Review Article

The adoption of artificial intelligence assisted endoscopy in the Middle East: challenges and future potential

Ahmed El-Sayed[1], Sara Salman[2], Laith Alrubaiy[3,4]

[1]Gastroenterology Department, Chelsea & Westminster Hospital, London, UK; [2]University of Sheffield Medical School, Sheffield, UK; [3]Gastroenterology Department, Healthpoint Hospital, Abu Dhabi, United Arab Emirates; [4]College of Medicine and Health Sciences, Khalifa University, Abu Dhabi, United Arab Emirates

Contributions: (I) Conception and design: L Alrubaiy; (II) Administrative support: L Alrubaiy; (III) Provision of study materials or patients: All authors; (IV) Collection and assembly of data: A El-Sayed, S Salman; (V) Data analysis and interpretation: All authors; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

Correspondence to: Laith Alrubaiy, MBChB, PhD. Gastroenterology Department, Healthpoint Hospital, M42 Healthcare, Zayed Sports City, Saif Gobash Street, Abu Dhabi, United Arab Emirates; College of Medicine and Health Sciences, Khalifa University, Shakhbout Bin Sultan Street, Abu Dhabi, United Arab Emirates. Email: l.alrubaiy@healthpoint.ae.

Abstract: The use of artificial intelligence (AI) in endoscopy has shown immense potential to enhance diagnostic accuracy, streamline procedures, and improve patient outcomes. There are potential uses in every field of endoscopy, from improving adenoma detection rate (ADR) in colonoscopy to reducing read time in capsule endoscopy or minimizing blind spots in gastroscopy. Indeed, some of these systems are already licensed and in commercial use across the world. In the Middle East, where healthcare systems are rapidly evolving, there is a growing interest in adopting AI technologies to revolutionise endoscopic practices. This article provides an overview of the advancements, potential opportunities and challenges associated with the implementation of AI in endoscopy within the Middle East region. Our aim is to contribute to the ongoing dialogue surrounding the implementation of AI in endoscopy and consider some of the factors that are particularly relevant in the Middle Eastern context, including the need to train the models for local populations, cost and training, as well as trying to ensure equity of access for patients. It provides valuable insights for healthcare professionals, policymakers, and researchers interested in leveraging AI to enhance endoscopic procedures, improve patient care, and address the unique healthcare needs of the Middle East population.

Keywords: Artificial intelligence (AI); endoscopy; colonoscopy; gastroscopy; capsule endoscopy

Received: 29 June 2023; Accepted: 07 October 2023; Published online: 25 October 2023.
doi: 10.21037/tgh-23-37
View this article at: https://dx.doi.org/10.21037/tgh-23-37

Introduction

Artificial intelligence (AI) plays an ever-increasing role in our lives. Medicine is no exception and endoscopy services are of particular interest, with the first global AI summit in Gastroenterology & Endoscopy taking place in 2019 (1).

The use of AI in endoscopy has been gaining traction in the Middle East healthcare sector in recent years. With a growing healthcare industry and a focus on implementing cutting-edge technologies, some countries such as the United Arab Emirates (UAE) and Saudi Arabia are already well-positioned to benefit from AI-based endoscopy solutions.

The potential benefits of AI are substantial; improving detection of subtle lesions and reducing the potential for human error (2), better characterization of lesions (3), reduction in endoscopic blind spots (4) and reducing time spent on interpretation of video capsule endoscopy (VCE) (5). However, more widespread use is hampered by the relative lack of data, especially in real time endoscopy.

We will look at the status of AI in endoscopy, what the future may entail and potential challenges in the Middle East region.

Use in colonoscopy

Colorectal cancer is the 2nd most common cause of cancer death worldwide (6) and the Middle East (3), with colonoscopy as the diagnostic gold standard. Adenoma detection rate (ADR) is a vital parameter for early diagnosis and survival, being inversely proportional to colorectal cancer outcomes, with a 1% increase in ADR associated with 3% decrease in risk of cancer (7). Unfortunately, adenoma miss rate remains high, at up to 26% (8).

