ISSN 1948-5190 (online)

World Journal of *Gastrointestinal Endoscopy*

World J Gastrointest Endosc 2023 June 16; 15(6): 420-490

Published by Baishideng Publishing Group Inc

W J G E

World Journal of Gastrointestinal Endoscopy

Contents

Monthly Volume 15 Number 6 June 16, 2023

ABOUT COVER

Editor-in-Chief of *World Journal of Gastrointestinal Endoscopy*, Anastasios Koulaouzidis, MD, PhD, Professor, Department of Social Medicine and Public Health, Faculty of Health Sciences, Pomeranian Medical University, Szczecin EH16 4SA, Poland. akoulaouzidis@hotmail.com

AIMS AND SCOPE

The primary aim of *World Journal of Gastrointestinal Endoscopy* (*WJGE*, *World J Gastrointest Endosc*) is to provide scholars and readers from various fields of gastrointestinal endoscopy with a platform to publish high-quality basic and clinical research articles and communicate their research findings online.

WJGE mainly publishes articles reporting research results and findings obtained in the field of gastrointestinal endoscopy and covering a wide range of topics including capsule endoscopy, colonoscopy, double-balloon enteroscopy, duodenoscopy, endoscopic retrograde cholangiopancreatography, endosonography, esophagoscopy, gastrointestinal endoscopy, gastroscopy, laparoscopy, natural orifice endoscopic surgery, proctoscopy, and sigmoidoscopy.

INDEXING/ABSTRACTING

The *WJGE* is now abstracted and indexed in Emerging Sources Citation Index (Web of Science), PubMed, PubMed Central, Reference Citation Analysis, China National Knowledge Infrastructure, China Science and Technology Journal Database, and Superstar Journals Database. The 2023 Edition of Journal Citation Reports® cites the 2022 impact factor (IF) for *WJGE* as 2.0; IF without journal self cites: 1.9; 5-year IF: 3.3; Journal Citation Indicator: 0.28.

RESPONSIBLE EDITORS FOR THIS ISSUE

Production Editor: *Yi-Xuan Cai*; **Production Department Director:** *Xu Guo*; **Editorial Office Director:** *Jia-Ping Yan*.

NAME OF JOURNAL
World Journal of Gastrointestinal Endoscopy

ISSN
ISSN 1948-5190 (online)

LAUNCH DATE
October 15, 2009

FREQUENCY
Monthly

EDITORS-IN-CHIEF
Anastasios Koulaouzidis, Bing Hu, Sang Chul Lee, Joo Young Cho

EDITORIAL BOARD MEMBERS
https://www.wjgnet.com/1948-5190/editorialboard.htm

PUBLICATION DATE
June 16, 2023

INSTRUCTIONS TO AUTHORS
https://www.wjgnet.com/bpg/gerinfo/204

GUIDELINES FOR ETHICS DOCUMENTS
https://www.wjgnet.com/bpg/GerInfo/287

GUIDELINES FOR NON-NATIVE SPEAKERS OF ENGLISH
https://www.wjgnet.com/bpg/gerinfo/240

PUBLICATION ETHICS
https://www.wjgnet.com/bpg/GerInfo/288

PUBLICATION MISCONDUCT
https://www.wjgnet.com/bpg/gerinfo/208

ARTICLE PROCESSING CHARGE
https://www.wjgnet.com/bpg/gerinfo/242

STEPS FOR SUBMITTING MANUSCRIPTS
https://www.wjgnet.com/bpg/GerInfo/239

ONLINE SUBMISSION
https://www.f6publishing.com

WJGE World Journal of Gastrointestinal Endoscopy

Submit a Manuscript: https://www.f6publishing.com

World J Gastrointest Endosc 2023 June 16; 15(6): 434-439

DOI: 10.4253/wjge.v15.i6.434

ISSN 1948-5190 (online)

MINIREVIEWS

Flexible robotic endoscopy for treating gastrointestinal neoplasms

Keiichiro Kume

Specialty type: Gastroenterology and hepatology

Provenance and peer review: Invited article; Externally peer reviewed.

