Robotic-assisted surgical endoscopy: a new era for endoluminal therapies

Diogo Turiani Hourneaux de Moura, MD, MSc, PhD, Hiroyuki Aihara, MD, PhD, Christopher C. Thompson, MD, MHES

Minimally invasive endoscopic procedures are associated with lower adverse events and shorter hospital stays compared with conventional open surgery.[1,2] However, some advanced endoscopic procedures, including endoscopic submucosal dissection (ESD), natural orifice transluminal endoscopic surgery (NOTES), and suturing, have typically required specialized training and a certain amount of experience to achieve competency. Therefore, these procedures are not widely performed in nonspecialized centers.[3-6]

Despite the availability of a wide range of accessory devices, including distal attachment caps, electrosurgical knifes, hemostatic forceps, and suturing devices, the conventional flexible endoscopes used in clinical practice struggle to support the performance of advanced endosurgical procedures. They lack the dexterity required to perform useful maneuvers, such as triangulation of instruments and nonaxial tissue manipulation. Transmission of force from operator to point of action is often suboptimal because of the instability of the flexible endoscope. Additionally, the visual field is fixed by the direction of the endoscope, making visualization difficult when the field is constantly reoriented with any movement of the endoscope.[3,5,7,8]

Owing to the limitations of conventional flexible endoscopes and the long learning curves required for some technically challenging procedures, many different types of endoscopic robotic systems have been developed.[3] The main goal of robotic endoscopy is to improve precision, effectiveness, safety, and reliability to enhance the interventional capabilities of endoscopists and to augment the field of possible interventions. Available instruments include dissection tools, graspers, electrocautery

Figure 1. The robot's flexible distal end including 2 working channels with a needle-knife and grasper (image used with permission from Medrobotics, Raynham, Mass, USA).

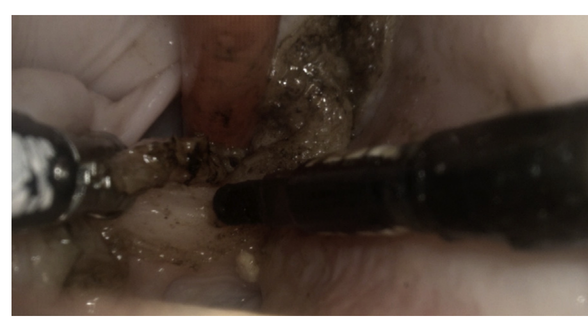

Figure 2. Bimanual control allowing better exposure during endoscopic treatment of a Zenker diverticulum.

Figure 3. Endoscopic submucosal dissection by use of a grasper to improve visualization and a needle-knife to dissect the tissue.

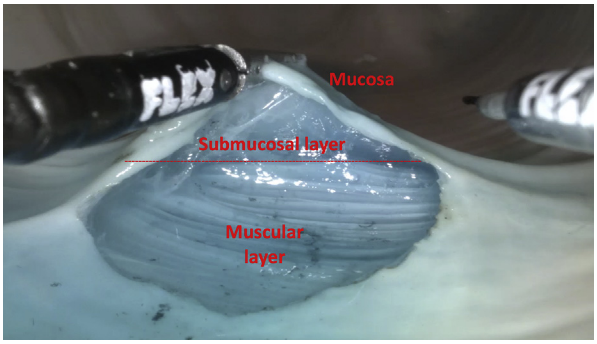

Figure 4. Robot-assisted endoscopic submucosal dissection providing better exposure of tissue layers, facilitating dissection.

Figure 5. Endoscopic submucosal dissection by use of a grasper to improve visualization and a scissors to dissect the tissue.

Figure 6. Robot-assisted full-thickness resection with use of a grasper and a spatula.