Computer aided detection (CADe) systems, including ENDOANGEL (9) and GI genius (10), which have been approved for commercial use, have shown benefit in improving the ADR of endoscopists (11,12), though this has often been for polyps <10 mm and especially for diminutive polyps (<5 mm) (10,13). Indeed, many of the trials run have shown no significant difference in the ADR of AI systems and endoscopists for polyps >10 mm or colorectal adenomas (10,12,13). Importantly, the role of polyps <10 mm in the eventual development of colorectal cancer is not clear and therefore the genuine utility of finding and removing these polyps is unclear (14).

AI systems that are commercially available, can be used for real-time computer aided diagnoses (CADx) (3,15,16). AI assisted endoscopy can accurately characterize diminutive polyps with a sensitivity and specificity of 80% (17) and could be used for a resect and discard strategy (18,19). This could save money, histopathology resources and be more environmentally friendly (20,21).

For colorectal cancer, risk assessment of lymph node metastases by AI systems can help determine appropriate management (22). Recently, analysis of inflammatory bowel disease (IBD) activity has also shown promise, with CADx systems used to analyze for ongoing inflammation (23).

It is important to note that many of the earlier studies in this area were performed on high quality, still endoscopic images (15,16,18), as opposed to real time endoscopy, where image quality and bowel preparation may be sub-par. Therefore, the sensitivity and specificity decline when dealing with dynamic video images compared to retrospective static image testing. Real life data typically comprises of 50,000 frames per colonoscopy (24), and a high false positive rate could lead to clinician frustration, deterioration of trust in the model, and more critically the oversight of legitimate events by the clinician (25). This is changing with more recent trials (9,19), which has allowed some AI systems, such as ENDOANGEL and GI Genius (9,10) to be used commercially in real-time endoscopy, across countries such as China, the United States of America (USA) and the United Kingdom (UK) (26).

Finally, AI systems can also improve endoscopy quality and endoscopist's key performance indicator (KPI) by evaluating withdrawal time (7), informing endoscopist of blind spots (4) and bowel preparation scores (27).

Use in esophagogastroscopy (EGD)

Oesophageal squamous cell carcinomas (SCC) are the most common oesophageal cancer worldwide and in the Middle East (28) and due to its subtle changes, are often diagnosed at an advanced stage. CADe tools have proven effective at detection of SCC (29,30), as well as differentiating submucosal (SM) micro-invasive (SM1) from deep invasive (SM2/3) cancers (31,32), which has therapeutic implications.

Up to 25% of oesophageal adenocarcinoma (OAC) can be missed on the index surveillance endoscopy for Barrett's Oesophagus (33). Targeting biopsy sites with CADe AI systems, some of which have been tested in real time, can help increase pickup of dysplasia and OAC and reduce unnecessary biopsies (34,35).

Early detection of gastric cancers improves survival (36). Missed cancer rates can be as high as 23% however (37). AI systems have been developed for both CADe (38,39), with some out-performing expert endoscopists from still images (40) and CADx (41), to predict invasion depth. Their high diagnostic accuracy and sensitivity in detecting gastric and oesophageal cancers has also highlighted their potential in training; to assist non-expert endoscopists in enhancing their ability to detect gastric cancers (42).

Atrophic gastritis is a pre-malignant condition which can eventually lead to gastric cancer. If found early, appropriate treatment may be offered depending on the underlying cause or a surveillance regime initiated. AI systems, including ENDOANGEL (43) have shown ability equivalent to experienced endoscopists and superior to non-expert endoscopists, in detecting chronic atrophic gastritis (43). An increased detection rate could help prevent some cases of gastric cancer.

There may also be utility for detection of *Helicobacter pylori* (*H. pylori*) status through endoscopic appearances only, though many of these systems have so far only been tested on still images (43). This could be especially beneficial in the Middle East given the relatively higher incidence of gastric and oesophageal cancers which may be attributed to the high rates of *H. pylori* infection as well as the dietary norms including high salt intake (44). A system that reliably detects and differentiates these etiologies could enhance the early detection of neoplastic changes and subsequent treatment efficacy and prognosis (45).

