGuide Endoscopy System, Los Gatos, CA, US) is a computer-aided colonoscope that utilizes computerized mapping to travel along the natural curves of the colon, resulting in less force applied to the walls of the organ [38, 52]. The scope is comprised of 16 electromechanically controlled segments which allows it to traverse the colonoscope in a snake-like pathway and reduce pressure and force applied to the colonic wall [52]. Perhaps most importantly, NeoGuide which was acquired by Intuitive Surgical (Sunnyvale, CA) in 2009, reduces the formation of colonic loops which may occur during colonoscopy—thereby potentially enabling the procedure to occur with little to no sedation. Multiple other self-advancing colonoscope systems are also underway including the Aer-O-Scope System (GI View, Ramat Gan, Israel), the Sightline ColonoSight (Stryker GI, Haifa, Israel), and the Endotics System (ERA Endoscopy Srl, Pisa, Italy) [53].

Bronchoscopy Platforms

Two additional platforms that are both FDA approved include the Monarch Platform (Auris Health, Redwood City, CA, US) and the Ion Endoluminal Platform (IEP; Intuitive Surgical, Sunnyvale, CA, US). Similar to the platforms designed for the gastrointestinal tract, the Monarch system and bronchoscope consists of an 130° articulating sheath and an inner bronchoscope that telescopes out of the sheath and can flex 180 degrees in any direction [54]. However, unlike current endoscopic models which are largely analogous to laparoscopic or endoscopic training or equipment, the teleoperated endoluminal bronchoscope model is similar to game controllers with two joysticks and minimal buttons [54, 55]. On the other hand, IEP is comprised of a single bronchoscope, catheter system, and robotic arm. Both platforms have shown promising results and are commercially available [56–61].

Conclusion

There are a variety of potential tools available to the surgeon and endoscopist. These operating platforms have attempted to address the need to provide minimally invasive treatment options for a variety of endoluminal interventions. As such, the field of surgical endoscopy has seen a dramatic shift toward innovation, pushing the boundaries of what is considered possible. In this review, we have discussed the history of the field, early platform designs, and innovative approaches, as well as highlighted new and future robotic options. While many of the operating platforms require more study, future design and innovation are likely to continue to blur the lines between surgery and endoscopy and radically change the future of operating through the endoscope [9].

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