Peer-review model: Single blind

Peer-review report's scientific quality classification

Grade A (Excellent): 0
Grade B (Very good): 0
Grade C (Good): C
Grade D (Fair): 0
Grade E (Poor): 0

P-Reviewer: Ohki T, Japan

Received: December 21, 2022
Peer-review started: December 21, 2022
First decision: April 13, 2023
Revised: April 14, 2023
Accepted: May 4, 2023
Article in press: May 4, 2023
Published online: June 16, 2023

Keiichiro Kume, Third Department of Internal Medicine, University of Occupational and Environmental Health, Kitakyushu 8078555, Japan

Corresponding author: Keiichiro Kume, MD, PhD, Associate Professor, Third Department of Internal Medicine, University of Occupational and Environmental Health, 1-1 Iseigaoka, Yahatanishi-ku, Kitakyushu 8078555, Japan. k-kume@med.uoeh-u.ac.jp

Abstract

Therapeutic flexible endoscopic robotic systems have been developed primarily as a platform for endoscopic submucosal dissection (ESD) in the treatment of early-stage gastrointestinal cancer. Since ESD can only be performed by highly skilled endoscopists, the goal is to lower the technical hurdles to ESD by introducing a robot. In some cases, such robots have already been used clinically, but they are still in the research and development stage. This paper outlined the current status of development, including a system by the author's group, and discussed future challenges.

Key Words: Therapeutic flexible endoscopic robotic systems; Endoscopic submucosal dissection; Tissue triangulation

Core Tip: The current status and future issues in the new standardization that therapeutic flexible endoscopic robotic systems have brought to endoscopic submucosal dissection and endoscopic full-thickness resection were outlined.

Citation: Kume K. Flexible robotic endoscopy for treating gastrointestinal neoplasms. *World J Gastrointest Endosc* 2023; 15(6): 434-439
URL: https://www.wjgnet.com/1948-5190/full/v15/i6/434.htm
DOI: https://dx.doi.org/10.4253/wjge.v15.i6.434

INTRODUCTION

Therapeutic flexible endoscopic robotic systems were initially developed as a platform for natural orifice transluminal endoscopic surgery (NOTES)[1,2]. However, NOTES was not widely adopted as a treatment modality, and development shifted to endoscopic submucosal dissection (ESD), a highly complex, gastrointestinal endoscopic procedure that emerged as a treatment modality for early-stage gastrointestinal cancer. The author's group has also developed a robotic system for ESD known as the Endoscopic Therapeutic Robot System (ETRS)[3]. Various reviews have been published on this subject[4-7]. This paper provided an overview from a developer's perspective of the current status and future issues in the development of a therapeutic flexible endoscopic robot that can be adapted to ESD and to next-generation endoscopic full-thickness resection (EFTR) therapy.

INTRODUCTION TO ROBOTICS IN ESD

ESD is a treatment modality that uses an electronic knife *via* the forceps channel of a flexible endoscope. First, an incision is made around the lesion (*e.g.*, early-stage cancer) at submucosal depth, and then the lesion is dissected from the wall of the digestive tract at the submucosal layer[8,9]. ESD allows en bloc resection of large lesions, which could not be performed with the conventional endoscopic mucosal resection modality. However, the procedure is very difficult and time-consuming because incision and dissection are performed by counter traction, which was achieved only by manual manipulation of the angle and axis of a single flexible endoscope.

This was an opportunity for the introduction of robotics. ENDOSAMURAI was developed for use with NOTES[10]. The system is equipped with two arm forceps that resemble hands at the tip of a flexible endoscope, with grasping forceps serving as the left hand and knife forceps as the right hand. Each element of the procedure, such as incision, dissection, and hemostasis, is intuitively performed by grasping and pulling with precise tissue triangulation[11]. The arrival of ENDOSAMURAI marked the beginning of the development of a therapeutic flexible endoscopic robot for performing ESD and EFTR [11]. Specifically, the shift from counter traction with a single flexible endoscope to tissue triangulation with two robotic arm forceps was a major contribution of robotics to ESD and other highly challenging endoscopic procedures.

A THERAPEUTIC FLEXIBLE ENDOSCOPIC ROBOT FOR PERFORMING ESD AND EFTR

In this section, systems that achieve tissue triangulation with multi-degrees-of-freedom (multi-DOF) robotic forceps and have been implemented for ESD and EFTR in animals or animal organs were reviewed along with a discussion of the clinical application of some systems.