Additionally, in some areas of the Middle East where there is a high population density such as Bahrain, an efficient screening method becomes imperative. A system powered by AI could potentially enable accelerated screening of larger populations, alongside helping to identify individual cases for further investigation (45). The capability to efficiently screen a large number of patients in a shorter timeframe could facilitate the development of a more extensive epidemiological map. This in turn may enhance identification of patterns in rates or populations leading to more effective public health strategies.

Performing high quality gastroscopy is vital to maximizing diagnostic yield and minimizing blind spots is an important factor in this (46). The WISENSE and ENDOANGEL systems have shown ability in real-time randomized control trials (RCT) to flag blind spots and improve gastroscopy quality when compared to endoscopists alone (43,47).

Use in VCE

While VCE has superb diagnostic utility for small intestinal pathology, it is time consuming, with the average capsule taking expert endoscopists and trainees an average of 12 and 20 minutes respectively to interpret. Some AI systems have been developed which significantly reduce this time (5), whilst also providing accurate lesion recognition (48).

Use in endoscopic ultrasound (EUS)

EUS is used for both diagnostics and tissue acquisition and is performed using linear or radial echoendoscopes. Radial views are broadly used for assessment, while linear views are generally used for tracking during needle puncture. Due to the different views obtained, a commercially viable AI system would therefore need to have been trained on images from both types of view (49) or only be usable for one of them (50).

AI systems have recently been developed to help differentiate between pancreatic cancer and chronic pancreatitis (49) or autoimmune pancreatitis (50), as well as between malignant and benign intraductal papillary mucinous neoplasm (51). There may also be benefit with diagnosis of subepithelial lesions (52) and training of practitioners in EUS (53). Many have shown better performance compared to EUS alone, though most have generally been tested on still images only.

When applying AI in EUS, one area of concern is the quality of the input data for AI powered EUS systems. To achieve a high diagnostic accuracy and generalisability in diagnosing and distinguishing pancreatic cancer from other pathologies, the dataset must be comprehensive. Evaluating multi-centre experiences would be vital to capture all the possible variations and variables considered in the decision-making process (54).

Given its various populations, the Middle East would be a prime candidate for the training of AI algorithms on a diverse population. It also holds potential value when testing existing datasets for robustness and applicability; as it is a population which is mostly underrepresented in the development of these models. However, one technical challenge when developing AI based systems, is the large amount of input data required, which makes it difficult to develop and train models for rare diseases, such as autoimmune pancreatitis, due to the limited human-labelled material (54).

It would also be important to emphasize the necessity for studies that utilize the data to report specific outcomes on pancreatic cancers, adhere to strong methodological quality and standards of reporting—which are meticulously regulated. Subpar quality standards with flawed methodologies and reporting system may lead to skepticism among healthcare professionals—leading to delays in policy changes and the adoption of this technology.

Challenges and future potential of AI in the Middle East area

In the Middle East region, the use of AI in endoscopy has the potential to enhance detection of lesions, reduce procedure time, provide real time feedback of endoscopy quality and helping trainees to improve their endoscopy skills. It should improve accuracy and reduce workload, as well as help with decision making.

Despite its potential benefits, the use of AI poses challenges in the Middle East. Almost no AI models were trained on Middle East population and every effort should be made to develop a database to test or even train AI models on the Middle East population. Most studies so far do not reflect real life endoscopy, in terms of real time images or different levels of endoscopist experience and are only internally validated, with a risk of inaccurately assessing AI performance. It is therefore difficult to assess genuine benefit, with RCT needed. Guidelines have been agreed upon to standardize reporting for AI trials (55) and should be used in future. Moral questions may also eventually arise regarding responsibility for missed lesions and the implications of this on the patient- practitioner relationship (56). As many of the existing systems are produced in a single institution, the AI algorithms will only be trained on one data set and consequently its performance may not be tested against variations in imaging techniques, equipment and procedural nuances. Therefore, results may not be reproducible outside this specific population and across diverse settings (57).

