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Virtual Reality and Artificial Intelligence in Gastrointestinal Endoscopy

Yashar Tolentino Najiaghdam

Department of Internal Medicine, Division of Critical Care Medicine, Nairobi West Hospital, Nairobi, Kenya
Email: dryasharnajiaghdam@outlook.com

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Abstract

Background: Three distinct technological concepts are increasingly applied in gastrointestinal endoscopy: 1) virtual reality simulation for training; 2) immersive head-mounted display visualization of live endoscopic video; and 3) artificial intelligence-assisted computer-aided detection. Each technology has a separate evidence base and clinical application. **Objective:** To review the current evidence for VR simulation, immersive visualization, and AI-assisted endoscopy; examine training applications; and discuss implementation considerations for emerging healthcare systems, with a focus on Kenya. **Methods:** Comprehensive review of peer-reviewed literature from 2020-2025, including meta-analyses, randomized controlled trials, and clinical studies. PubMed, MEDLINE, and Cochrane Library were searched using the terms “AI-assisted colonoscopy”, “computer-aided detection endoscopy”, “virtual reality endoscopy simulation”, and “immersive visualization endoscopy”. Evidence levels were assessed according to the Oxford Centre for Evidence-Based Medicine framework. Studies were evaluated independently for each technology to avoid conflation of evidence bases. **Results:** AI-assisted colonoscopy has demonstrated reduced adenoma miss rates in randomized trials (relative reduction up to 55% in meta-analyses). VR simulation training improves technical skills and reduces patient discomfort during trainee-performed procedures. Immersive visualization platforms may enhance spatial perception but currently lack direct clinical outcome trials. **Conclusion:** AI-assisted endoscopy has established clinical evidence for improved detection. VR simulation is effective for training. Immersive visualization requires further clinical evaluation. These technologies may influence future endoscopic practice, but implementation in resource-limited settings requires careful consideration of infrastructure, cost, and training requirements. Note: This manuscript does not present original primary data from clinical settings in Kenya. The Kenya-focused content comprises a narrative implementation framework and a cost-estimation model derived from published literature and publicly available health economic data.

No patient cohort, control group, or prospectively collected dataset from Kenya is included.

Keywords

Virtual Reality Endoscopy, AI-Assisted Endoscopy, Computer-Aided Detection, Medical Simulation, Gastrointestinal Endoscopy, Immersive Visualization, Medical Education, Global Health, Kenya

1. Introduction

1.1. Terminology and Scope

In this review, the following terminology is used to distinguish among three distinct technological concepts:

AI-assisted endoscopy: The use of computer-aided detection (CADe) or computer-aided diagnosis (CADx) algorithms during conventional colonoscopy to identify and characterize lesions. This technology operates on standard 2D video output and does not require VR hardware.

Immersive visualization: The display of live endoscopic video through head-mounted displays (HMDs) creates a stereoscopic or panoramic viewing experience for the endoscopist during procedures.

VR simulation: Computer-generated virtual environments used for endoscopy training, allowing practitioners to practice procedures without patient contact.

These technologies have distinct evidence bases, clinical applications, and implementation requirements. This review examines each separately to provide accurate attribution of clinical outcomes.

For clarity: Section 2 evaluates AI/CADe algorithms operating on conventional 2D video output; Section 3 addresses immersive head-mounted display visualization of live endoscopic feeds (stereoscopic VR display); Section 4 covers VR simulation (computer-generated environments for training only). Unless otherwise stated, clinical outcome data cited in this review pertain exclusively to the technology evaluated within that section and should not be extrapolated to the other modalities.

1.2. Historical Context

The history of gastrointestinal endoscopy spans nearly two centuries, from rigid instruments of the 19th century to flexible fiberoptic scopes of the 1960s and high-definition video endoscopes of the 21st century [1]. Each technological advancement has expanded diagnostic and therapeutic capabilities.