Master and slave transluminal endoscopic robot

Master and slave transluminal endoscopic robot (MASTER) (Endomaster Pte Ltd., Singapore, Singapore) was developed primarily by the University of Singapore and was the first robot to clinically implement ESD for early-stage gastric cancer[12-14]. Grasping forceps and knife forceps with 7 DOF were mounted in the two forceps channels of an Olympus GIF-2T240 endoscope, and they could be manipulated by computer control using a dedicated master device. Submucosal dissection was made possible by good tissue triangulation, but other procedures such as marking and peripheral incision were performed separately using a conventional flexible endoscope, which necessitated repeated replacement of the flexible endoscope. The system also required another endoscopist to operate the flexible endoscope itself. This system has been implemented for EFTR of the stomach using live pigs[15].

Endomaster endoluminal assistant for surgical endoscopy system

The fixed configuration of the two robotic forceps in the old MASTER system made it impossible to exchange forceps, whereas a notable improvement of the next-generation MASTER systems was that the two grasping and knife robotic forceps could now be inserted and removed. The dedicated flexible endoscope has three channels: Two for robotic forceps and one for surgical instruments. The addition of rotation, insertion, and removal capabilities to the operations of the robotic forceps themselves resulted in 9 DOF and made the system more intuitive and easier to operate[16]. This system was initially implemented in colorectal ESD using live cows and is now being applied in a clinical setting[17]. Insofar as the flexible endoscope itself is not robotically operated and requires another endoscopist, there are no major changes in this regard.

Endoluminal surgical system

The endoluminal surgical system (ColubrisMX, Inc., Houston, TX, United States) consists of a scope called a Colubriscope, robotic forceps inserted into the scope, and an operating console for the forceps [18,19]. The Colubriscope has an external diameter of 22 mm and four channels: Two for robotic forceps (one dedicated camera channel and one surgical instrument channel) and a separate dedicated channel for air supply and degassing. Unlike other robotic systems that have a camera function in the flexible endoscope itself, a single camera scope can be inserted into the Colubriscope's forceps channel, allowing independent adjustment of the field of view. Another advanced feature is the use of robotic grasping forceps in the left hand to obtain good tissue triangulation while using built-in powered scissors in the robotic forceps of the right hand to perform incision and dissection by means of hot dissection. This feature also has the potential for use in procedures other than ESD. This system is also noteworthy in that it allows suture manipulation using both left and right robotic grasping forceps, and it is capable of EFTR. ESD and postresection suturing were performed 20 times using porcine colons[18].

Flex robotic system

The Flex Robotic System (Medrobotics Corporation, Raynham, MA, United States) is a master-slave robotic system approved by the United States Food and Drug Administration in 2017 as a robotic system for head and neck surgery[20,21]. This perfected system has two forceps channels (left and right) on the outside of the flexible endoscope, through which dedicated forceps are inserted to allow two-handed operation. Two forceps can be selected from several types, such as grasping, electric scalpel, and powered scissors, to perform incision, dissection, resection, suturing, and so forth. The flexible endoscope itself can also be remotely operated, allowing almost all operations to be performed by a single endoscopist sitting at a dedicated console. The implementation of ESD in the bovine colon has shown that even a surgeon inexperienced in ESD can easily master this technique[20]. However, because this system is designed for head and neck surgery, the external diameter of the flexible endoscope is too large for insertion into the upper gastrointestinal tract, and with a length of 25 cm, it cannot be used for deep lesions in the colon.

Endoluminal assistant for surgical endoscopy

The Endoluminal Assistant for Surgical Endoscopy (ICube Laboratory, Strasbourg, France) is a master-slave robotic system developed as a successor to the ISIS-Scope/STRAS system (Karl Storz, IRCAD, Tuttlingen, Germany)[22,23]. It has two channels for robotic forceps and a channel for conventional surgical instruments, and through robotic control of the grasping and knife forceps, it can be used to perform mucous membrane incision and submucosal dissection with precise tissue triangulation. Submucosal local injection is also possible by inserting a syringe needle through the channel for conventional surgical instruments. The flexible endoscope itself can also be operated by a joystick, allowing almost all procedures to be performed by a single endoscopist sitting at a dedicated console. ESD of the colon has been achieved in live pigs[23].