Undoubtedly, implementing AI technology in endoscopy will necessitate computational resources and infrastructure, leading to associated costs. Offsetting these expenses and optimizing the benefits of AI will largely be influenced by the practitioner's willingness to embrace and incorporate AI, alongside the technologies' efficiency and practicality (58). Consequently, adequate training will be essential to ensure practitioners acquire the necessary understanding of AI systems, interpreting outcomes and utility in practice (59). Lastly, the development of systems with a user-friendly interface will be crucial in precipitating a smooth integration into existing workflows.

There are also potential financial implications associated with the use of AI in endoscopy in the Middle East. The costs associated with the use of AI in endoscopy can vary depending on the specific application and the technology used. Equipment such as high-definition endoscopes and related hardware will need upgrading or replacing to be compatible with AI and this can be costly (60). Developing the algorithm would also involve the collaboration between AI software experts responsible for designing and testing the model and medical experts to gather, organise, select and annotate a sufficiently extensive database (45). Moreover, the development and functioning requirements of this database will result in significant computational costs, such as a cloud or high-performance hardware, sufficient to also withstand privacy and security concerns (60).

When implementing the AI model into practice, various considerations will have to be made such as local policy and interface customization. One approach to cut down costs is sharing central computing resources for all non-real-time and potentially real-time applications. However, the Middle East is made up of various countries; each with their own set of legislations and regulatory frameworks related to healthcare and medical technology. It may prove challenging and time consuming to navigate these various regulations and obtain the required approvals which will also incur legal and administrative expenses. Additional expenses may also be needed to made to make the interfaces customizable and understandable in the various languages which are spoken in the Middle East.

Healthcare professionals will need training on using AI powered systems; how to operate them, interpret them and incorporate them in practice. Employing and organizing specialized trainers to provide workshops and subsequently providing educational materials will entail further expense (54). Generally speaking, the costs associated with AI in endoscopy can be broken down into several categories:

(I) Equipment costs: the cost of acquiring the necessary hardware and software for AI-based endoscopy solutions can be significant. This includes the cost of purchasing endoscopes, cameras, and other hardware components, as well as the cost of licensing and implementing the AI software.
(II) Training costs: training clinicians and other medical professionals to use AI-based endoscopy solutions can also be costly. This includes the cost of training programs, continuing education, and other professional development activities.
(III) Maintenance costs: the cost of maintaining and updating AI-based endoscopy solutions can also be significant. This includes the cost of hardware maintenance, software updates, and other ongoing maintenance activities.
(IV) Integration costs: integrating AI-based endoscopy solutions into existing healthcare systems can also be costly. This includes the cost of integrating the AI software with electronic health records (EHRs), patient management systems, and other healthcare IT systems.

Although the costs associated with AI-based endoscopy solutions can be significant, they may be offset by the potential to reduce healthcare costs. By reducing the number of missed lesions and unnecessary procedures, AI-based endoscopy solutions can potentially help to reduce the overall cost of care while improving patient outcomes.

The use of AI in endoscopy may increase the gap in endoscopy practice between rich and poor countries. However, AI-based endoscopy solutions may be particularly useful in resource-limited settings, where access to skilled medical professionals and specialized equipment may be limited.

One potential application of AI-based endoscopy solutions in low-resource settings is in the training of medical professionals. AI algorithms can be used to help train clinicians to identify and diagnose gastrointestinal conditions, even in the absence of specialized training or equipment. This could be particularly useful in areas where access to specialized training and equipment is limited.

AI-based endoscopy solutions could also help to improve the efficiency of endoscopy procedures in resource-limited settings. By automating certain aspects of the endoscopy procedure, such as image analysis and interpretation, AI algorithms could help to reduce the time and resources required to perform these procedures. This could help to increase the number of patients who can be treated with endoscopy, even in settings with limited resources.

One of the other challenges is the need for skilled personnel to implement and operate the technology. While a few countries have a well-educated and technologically-savvy workforce, the implementation of AI-based endoscopy solutions will require specialized training and expertise in many Middle Eastern countries.