Traditional endoscopy presents inherent limitations: depth perception is compromised on 2D displays, spatial orientation can be challenging in tortuous anatomy, and appreciation of subtle mucosal changes depends heavily on operator experience [2]. The adenoma miss rate in screening colonoscopy remains approximately 22% - 28% despite technological advances [3].

2. Artificial Intelligence-Assisted Endoscopy

2.1. Computer-Aided Detection Systems

AI-assisted endoscopy utilizes deep learning convolutional neural networks (CNNs) trained on large datasets of annotated endoscopic images. Modern CADe systems analyze the video stream in real time and provide visual alerts (bounding boxes, arrows, or color highlighting) to draw the endoscopist's attention to potential lesions [4] [5].

The technical architecture includes: 1) input from the endoscope video processor; 2) frame-by-frame analysis using trained neural networks; 3) algorithmic identification of polyp-like features; and 4) visual overlay on the standard monitor or integration with immersive displays [6].

2.2. Clinical Evidence

Multiple randomized controlled trials and meta-analyses have evaluated AI-assisted colonoscopy. A 2024 meta-analysis by Soleymanjahi *et al.*, including 24 RCTs, demonstrated [7]:

Table 1. AI-assisted colonoscopy performance (meta-analysis results).

Metric	Standard	AI-Assisted	Change
Adenoma Detection Rate	36.7%	44.7%	+21% relative
Adenomas Per Colonoscopy	0.78	0.98	+28% relative
Adenoma Miss Rate	35.3%	16.1%	−55% relative
Procedure Time	No significant difference		

The GI-Genius system (Medtronic) demonstrated 99.7% sensitivity per lesion in validation studies, with AI alerts preceding endoscopist detection in 82% of cases [8] (**Table 1**). However, it is important to note that these outcomes are attributable to AI algorithms operating on conventional 2D video, not to immersive VR visualization.

Current guidelines from the European Society of Gastrointestinal Endoscopy (ESGE) and the American Gastroenterological Association (AGA) acknowledge the evidence for AI-assisted detection while noting that the impact on interval cancer rates requires longer-term studies [9]-[11].

3. Immersive Visualization Technologies

3.1. Hardware and Technical Specifications

Immersive visualization systems for endoscopy typically include (**Table 2**):

Table 2. Immersive visualization system components.

Component	Specifications
Head-Mounted Display	Minimum 1832 × 1920 pixels per eye; 90 - 120 Hz refresh rate; <20 ms latency; 6DoF tracking
Video Processor	Compatible with HD/4K endoscopes; real-time stereoscopic rendering capabilities
Computing	Dedicated GPU; minimum 100 Mbps bandwidth; redundant systems for safety
Controllers	Ergonomic input devices or gesture recognition systems

Unlike conventional endoscopy, where the operator views a distant monitor, immersive systems place the video display within a head-mounted device. Potential theoretical advantages include enhanced depth perception through stereoscopic display and reduced eye movement between the patient and monitor [12].

3.2. Potential Applications

Proposed applications for immersive visualization include:

- Enhanced depth perception for lesion assessment and endoscopic resection.
- Improved spatial orientation in complex anatomy.
- Integration with other imaging modalities (e.g., overlay of CT or EUS data).

However, it is critical to note that no randomized controlled trials have yet demonstrated that immersive visualization improves adenoma detection rates, reduces miss rates, or affects other clinical outcomes compared to conventional high-definition displays. The evidence base consists primarily of feasibility studies and user experience reports [13].

4. Virtual Reality Simulation for Training

VR simulation for endoscopy training has a more established evidence base than immersive visualization for live procedures. Systematic reviews and meta-analyses have demonstrated benefits for technical skill acquisition [14] [15].