ETRS

The ETRS (Figure 1) is a master-slave robotic system developed by the author’s group exclusively for ESD[3]. We started by developing a platform to remotely control movements of the endoscope itself, which we named the Endoscopic Operation Robot (EOR)[24]. The current third-generation EOR is equipped with two-way haptic feedback functions that provide haptic feedback (force sensation) *via* the master unit while transmitting a force equal to that applied by the operator on the master unit to the endoscope tip, and all scope operations can be performed with one hand[24]. We then developed a master-slave system capable of remotely operating three different endoscopic instruments (grasping forceps, knife forceps, and injection-needle catheters), and we combined this system with the improved EOR version 3 (Figure 2) to create a novel gastrointestinal endoscopic robot in which all operations are controlled remotely. All procedural elements required for ESD, such as incision, dissection, submucosal local injection, water jetting, air supply, aspiration, and lesion recovery, can be performed by a single endoscopist sitting at a console. ESD has been performed in a resected pig stomach[3].

FUTURE ISSUES

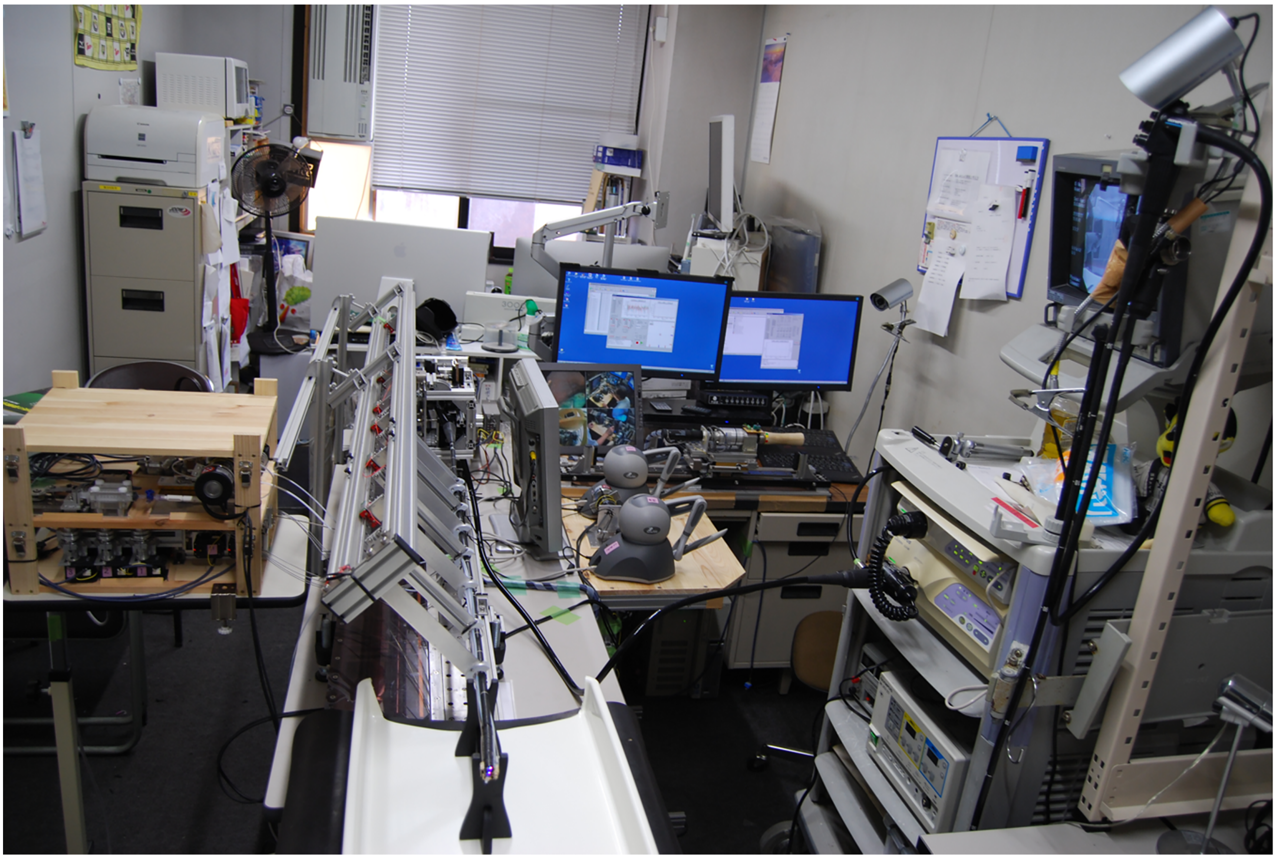
ESD is a procedure that can only be performed by highly skilled endoscopists, but therapeutic flexible endoscopic robotic systems allow less-experienced endoscopists to perform ESD by tissue triangulation using both hands to manipulate two multi-DOF robotic arm forceps. However, compared to the perfected surgical robots as exemplified by da Vinci, there are still many issues that need to be addressed at the research level before wider general clinical application.