Moreover, steps need to be taken to ensure that the benefits of AI-based endoscopy solutions are accessible to all patients, regardless of their socioeconomic status or geographic location. There are still disparities in access to care, particularly in remote or underserved areas. Efforts must be made to ensure that AI-based endoscopy solutions are accessible to all patients who can benefit from them, regardless of their location or socioeconomic status.

Legislation for the use AI in endoscopy is crucial to ensure patient safety, advance medical technology, and address ethical concerns. We need to establish guidelines to ensure the safety and reliability of AI algorithms used in endoscopy, as well as minimizing the risk of misdiagnosis or incorrect treatment. AI in endoscopy raises ethical questions, such as patient privacy, data protection, and informed consent. Legislation can address these concerns by establishing guidelines for data handling, anonymization, and patient consent, ensuring that AI technologies are used ethically and with respect for patients' rights. Furthermore, guidelines are needed to mandate appropriate training and certification for healthcare professionals and technicians who operate AI-assisted endoscopy systems. This can help ensure that healthcare providers have the necessary skills to utilize AI technology effectively and safely in their practice. Questions of liability and accountability may arise in case of adverse events or medical errors. Therefore, policymakers and experts need to collaborate closely to develop appropriate and adaptive legislation that supports innovation while safeguarding patient well-being and societal interests.

The use of AI in endoscopy is gaining traction in the Middle East, with a number of innovative solutions being developed and implemented (61,62). While there are challenges associated with the implementation of these solutions, the potential benefits in terms of improved patient outcomes, increased efficiency, and reduced healthcare costs make it a promising area for continued research and development.

Conclusions

There is no doubt that AI has the potential to revolutionise endoscopic practice across the world, improving diagnosis, training and the taking of unnecessary samples, with the environmental benefits this brings. Already systems such as ENDOANGEL and GI Genius are being commercially used to improve ADR and overall endoscopy quality.

Within the Middle Eastern context, there is a definite need to train AI models on images and videos from the local populations, or at least to test the existing models there to ensure they are applicable. The costs to acquire equipment and train people appropriately must be considered by policymakers as potential hurdles. However, if implemented correctly, there is a genuine opportunity to improve training for trainees and outcomes for patients, particularly in more resource limited settings and hopefully increase equity in access.

Acknowledgments

Funding: None.

Footnote

Peer Review File: Available at https://tgh.amegroups.com/article/view/10.21037/tgh-23-37/prf

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://tgh.amegroups.com/article/view/10.21037/tgh-23-37/coif). LA serves as an unpaid editorial board member of *Translational Gastroenterology and Hepatology* from May 2023 to April