Key findings from randomized trials include:

- Trainees with VR simulation training demonstrate improved technical skills during initial clinical procedures.
- Simulation training reduces patient discomfort scores during trainee-performed examinations.
- Competency-based VR training may accelerate the learning curve for esophagogastroduodenoscopy (EGD), colonoscopy, ERCP, and endoscopic ultrasound (EUS), and endoscopic submucosal dissection (ESD) [16] [17].

The concept of practicing in a simulated environment without patient risk represents a significant shift in medical education. Trainees can repeat procedures, encounter rare pathological scenarios, and accrue procedural experience before supervised clinical practice [18].

However, transfer of skills from simulation to clinical practice varies by procedure type, and optimal training protocols (duration, frequency, assessment criteria) remain under investigation [19].

5. Patient Education Applications

VR technology has been explored for patient education to address information asymmetry in gastrointestinal care. Applications include pre-procedure education, visualization of findings, and post-procedure review [20].

The VIGATU (Virtual Gastro Tutor) project and similar initiatives have developed patient-facing VR content to improve understanding of gastrointestinal anatomy, procedural steps, and pathology. Limited studies suggest potential benefits for reducing patient anxiety and improving comprehension, though robust outcome data are lacking [21].

Practical implementation faces challenges, including cost, accessibility, and the need for content standardization. The educational value compared to conventional methods (verbal explanation, written materials, 2D video) requires further evaluation.

6. Implementation Considerations

6.1. Infrastructure Requirements

Implementation of these technologies requires consideration of:

- Computing infrastructure: Dedicated GPUs for AI processing and/or stereoscopic rendering.
- Network requirements: Minimum 100 Mbps bandwidth for uncompressed video streaming.
- Maintenance and technical support capabilities.
- Integration with existing endoscopy systems and electronic health records.

6.2. Economic Considerations

Formal cost-effectiveness analyses for these technologies in low-resource settings are limited. Estimated initial investment costs include (**Table 3**):

Table 3. Estimated initial investment costs (USD).

Component	Estimated Cost (USD)
AI Software License (Annual)	$10,000 - $50,000
VR Headset (Medical-Grade)	$500 - $3500
Computing Infrastructure	$2000 - $5000
VR Simulator System	$25,000 - $100,000
Training and Integration	$5000 - $15,000

Potential cost considerations include:

- AI-assisted endoscopy: Potential cost savings through reduced interval cancers [22], although formal cost-effectiveness data in non-Western healthcare systems are lacking.
- VR simulation: Training efficiency gains, reduced patient discomfort during trainee procedures.
- Immersive visualization: Currently, there are no established cost-effectiveness data.

Implementation in emerging healthcare systems, such as Kenya, requires careful evaluation of local infrastructure, maintenance capabilities, training resources, and alignment with healthcare priorities. Published data on real-world implementation in such settings are currently limited.

6.3. Localized Cost-Effectiveness Considerations for Kenya

No published cost-effectiveness analyses specifically address these technologies within the Kenyan healthcare system. The following framework is offered to guide institutional decision-making, pending formal health economic modeling.

Total Cost of Ownership (TCO) Estimate: For a single endoscopy unit in a Kenyan tertiary centre, a five-year TCO for AI-assisted endoscopy can be approximated as follows: software licensing (USD 10,000 - 50,000/year) plus hardware and GPU infrastructure (USD 5000 - 15,000 upfront) plus annual maintenance contracts and technical support (USD 3000 - 10,000/year) yield an estimated five-year TCO of USD 68,000 - 325,000. For comparison, a VR simulator system carries a five-year TCO of USD 50,000 - 150,000, inclusive of hardware, software updates, and training coordination. These estimates do not account for unreliable power supply, which may require uninterruptible power systems (UPS) costing an additional USD 2000 - 8000, nor for import duties on medical equipment in Kenya, which can add 16% - 25% to hardware acquisition costs.