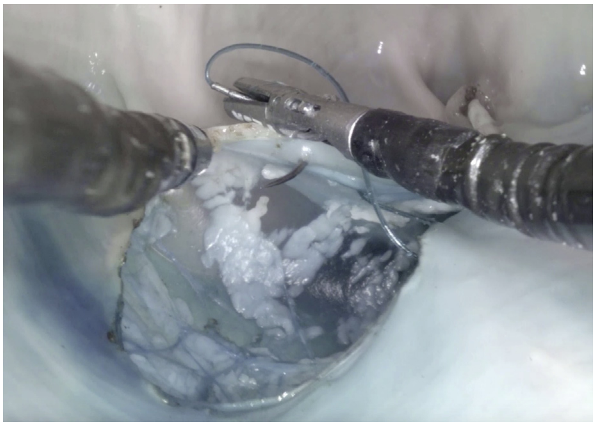

Figure 7. Endoscopic suturing with use of the robot system to close the defect after a full-thickness resection.

devices, and sutures. However, some problems still need to be addressed, including locomotion and instrument control, along with better understanding of clinical applications.[1,3,5,7,8]

In this video (Video 1, available online at www.VideoGIE.org), possible benefits of robotic assistance applied to complex tissue dissection and defect closure are demonstrated. Equipment characteristics, indications, contraindications, limitations, and possible adverse events are also discussed.

TOOLS AND TECHNIQUE

The original Flex Robotic System (Medrobotics, Raynham, Mass, USA) was developed for head and neck surgery to provide robotic positioning of flexible instruments and cutting devices. The system did not originally have a seal to maintain insufflation, which is required for GI procedures.[9-11] Recently, the device has been modified to maintain insufflation, allowing transanal access to the sigmoid colon and the deployment of compatible articulating instruments to facilitate tissue dissection. This system was cleared by the U.S. Food and Drug Administration in 2017.[12,13]

The robot has a flexible and steerable insertion tube, providing access to lesions up to 25 cm from the anal verge, and in the oropharynx, hypopharynx, and larynx. The dimensions of the flexible robotic endoscope are 18 mm × 28 mm, including two 4-mm working channels. The device provides bimanual control, which facilitates the use of 2 instruments. Additionally, a complete set of 2.0-mm to 4.0-mm instruments for grasping, cutting, and suturing are available (Fig. 1). This system also has automatic light control and 3-dimensional visualization with improved depth of field.

A system including a longer insertion tube is currently under development, targeting procedures in the upper GI tract and proximal colon.

In this video, we demonstrate the use of the robotic system in ex-vivo animal models as it is applied to 4 different procedures.

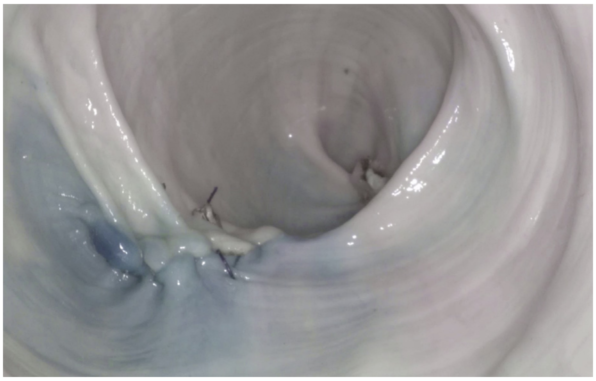

Figure 8. Final appearance after suturing a transmural defect after full-thickness resection.

Zenker diverticulum treatment

In this procedure, the robot provides a stable position for instrument triangulation in a rather small space. A grasper is used to better expose the tissue planes, and an electrocautery spatula is used to perform the myotomy (Fig. 2).

Robot-assisted ESD

The method used to perform ESD with the robotic system is similar to conventional ESD technique. First, an injection needle is positioned with grasper assistance to inject saline solution and methylene blue to provide a mucosal lift. Next, the grasper is used to hold the tissue and provide traction for better exposure and tissue tension to aid in dissection. In this case, scissors were used to perform the incision and submucosal dissection. However, this procedure can also be performed with other devices such as a spatula or needle-knife (Figs. 3 to 5).

Full-thickness resection

The bimanual control provided by the robotic system was particularly helpful in full-thickness resection. First, an incision was performed with a needle-knife, then traction was applied by use of a grasper, as with the previous ESD procedure. Subsequently, full-thickness resection was performed by use of a spatula, with the help of triangulation to avoid trauma to deep structures (Fig. 6). Another advantage of the system is the ability to close the defect with suturing after resection.