2025. The other authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

References

1. Parasa S, Wallace M, Bagci U, et al. Proceedings from the First Global Artificial Intelligence in Gastroenterology and Endoscopy Summit. Gastrointest Endosc 2020;92:938-945.e1.
2. Marcondes FO, Gourevitch RA, Schoen RE, et al. Adenoma Detection Rate Falls at the End of the Day in a Large Multi-site Sample. Dig Dis Sci 2018;63:856-9.
3. Chen PJ, Lin MC, Lai MJ, et al. Accurate Classification of Diminutive Colorectal Polyps Using Computer-Aided Analysis. Gastroenterology 2018;154:568-75.
4. Freedman D, Blau Y, Katzir L, et al. Detecting Deficient Coverage in Colonoscopies. IEEE Trans Med Imaging 2020;39:3451-62.
5. Aoki T, Yamada A, Aoyama K, et al. Clinical usefulness of a deep learning-based system as the first screening on small-bowel capsule endoscopy reading. Dig Endosc 2020;32:585-91.
6. Sung H, Ferlay J, Siegel RL, et al. Global Cancer Statistics 2020: GLOBOCAN Estimates of Incidence and Mortality Worldwide for 36 Cancers in 185 Countries. CA Cancer J Clin 2021;71:209-49.
7. Corley DA, Jensen CD, Marks AR, et al. Adenoma detection rate and risk of colorectal cancer and death. N Engl J Med 2014;370:1298-306.
8. Zhao S, Wang S, Pan P, et al. Magnitude, Risk Factors, and Factors Associated With Adenoma Miss Rate of Tandem Colonoscopy: A Systematic Review and Meta-analysis. Gastroenterology 2019;156:1661-1674.e11.
9. Gong D, Wu L, Zhang J, et al. Detection of colorectal adenomas with a real-time computer-aided system (ENDOANGEL): a randomised controlled study. Lancet Gastroenterol Hepatol 2020;5:352-61.
10. Repici A, Badalamenti M, Maselli R, et al. Efficacy of Real-Time Computer-Aided Detection of Colorectal Neoplasia in a Randomized Trial. Gastroenterology 2020;159:512-520.e7.
11. Repici A, Spadaccini M, Antonelli G, et al. Artificial intelligence and colonoscopy experience: lessons from two randomised trials. Gut 2022;71:757-65.
12. Deliwala SS, Hamid K, Barbarawi M, et al. Artificial intelligence (AI) real-time detection vs. routine colonoscopy for colorectal neoplasia: a meta-analysis and trial sequential analysis. Int J Colorectal Dis 2021;36:2291-303.
13. Wang P, Berzin TM, Glissen Brown JR, et al. Real-time automatic detection system increases colonoscopic polyp and adenoma detection rates: a prospective randomised controlled study. Gut 2019;68:1813-9.
14. Brenner H, Hoffmeister M, Stock C. Time to reduce the burden of removing diminutive polyps in colorectal cancer screening. Gastrointest Endosc 2017;85:1177-9.
15. Kudo SE, Misawa M, Mori Y, et al. Artificial Intelligence-assisted System Improves Endoscopic Identification of Colorectal Neoplasms. Clin Gastroenterol Hepatol 2020;18:1874-1881.e2.
16. Takeda K, Kudo SE, Mori Y, et al. Accuracy of diagnosing invasive colorectal cancer using computer-aided endocytoscopy. Endoscopy 2017;49:798-802.
17. Houwen BBSL, Hassan C, Coupé VMH, et al. Definition of competence standards for optical diagnosis of diminutive colorectal polyps: European Society of Gastrointestinal Endoscopy (ESGE) Position Statement. Endoscopy 2022;54:88-99.
18. Zachariah R, Samarasena J, Luba D, et al. Prediction of Polyp Pathology Using Convolutional Neural Networks Achieves "Resect and Discard" Thresholds. Am J Gastroenterol 2020;115:138-44.
19. Hassan C, Balsamo G, Lorenzetti R, et al. Artificial Intelligence Allows Leaving-In-Situ Colorectal Polyps. Clin Gastroenterol Hepatol 2022;20:2505-2513.e4.
20. Gordon IO, Sherman JD, Leapman M, et al. Life Cycle Greenhouse Gas Emissions of Gastrointestinal Biopsies in a Surgical Pathology Laboratory. Am J Clin Pathol 2021;156:540-9.
21. Mori Y, Kudo SE, East JE, et al. Cost savings in colonoscopy with artificial intelligence-aided polyp