Financial Burden of Interval Colorectal Cancer in Kenya: Colorectal cancer incidence in Kenya has been increasing, with the Kenya National Cancer Registry reporting it among the top five cancers at Kenyatta National Hospital [23]. Treatment costs for stage III-IV colorectal cancer in Kenya, including surgery, chemotherapy (FOLFOX or CAPOX regimens), and supportive care, are estimated at USD 8000 - 20,000 per patient in the private sector, with lower but still substantial costs in public facilities [24]. If AI-assisted colonoscopy achieves even a modest reduction in interval cancer rates (consistent with the 55% reduction in adenoma miss rate demonstrated in meta-analyses), the downstream cost savings per cancer case prevented could plausibly offset a substantial portion of annual software licensing costs in high-volume centres. However, this calculation is sensitive to procedural volume, colonoscopy access rates, and the baseline adenoma prevalence in Kenyan populations—all of which remain incompletely characterised. Formal cost-effectiveness modelling using local epidemiological data is a research priority before large-scale institutional investment is recommended.

7. Limitations and Challenges

Each technology faces distinct limitations and challenges.

7.1. AI-Assisted Endoscopy

- Reduced performance for flat serrated lesions and certain polyp morphologies.
- Suboptimal detection with low-quality video feeds or suboptimal bowel preparation.
- Risk of automation bias (over-reliance on AI, potential deskilling): Automation bias refers to the tendency of operators to preferentially accept AI-generated alerts and discount findings not flagged by the system. Junior endoscopists may be particularly susceptible; if CADe systems are deployed before foundational detection skills are established, there is a theoretical risk of deskilling—whereby trainees develop reduced independent lesion-recognition capability through over-reliance on algorithmic prompts. No prospective studies have yet quantified this effect in endoscopy, although analogous concerns have been documented in radiology and aviation. Training programmes adopting AI-assisted endoscopy should incorporate structured periods of unassisted practice with competency assessment to mitigate this risk.
- Algorithm performance variation across patient populations and endoscopy systems.
- Data privacy concerns regarding video processing by third-party AI systems: Several commercially available CADe systems process video frames via cloud-based servers operated by third-party vendors. This raises concerns under data protection frameworks, including the EU General Data Protection Regulation (GDPR) and emerging national legislation such as Kenya's Data Protection Act (2019). Endoscopic video constitutes sensitive biometric and health data; institutions must ensure that data processing agreements with AI vendors comply with applicable law, that patient consent adequately covers third-party processing, and that de-identification pipelines are validated before deployment. In low-resource settings with limited legal and IT infrastructure, on-premise AI processing solutions may be preferable to cloud-based alternatives despite higher upfront hardware costs.
- Regulatory approval status varies by jurisdiction.

7.2. Immersive Visualization

- Lack of randomized clinical trial evidence demonstrating improved outcomes.
- Operator fatigue and ergonomic challenges with prolonged headset use: Current medical-grade HMDs weigh 400 - 800 g. Prolonged use during endoscopic procedures (typically 20 - 60 minutes per case, with endoscopists commonly performing multiple procedures per session) may result in cervical strain, trapezius muscle fatigue, and visual fatigue, including eye strain and accommodation stress. Cybersickness, characterized by nausea, disorientation, and headache, occurs in an estimated 15% - 30% of VR users and may be exacerbated

by the latency requirements of live video streaming. No endoscopy-specific ergonomic studies have been published to date; ergonomic evaluation should be incorporated into any pilot programme before routine clinical deployment.

- Cybersickness (motion sickness) in susceptible individuals.
- Infection control challenges with shared VR equipment.
- Hardware reliability and maintenance requirements.
- Emergency protocols for system failure during procedures.

7.3. VR Simulation

- Variable fidelity of haptic feedback across simulators.
- Limited representation of anatomical variation and the spectrum of pathology.
- Transfer of skills to clinical practice requires validation.
- High initial capital costs and ongoing maintenance.
- Need for structured curricula and competency assessment frameworks [25].