Lesion access

For example, ESD is intended to treat lesions in the upper gastrointestinal tract as far as the duodenum and lesions in the lower gastrointestinal tract as far as the cecum. Each robotic system must be able to easily reach the lesion site so that it can adequately fulfill its potential. Current systems are still inadequate for accessing lesions, mainly because the scope cannot be operated over a sufficient length.

Versatility with cost-effectiveness

Dedicated ESD and EFTR robots are not cost-effective in terms of system scale because they tend to be large and complex. The Flex Robotic System was developed for head and neck surgery and has been



DOI: 10.4253/wjge.v15.i6.434 **Copyright** ©The Author(s) 2023.

Figure 1 Endoscopic therapeutic robot system.

applied to colorectal ESD, but this system should be further developed so that it can be adapted to other diseases. Many of the systems introduced allow the replacement of robotic forceps. However, by expanding the robotic forceps options and forceps channels so that complex sutures and anastomoses can be performed at will, there is also room for development that extends the application of these systems to areas where flexible endoscopes are superior to rigid endoscopes, such as thoracic and intra-abdominal surgery. Nevertheless, all procedures must be performed within the caliber of a gastrointestinal endoscope, and greater development within these fine size constraints is needed.

Arrangement of operators

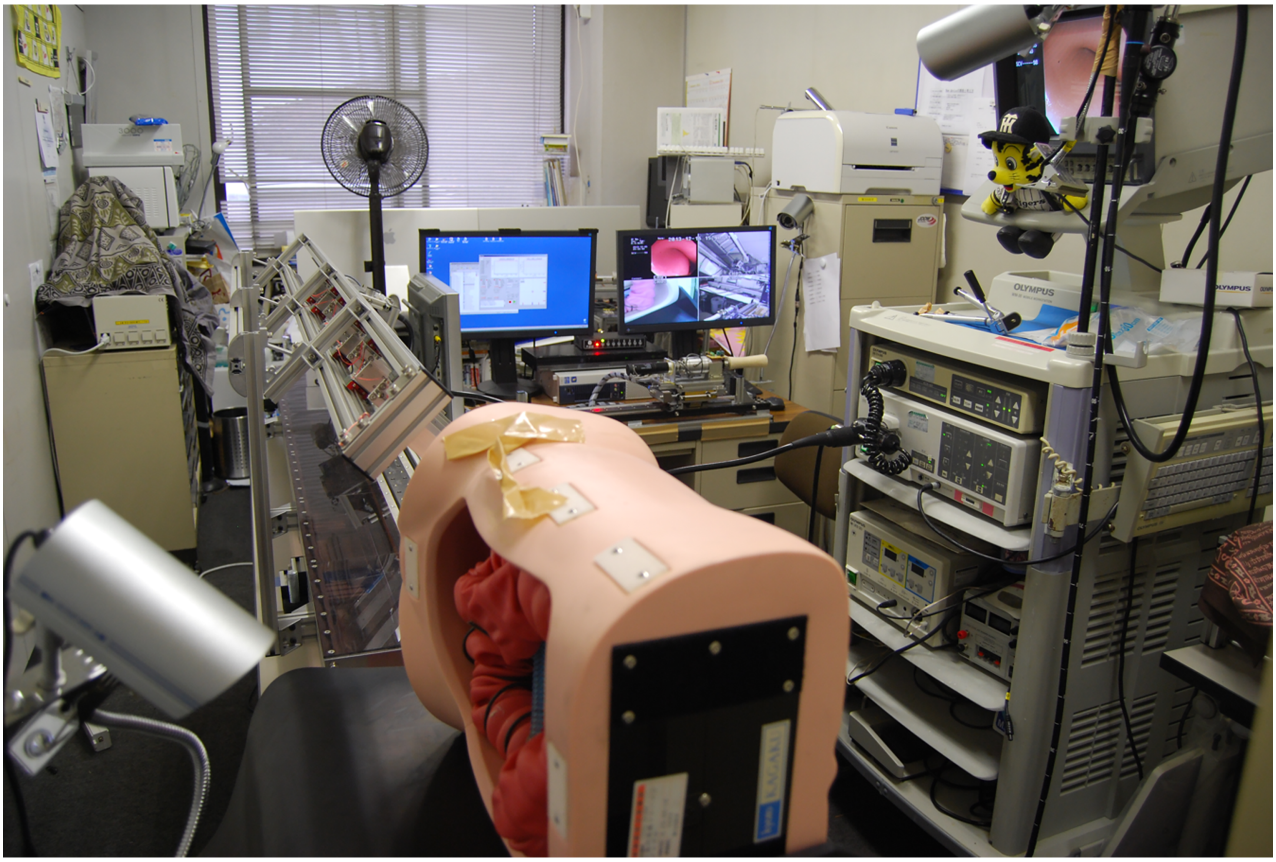
The ETRS developed by the author's group enables a single endoscopist sitting at a console to perform all the procedures required for ESD, although the system still has many other issues. Many current flexible endoscopes require assistants for their operation, and when complex, coordinated operation by two or more operators is needed, the hurdle for standardized operations becomes high. In the author's opinion, assistants should perform only the minimum necessary operations, such as changing forceps, and a single endoscopist should be able to perform as much of the surgery as possible.