diagnosis: an add-on analysis of a clinical trial (with video). Gastrointest Endosc 2020;92:905-911.e1.
22. Kudo SE, Ichimasa K, Villard B, et al. Artificial Intelligence System to Determine Risk of T1 Colorectal Cancer Metastasis to Lymph Node. Gastroenterology 2021;160:1075-1084.e2.
23. Yang LS, Perry E, Shan L, et al. Clinical application and diagnostic accuracy of artificial intelligence in colonoscopy for inflammatory bowel disease: systematic review. Endosc Int Open 2022;10:E1004-13.
24. Hardy NP, Mac Aonghusa P, Neary PM, et al. Intraprocedural Artificial Intelligence for Colorectal Cancer Detection and Characterisation in Endoscopy and Laparoscopy. Surg Innov 2021;28:768-75.
25. Ken Namikawa, Toshiaki Hirasawa, Toshiyuki Yoshio, Junko Fujisaki, Tsuyoshi Ozawa, Soichiro Ishihara, Tomonori Aoki, Atsuo Yamada, Kazuhiko Koike, Hideo Suzuki & Tomohiro Tada (2020) Utilizing artificial intelligence in endoscopy: a clinician's guide, Expert Review of Gastroenterology & Hepatology, 14:8, 689-706, DOI: 10.1080/17474124.2020.1779058
26. Vulpoi RA, Luca M, Ciobanu A, et al. Artificial Intelligence in Digestive Endoscopy-Where Are We and Where Are We Going? Diagnostics (Basel) 2022;12:927.
27. Zhou J, Wu L, Wan X, et al. A novel artificial intelligence system for the assessment of bowel preparation (with video). Gastrointest Endosc 2020;91:428-435.e2.
28. Arnold M, Ferlay J, van Berge Henegouwen MI, et al. Global burden of oesophageal and gastric cancer by histology and subsite in 2018. Gut 2020;69:1564-71.
29. Guo L, Xiao X, Wu C, et al. Real-time automated diagnosis of precancerous lesions and early esophageal squamous cell carcinoma using a deep learning model (with videos). Gastrointest Endosc 2020;91:41-51.
30. Yang XX, Li Z, Shao XJ, et al. Real-time artificial intelligence for endoscopic diagnosis of early esophageal squamous cell cancer (with video). Dig Endosc 2021;33:1075-84.
31. Nakagawa K, Ishihara R, Aoyama K, et al. Classification for invasion depth of esophageal squamous cell carcinoma using a deep neural network compared with experienced endoscopists. Gastrointest Endosc 2019;90:407-14.
32. Tokai Y, Yoshio T, Aoyama K, et al. Application of artificial intelligence using convolutional neural networks in determining the invasion depth of esophageal squamous cell carcinoma. Esophagus 2020;17:250-6.
33. Visrodia K, Singh S, Krishnamoorthi R, et al. Magnitude of Missed Esophageal Adenocarcinoma After Barrett's Esophagus Diagnosis: A Systematic Review and Meta-analysis. Gastroenterology 2016;150:599-607.e7; quiz e14-5.
34. de Groof AJ, Struyvenberg MR, van der Putten J, et al. Deep-Learning System Detects Neoplasia in Patients With Barrett's Esophagus With Higher Accuracy Than Endoscopists in a Multistep Training and Validation Study With Benchmarking. Gastroenterology 2020;158:915-929.e4.
35. de Groof AJ, Struyvenberg MR, Fockens KN, et al. Deep learning algorithm detection of Barrett's neoplasia with high accuracy during live endoscopic procedures: a pilot study (with video). Gastrointest Endosc 2020;91:1242-50.
36. Isobe Y, Nashimoto A, Akazawa K, et al. Gastric cancer treatment in Japan: 2008 annual report of the JGCA nationwide registry. Gastric Cancer 2011;14:301-16.
37. Pimenta-Melo AR, Monteiro-Soares M, Libânio D, et al. Missing rate for gastric cancer during upper gastrointestinal endoscopy: a systematic review and meta-analysis. Eur J Gastroenterol Hepatol 2016;28:1041-9.
38. Ueyama H, Kato Y, Akazawa Y, et al. Application of artificial intelligence using a convolutional neural network for diagnosis of early gastric cancer based on magnifying endoscopy with narrow-band imaging. J Gastroenterol Hepatol 2021;36:482-9.
39. Li L, Chen Y, Shen Z, et al. Convolutional neural network for the diagnosis of early gastric cancer based on magnifying narrow band imaging. Gastric Cancer 2020;23:126-32.
40. Wu L, Zhou W, Wan X, et al. A deep neural network improves endoscopic detection of early gastric cancer without blind spots. Endoscopy 2019;51:522-31.
41. Kim JH, Oh SI, Han SY, et al. An Optimal Artificial Intelligence System for Real-Time Endoscopic Prediction of Invasion Depth in Early Gastric Cancer. Cancers (Basel) 2022;14:6000.
42. Pannala R, Krishnan K, Melson J, et al. Artificial intelligence in gastrointestinal endoscopy. VideoGIE 2020;5:598-613.
43. Luo Q, Yang H, Hu B. Application of artificial intelligence in the endoscopic diagnosis of early gastric cancer, atrophic gastritis, and Helicobacter pylori infection. J Dig Dis 2022;23:666-74.
44. Hussein NR. Helicobacter pylori and gastric cancer in the Middle East: a new enigma? World J Gastroenterol 2010;16:3226-34.
45. Bossuyt P, Vermeire S, Bisschops R. Scoring endoscopic disease activity in IBD: artificial intelligence sees more and