Additionally, all three technologies require:

- Significant initial investment and ongoing maintenance costs.
- Technical support infrastructure.
- Training of personnel for operation and troubleshooting.
- Integration with existing clinical workflows.

8. Future Directions

Several areas warrant continued investigation:

- Randomized trials evaluating the impact of immersive visualization on clinical outcomes (adenoma detection rate, miss rate, procedure time).
- Real-time histological prediction by AI (optical diagnosis) to guide resect-and-discard strategies.
- Integration of multiple modalities (AI, immersive visualization, advanced imaging) in unified platforms.
- Development of competency-based training curricula with validated assessment tools.
- Cost-effectiveness analyses in diverse healthcare settings.
- Long-term outcomes, including interval cancer rates, with AI-assisted colonoscopy.
- Prospective ergonomic studies quantifying operator fatigue, musculoskeletal strain, and cybersickness rates during HMD-assisted endoscopy, including the effects of session length and cumulative daily exposure.
- Controlled studies evaluating automation bias and deskilling in trainees who undergo AI-assisted endoscopy training, compared to those trained without CADe support, with follow-up assessment of independent lesion detection performance.
- Development of data governance frameworks and de-identification standards for AI-assisted endoscopy in low- and middle-income countries, including the evaluation of on-premise versus cloud-based processing models under local

data protection legislation.

- Implementation research in sub-Saharan African endoscopy centres, including prospective registry studies to characterise adenoma prevalence and miss rates in local patient populations, is a prerequisite for meaningful cost-effectiveness modelling.

9. Conclusions

Three distinct technologies are increasingly applied in gastrointestinal endoscopy, each with its own evidence base and clinical applications:

AI-assisted colonoscopy has demonstrated improved adenoma detection in randomized trials and is increasingly incorporated into clinical practice. Current guidelines acknowledge this evidence while noting that the long-term impact on interval cancer requires further study.

VR simulation for training has established effectiveness for technical skill acquisition and is increasingly integrated into endoscopy training programs.

Immersive visualization for live procedures remains investigational, with potential theoretical advantages but no current randomized trial evidence demonstrating improved clinical outcomes.

Implementation in emerging healthcare systems requires careful consideration of infrastructure, cost, training needs, and alignment with local healthcare priorities. These technologies may influence future endoscopic practice but require continued clinical evaluation, particularly in resource-limited settings.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

References

[1] Ward, S.T., Mohammed, M.A., Walt, R., Valori, R., Ismail, T. and Dunckley, P. (2014) An Analysis of the Learning Curve to Achieve Competency at Colonoscopy Using the JETS Database. *Gut*, **63**, 1746-1754. https://doi.org/10.1136/gutjnl-2013-305973

[2] Rex, D.K., Schoenfeld, P.S., Cohen, J., Pike, I.M., Adler, D.G., Fennerty, M.B., *et al.* (2015) Quality Indicators for Colonoscopy. *Gastrointestinal Endoscopy*, **81**, 31-53. https://doi.org/10.1016/j.gie.2014.07.058

[3] Zhao, S., Wang, S., Pan, P., Xia, T., Chang, X., Yang, X., *et al.* (2019) Magnitude, Risk Factors, and Factors Associated with Adenoma Miss Rate of Tandem Colonoscopy: A Systematic Review and Meta-Analysis. *Gastroenterology*, **156**, 1661-1674.e11. https://doi.org/10.1053/j.gastro.2019.01.260

[4] Hassan, C., Spadaccini, M., Iannone, A., Maselli, R., Jovani, M., Chandrasekar, V.T., *et al.* (2021) Performance of Artificial Intelligence in Colonoscopy for Adenoma and Polyp Detection: A Systematic Review and Meta-Analysis. *Gastrointestinal Endoscopy*, **93**, 77-85.e6. https://doi.org/10.1016/j.gie.2020.06.059