Suturing

The bimanual control and flexible arms are particularly useful for suturing. When a curved needle and barbed suture are used, most suture patterns are possible. The barbed suture also simplifies knot tying. In this video we demonstrate the closure of a transmural defect after full-thickness resection with running sutures (Figs. 7 and 8). The suturing applications for this device are likely broad and may also include antireflux and bariatric procedures.

ADVERSE EVENTS

Because of the relatively large size of the equipment, introduction and removal should be performed with caution. Additionally, as with any other therapeutic endoscopic procedures, adverse events such as perforation and bleeding can occur.

CONCLUSION

Robotic-assisted surgical endoscopy is technically feasible. This system appears to simplify complex procedures by improving visualization, exposure, and tissue manipulation. It has the potential to shorten the learning curve and broaden the adoption of challenging procedures, including tissue dissection, NOTES, suturing, and other techniques. Further clinical studies are warranted.

DISCLOSURE

Dr Aihara is a consultant for Boston Scientific, Fujinon, and Olympus. Dr Thompson is a consultant for Apollo Endosurgery, USGI Medical, Medtronic, Boston Scientific, and Olympus. The other author disclosed no financial relationships relevant to this publication.

Abbreviations: ESD, endoscopic submucosal dissection; NOTES, natural orifice transluminal endoscopic surgery.

REFERENCES

1. Lomanto D, Wijerathne S, Ho LK, et al. Flexible endoscopic robot. Minim Invasive Ther Allied Technol 2015;24:37-44.
2. Farias GFA, Bernardo WM, De Moura DTH, et al. Endoscopic versus surgical treatment for pancreatic pseudocysts: systematic review and meta-analysis. Medicine (Baltimore) 2019;98:e14255.
3. Boškoski I, Costamagna G. Endoscopy robotics: current and future applications. Dig Endosc 2018;31:119-24.
4. de Moura DTH, Sachdev AH, Thompson CC. Endoscopic full-thickness defects and closure techniques. Curr Treat Options Gastroenterol 2018;16:386-405.
5. Yeung BP, Chiu PW. Application of robotics in gastrointestinal endoscopy: a review. World J Gastroenterol 2016;22:1811-25.
6. De Moura DT, Mestieri LH, Cheng S, et al. Natural orifice transluminal endoscopic surgery to salvage a migrated stent during EUS-guided hepaticogastrostomy. Gastrointest Endosc 2016;83:656-7.
7. Wong JYY, Ho KY. Robotics for advanced therapeutic colonoscopy. Clin Endosc 2018;51:552-7.
8. Hourneax de Moura DT, Aihara H, Jirapinyo P, et al. Robot-assisted endoscopic submucosal dissection versus conventional ESD for

colorectal lesions: outcomes of a randomized pilot study in endoscopists without prior ESD experience (with video). Gastrointest Endosc. 2019 Epub Mar 25.
9. Lang S, Mattheis S, Hasskamp P, et al. A European multicenter study evaluating the flex robotic system in transoral robotic surgery. Laryngoscope 2017;127:391-5.
10. Peters BS, Armijo PR, Krause C, et al. Review of emerging surgical robotic technology. Surg Endosc 2018;32:1636-55.
11. Persky MJ, Issa M, Bonfili JR, et al. Transoral surgery using the Flex robotic system: initial experience in the United States. Head Neck 2018;40:2482-6.
12. Paull JO, Pudalov N, Obias V. Medrobotics Flex transanal excision of a rectal gastrointestinal stromal tumour: first video of the transanal Flex robot used in a human - a video vignette. Colorectal Dis 2018;20:1048-9.
13. Atallah S, Hodges A, Larach SW. Direct target NOTES: prospective applications for next generation robotic platforms. Tech Coloproctol 2018;22:363-71.

Division of Gastroenterology, Hepatology and Endoscopy, Brigham and Women's Hospital, Harvard Medical School, Boston, Massachusetts, USA.

If you would like to chat with an author of this article, you may contact Dr Thompson at cthompson@hms.harvard.edu.

https://doi.org/10.1016/j.vgie.2019.04.014