better than we do. Gut 2020;69:788-9.
46. Rutter MD, Rees CJ. Quality in gastrointestinal endoscopy. Endoscopy 2014;46:526-8.
47. Wu L, Zhang J, Zhou W, et al. Randomised controlled trial of WISENSE, a real-time quality improving system for monitoring blind spots during esophagogastroduodenoscopy. Gut 2019;68:2161-9.
48. Ding Z, Shi H, Zhang H, et al. Artificial intelligence-based diagnosis of abnormalities in small-bowel capsule endoscopy. Endoscopy 2023;55:44-51.
49. Tonozuka R, Itoi T, Nagata N, et al. Deep learning analysis for the detection of pancreatic cancer on endosonographic images: a pilot study. J Hepatobiliary Pancreat Sci 2021;28:95-104.
50. Marya NB, Powers PD, Chari ST, et al. Utilisation of artificial intelligence for the development of an EUS-convolutional neural network model trained to enhance the diagnosis of autoimmune pancreatitis. Gut 2021;70:1335-44.
51. Kuwahara T, Hara K, Mizuno N, et al. Usefulness of Deep Learning Analysis for the Diagnosis of Malignancy in Intraductal Papillary Mucinous Neoplasms of the Pancreas. Clin Transl Gastroenterol 2019;10:1-8.
52. Minoda Y, Ihara E, Komori K, et al. Efficacy of endoscopic ultrasound with artificial intelligence for the diagnosis of gastrointestinal stromal tumors. J Gastroenterol 2020;55:1119-26.
53. Zhang J, Zhu L, Yao L, et al. Deep learning-based pancreas segmentation and station recognition system in EUS: development and validation of a useful training tool (with video). Gastrointest Endosc 2020;92:874-885.e3.
54. Dahiya DS, Al-Haddad M, Chandan S, et al. Artificial Intelligence in Endoscopic Ultrasound for Pancreatic Cancer: Where Are We Now and What Does the Future Entail? J Clin Med 2022;11:7476.
55. Liu X, Cruz Rivera S, Moher D, et al. Reporting guidelines for clinical trial reports for interventions involving artificial intelligence: the CONSORT-AI extension. Lancet Digit Health 2020;2:e537-48.
56. Okagawa Y, Abe S, Yamada M, et al. Artificial Intelligence in Endoscopy. Dig Dis Sci 2022;67:1553-72.
57. Parasher G, Wong M, Rawat M. Evolving role of artificial intelligence in gastrointestinal endoscopy. World J Gastroenterol 2020;26:7287-98.
58. Hadjiiski L, Cha K, Chan HP, et al. AAPM task group report 273: Recommendations on best practices for AI and machine learning for computer-aided diagnosis in medical imaging. Med Phys 2023;50:e1-e24.
59. Zacharakis G, Almasoud A. Using of artificial intelligence: Current and future applications in colorectal cancer screening. World J Gastroenterol 2022;28:2778-81.
60. He J, Baxter SL, Xu J, et al. The practical implementation of artificial intelligence technologies in medicine. Nat Med 2019;25:30-6.
61. Ahmed IA, Senan EM, Shatnawi HSA. Hybrid Models for Endoscopy Image Analysis for Early Detection of Gastrointestinal Diseases Based on Fused Features. Diagnostics (Basel) 2023;13:1758.
62. Fati SM, Senan EM, Azar AT. Hybrid and Deep Learning Approach for Early Diagnosis of Lower Gastrointestinal Diseases. Sensors (Basel) 2022;22:4079.

doi: 10.21037/tgh-23-37
Cite this article as: El-Sayed A, Salman S, Alrubaiy L. The adoption of artificial intelligence assisted endoscopy in the Middle East: challenges and future potential. Transl Gastroenterol Hepatol 2023;8:42.