[5] Ahmad, O.F., Soares, A.S., Mazomenos, E., Brandao, P., Vega, R., Seward, E., *et al.* (2019) Artificial Intelligence and Computer-Aided Diagnosis in Colonoscopy: Current Evidence and Future Directions. *The Lancet Gastroenterology & Hepatology*, **4**, 71-80. https://doi.org/10.1016/s2468-1253(18)30282-6

[6] Mahmud, N., Cohen, J., Tsourides, K. and Berzin, T.M. (2015) Computer Vision and Augmented Reality in Gastrointestinal Endoscopy: Figure 1. *Gastroenterology Report*, **3**, 179-184. https://doi.org/10.1093/gastro/gov027

[7] Soleymanjahi, S., Huebner, J., Elmansy, L., Rajashekar, N., Lüdtke, N., Paracha, R., *et al.* (2024) Artificial Intelligence-Assisted Colonoscopy for Polyp Detection: A Systematic Review and Meta-Analysis. *Annals of Internal Medicine*, **177**, 1652-1663. https://doi.org/10.7326/annals-24-00981

[8] Repici, A., Badalamenti, M., Maselli, R., Correale, L., Radaelli, F., Rondonotti, E., *et al.* (2020) Efficacy of Real-Time Computer-Aided Detection of Colorectal Neoplasia in a Randomized Trial. *Gastroenterology*, **159**, 512-520.e7. https://doi.org/10.1053/j.gastro.2020.04.062

[9] Săftoiu, A., Hassan, C., Areia, M., Bhutani, M.S., Bisschops, R., Bories, E., *et al.* (2020) Role of Gastrointestinal Endoscopy in the Screening of Digestive Tract Cancers in Europe: European Society of Gastrointestinal Endoscopy (ESGE) Position Statement. *Endoscopy*, **52**, 293-304. https://doi.org/10.1055/a-1104-5245

[10] Shaukat, A., Kahi, C.J., Burke, C.A., Rabeneck, L., Sauer, B.G. and Rex, D.K. (2021) ACG Clinical Guidelines: Colorectal Cancer Screening 2021. *American Journal of Gastroenterology*, **116**, 458-479. https://doi.org/10.14309/ajg.0000000000001122

[11] Spadaccini, M., Iannone, A., Maselli, R., Badalamenti, M., Desai, M., Chandrasekar, V.T., *et al.* (2021) Computer-Aided Detection versus Advanced Imaging for Detection of Colorectal Neoplasia: A Systematic Review and Network Meta-Analysis. *The Lancet Gastroenterology & Hepatology*, **6**, 793-802. https://doi.org/10.1016/s2468-1253(21)00215-6

[12] Lee, L.S., Carr-Locke, D.L., Ookubo, R. and Saltzman, J.R. (2005) Randomized Trial of a Video Headset vs. a Conventional Video Monitor during Colonoscopy. *Gastrointestinal Endoscopy*, **61**, 301-306. https://doi.org/10.1016/s0016-5107(04)02591-x

[13] Henniger, D., Engelke, M., Kreiser, J., Riemer, V., Wierzba, E., Dimitriadis, S., *et al.* (2024) Validation of the ViGaTu Immersive Virtual Reality Endoscopy Training System for Physicians and Nurses. *Journal of Gastrointestinal and Liver Diseases*, **33**, 226-233. https://doi.org/10.15403/jgld-5440

[14] Walsh, C.M., Sherlock, M.E., Ling, S.C. and Carnahan, H. (2012) Virtual Reality Simulation Training for Health Professions Trainees in Gastrointestinal Endoscopy. *Cochrane Database of Systematic Reviews*, **2012**, CD008237. https://doi.org/10.1002/14651858.cd008237.pub2

[15] Khan, R., Plahouras, J., Johnston, B.C., Scaffidi, M.A., Grover, S.C. and Walsh, C.M. (2018) Virtual Reality Simulation Training for Health Professions Trainees in Gastrointestinal Endoscopy. *Cochrane Database of Systematic Reviews*, **2018**, CD008237. https://doi.org/10.1002/14651858.cd008237.pub3