Developing autonomy

The purpose of the surgical robotic systems currently used clinically is to provide operational support to surgeons and not to operate autonomously. If a robot were to be perfected as an operational support robot, it could be implemented clinically. For example, the smart tissue autonomous robot, which was developed as an autonomous surgical robot, is already performing automated intestinal anastomosis in live pigs[25]. Autonomous support was introduced into surgical robotic systems along with the establishment of phased objectives that must be met, in the same way that levels have been set for automated driving in automobiles[26]. This should begin with autonomous optimization of the surgical field so that the surgeon can always operate under an optimal surgical field.

CONCLUSION

Therapeutic flexible endoscopic robotic systems are being developed for ESD and EFTR. While some have been used clinically, most systems remain in the research and development stage. These robotic



DOI: 10.4253/wjge.v15.i6.434

Figure 2 Endoscopic operation robot version 3.

systems are expected to offer numerous advantages to surgeons, but a number of issues will need to be addressed before there is widespread application in clinical settings.

FOOTNOTES

Author contributions: Kume K conceived of, designed, prepared and wrote this review.

Supported by Grant-in-Aid for Scientific Research (KAKENHI), No. 23500573, No. 263500554, No. 17K01431 and No. 20K12700; Grant of the Princess Takamatsu Cancer Research Fund, No. 13-24505; and Terumo Life Science Foundation, No. 15-I101 and No. 20-III119.

Conflict-of-interest statement: Dr. Kume reports grants from Grant-in-Aid for Scientific Research, grants from Grant of the Princess Takamatsu Cancer Research Fund, grants from Terumo Foundation for Life and Arts, during the conduct of the study; In addition, Dr. Kume has a patent in Japan. No. 5605613 issued, and a patent in Japan No. 5880952 was issued.

Country/Territory of origin: Japan

ORCID number: Keiichiro Kume 0000-0002-0444-4739.