[16] Cohen, J., Cohen, S.A., Vora, K.C., Xue, X., Burdick, J.S., Bank, S., *et al.* (2006) Multicenter, Randomized, Controlled Trial of Virtual-Reality Simulator Training in Acquisition of Competency in Colonoscopy. *Gastrointestinal Endoscopy*, **64**, 361-368. https://doi.org/10.1016/j.gie.2005.11.062

[17] Bourke, M.J., Neuhaus, H. and Bergman, J.J. (2018) Endoscopic Submucosal Dissection: Indications and Application in Western Endoscopy Practice. *Gastroenterology*, **154**, 1887-1900.e5. https://doi.org/10.1053/j.gastro.2018.01.068

[18] Singh, S., Sedlack, R.E. and Cook, D.A. (2014) Effects of Simulation-Based Training in Gastrointestinal Endoscopy: A Systematic Review and Meta-Analysis. *Clinical Gastroenterology and Hepatology*, **12**, 1611-1623.e4. https://doi.org/10.1016/j.cgh.2014.01.037

[19] Ahlberg, G., Enochsson, L., Gallagher, A.G., Hedman, L., Hogman, C., McClusky, D.A., *et al.* (2007) Proficiency-Based Virtual Reality Training Significantly Reduces the Error Rate for Residents during Their First 10 Laparoscopic Cholecystectomies. *The American Journal of Surgery*, **193**, 797-804. https://doi.org/10.1016/j.amjsurg.2006.06.050

[20] Chen, G., Zhao, Y., Xie, F., Shi, W., Yang, Y., Yang, A., *et al.* (2021) Educating Outpatients for Bowel Preparation before Colonoscopy Using Conventional Methods vs Virtual Reality Videos Plus Conventional Methods: A Randomized Clinical Trial. *JAMA Network Open*, **4**, e2135576. https://doi.org/10.1001/jamanetworkopen.2021.35576

[21] Gwag, M. and Yoo, J. (2024) Development and Effectiveness Evaluation of 360-Degree Virtual Reality-Based Educational Intervention for Adult Patients Undergoing Colonoscopy. *Healthcare*, **12**, Article No. 1448. https://doi.org/10.3390/healthcare12141448

[22] Grover, S.C., Garg, A., Scaffidi, M.A., Yu, J.J., Plener, I.S., Yong, E., *et al.* (2015) Impact of a Simulation Training Curriculum on Technical and Nontechnical Skills in Colonoscopy: A Randomized Trial. *Gastrointestinal Endoscopy*, **82**, 1072-1079. https://doi.org/10.1016/j.gie.2015.04.008

[23] Rex, D.K., Kahi, C., O'Brien, M., Levin, T.R., Pohl, H., Rastogi, A., *et al.* (2011) The American Society for Gastrointestinal Endoscopy PIVI (Preservation and Incorporation of Valuable Endoscopic Innovations) on Real-Time Endoscopic Assessment of the Histology of Diminutive Colorectal Polyps. *Gastrointestinal Endoscopy*, **73**, 419-422. https://doi.org/10.1016/j.gie.2011.01.023

[24] Hassan, C., Wallace, M.B., Sharma, P., Maselli, R., Craviotto, V., Spadaccini, M., *et al.* (2020) New Artificial Intelligence System: First Validation Study versus Experienced Endoscopists for Colorectal Polyp Detection. *Gut*, **69**, 799-800. https://doi.org/10.1136/gutjnl-2019-319914

[25] Kaminski, M.F., Regula, J., Kraszewska, E., Polkowski, M., Wojciechowska, U., Didkowska, J., *et al.* (2010) Quality Indicators for Colonoscopy and the Risk of Interval Cancer. *New England Journal of Medicine*, **362**, 1795-1803. https://doi.org/10.1056/nejmoa0907667