S-Editor: Fan JR
L-Editor: Filipodia
P-Editor: Cai YX

REFERENCES

1 **Swanstrom LL**. NOTES: Platform development for a paradigm shift in flexible endoscopy. *Gastroenterology* 2011; **140**: 1150-1154.e1 [PMID: 21334331 DOI: 10.1053/j.gastro.2011.02.031]

2 **Yeung BP**, Gourlay T. A technical review of flexible endoscopic multitasking platforms. *Int J Surg* 2012; **10**: 345-354 [PMID: 22641123 DOI: 10.1016/j.ijsu.2012.05.009]

3 **Kume K**, Sakai N, Ueda T. Development of a Novel Gastrointestinal Endoscopic Robot Enabling Complete Remote Control of All Operations: Endoscopic Therapeutic Robot System (ETRS). *Gastroenterol Res Pract* 2019; **2019**: 6909547 [PMID: 31781197 DOI: 10.1155/2019/6909547]

4 **Cui Y**, Thompson CC, Chiu PWY, Gross SA. Robotics in therapeutic endoscopy (with video). *Gastrointest Endosc* 2022; **96**: 402-410 [PMID: 35667390 DOI: 10.1016/j.gie.2022.05.019]

5 **Marlicz W**, Ren X, Robertson A, Skonieczna-Żydecka K, Łoniewski I, Dario P, Wang S, Plevris JN, Koulaouzidis A, Ciuti G. Frontiers of Robotic Gastroscopy: A Comprehensive Review of Robotic Gastroscopes and Technologies. *Cancers (Basel)* 2020; **12** [PMID: 32998213 DOI: 10.3390/cancers12102775]

6 **Saito Y**, Sumiyama K, Chiu PW. Robot assisted tumor resection devices. *Expert Rev Med Devices* 2017; **14**: 657-662 [PMID: 28726517 DOI: 10.1080/17434440.2017.1358087]

7 **Yeung BP**, Chiu PW. Application of robotics in gastrointestinal endoscopy: A review. *World J Gastroenterol* 2016; **22**: 1811-1825 [PMID: 26855540 DOI: 10.3748/wjg.v22.i5.1811]

8 **Ono H**, Kondo H, Gotoda T, Shirao K, Yamaguchi H, Saito D, Hosokawa K, Shimoda T, Yoshida S. Endoscopic mucosal resection for treatment of early gastric cancer. *Gut* 2001; **48**: 225-229 [PMID: 11156645 DOI: 10.1136/gut.48.2.225]

9 **Oka S**, Tanaka S, Kaneko I, Mouri R, Hirata M, Kawamura T, Yoshihara M, Chayama K. Advantage of endoscopic submucosal dissection compared with EMR for early gastric cancer. *Gastrointest Endosc* 2006; **64**: 877-883 [PMID: 17140890 DOI: 10.1016/j.gie.2006.03.932]

10 **Spaun GO**, Zheng B, Swanström LL. A multitasking platform for natural orifice translumenal endoscopic surgery (NOTES): a benchtop comparison of a new device for flexible endoscopic surgery and a standard dual-channel endoscope. *Surg Endosc* 2009; **23**: 2720-2727 [PMID: 19360364 DOI: 10.1007/s00464-009-0476-5]

11 **Ikeda K**, Sumiyama K, Tajiri H, Yasuda K, Kitano S. Evaluation of a new multitasking platform for endoscopic full-thickness resection. *Gastrointest Endosc* 2011; **73**: 117-122 [PMID: 21074762 DOI: 10.1016/j.gie.2010.09.016]

12 **Ho KY**, Phee SJ, Shabbir A, Low SC, Huynh VA, Kencana AP, Yang K, Lomanto D, So BY, Wong YY, Chung SC. Endoscopic submucosal dissection of gastric lesions by using a Master and Slave Transluminal Endoscopic Robot (MASTER). *Gastrointest Endosc* 2010; **72**: 593-599 [PMID: 20646698 DOI: 10.1016/j.gie.2010.04.009]

13 **Wang Z**, Phee SJ, Lomanto D, Goel R, Rebala P, Sun ZL, Trasti S, Reddy N, Wong JY, Ho KY. Endoscopic submucosal dissection of gastric lesions by using a master and slave transluminal endoscopic robot: an animal survival study. *Endoscopy* 2012; **44**: 690-694 [PMID: 22723184 DOI: 10.1055/s-0032-1309404]

14 **Phee SJ**, Reddy N, Chiu PW, Rebala P, Rao GV, Wang Z, Sun Z, Wong JY, Ho KY. Robot-assisted endoscopic submucosal dissection is effective in treating patients with early-stage gastric neoplasia. *Clin Gastroenterol Hepatol* 2012; **10**: 1117-1121 [PMID: 22642951 DOI: 10.1016/j.cgh.2012.05.019]

15 **Chiu PW**, Phee SJ, Wang Z, Sun Z, Poon CC, Yamamoto T, Penny I, Wong JY, Lau JY, Ho KY. Feasibility of full-thickness gastric resection using master and slave transluminal endoscopic robot and closure by Overstitch: a preclinical study. *Surg Endosc* 2014; **28**: 319-324 [PMID: 23990156 DOI: 10.1007/s00464-013-3149-3]

16 **Chiu PWY**, Ho KY, Phee SJ. Colonic endoscopic submucosal dissection using a novel robotic system (with video). *Gastrointest Endosc* 2021; **93**: 1172-1177 [PMID: 32991869 DOI: 10.1016/j.gie.2020.09.042]

17 **Chiu PW**. ESD of rectal lesion by EndoMASTER EASE system. Endo Swiss Channel. Available from: https://www.youtube.com/watch?v=g2huLJEfDZ4&t=388s

18 **Atallah S**, Sanchez A, Bianchi E, Larach SW. Envisioning the future of colorectal surgery: preclinical assessment and detailed description of an endoluminal robotic system (ColubrisMX ELS). *Tech Coloproctol* 2021; **25**: 1199-1207 [PMID: 34224035 DOI: 10.1007/s10151-021-02481-0]

19 **Robotic Surgery Academy**. Colobris MX. Available from: https://www.youtube.com/watch?v=in_IuQiAZg8&t=500s

20 **Turiani Hourneaux de Moura D**, Aihara H, Jirapinyo P, Farias G, Hathorn KE, Bazarbashi A, Sachdev A, Thompson CC. 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; **90**: 290-298 [PMID: 30922861 DOI: 10.1016/j.gie.2019.03.016]

21 **Moura DTH**, Aihara H, Thompson CC. Robotic-assisted surgical endoscopy: a new era for endoluminal therapies. *VideoGIE* 2019; **4**: 399-402 [PMID: 31517160 DOI: 10.1016/j.vgie.2019.04.014]

22 **Zorn L**, Nageotte F, Zanne P, Legner A, Dallemagne B, Marescaux J, de Mathelin M. A Novel Telemanipulated Robotic Assistant for Surgical Endoscopy: Preclinical Application to ESD. *IEEE Trans Biomed Eng* 2018; **65**: 797-808 [PMID: 28678698 DOI: 10.1109/TBME.2017.2720739]

23 **Mascagni P**, Lim SG, Fiorillo C, Zanne P, Nageotte F, Zorn L, Perretta S, de Mathelin M, Marescaux J, Dallemagne B. Democratizing Endoscopic Submucosal Dissection: Single-Operator Fully Robotic Colorectal Endoscopic Submucosal Dissection in a Pig Model. *Gastroenterology* 2019; **156**: 1569-1571.e2 [PMID: 30768985 DOI: 10.1053/j.gastro.2018.12.046]

24 **Kume K**, Sakai N, Goto T. Development of a novel endoscopic manipulation system: the Endoscopic Operation Robot ver.3. *Endoscopy* 2015; **47**: 815-819 [PMID: 25910062 DOI: 10.1055/s-0034-1391973]

25 **Saeidi H**, Opfermann JD, Kam M, Wei S, Leonard S, Hsieh MH, Kang JU, Krieger A. Autonomous robotic laparoscopic surgery for intestinal anastomosis. *Sci Robot* 2022; **7**: eabj2908 [PMID: 35080901 DOI: 10.1126/scirobotics.abj2908]

26 **Haidegger T**. Autonomy for surgical robots: Concepts and paradigms. *IEEE Trans Med Robot Bionics* 2019; **1**: 65-76 [DOI: 10.1109/TMRB.2019.2913282]

Baishideng®

Published by **Baishideng Publishing Group Inc**
7041 Koll Center Parkway, Suite 160, Pleasanton, CA 94566, USA
Telephone: +1-925-3991568
E-mail: bpgoffice@wjgnet.com
Help Desk: https://www.f6publishing.com/helpdesk
https://www.wjgnet.com