Artificial intelligence improves adenoma detection rate during colonoscopy

Cameron Schauer, Michael Chieng, Michael Wang, Michelle Neave, Sarah Watson, Marius Van Rijnsoever, Russell Walmsley, Ali Jafer

ABSTRACT

BACKGROUND: Artificial intelligence-assisted colonoscopy (AIAC) has gained attention as a tool to assist with polyp detection during colonoscopy. Uncertainty remains as to the clinical benefit, given limited publications using different modules.

METHOD: A single-centre retrospective study was performed at Waitematā Endoscopy, a private endoscopy centre in Auckland, New Zealand. An Olympus Endo-AID module was utilised for the first time by 13 experienced endoscopists. Outcomes from AIAC between 10 March 2021 to 23 April 2021 were compared to a subsequent non-AI conventional colonoscopy (CC) control group from 27/4/21 to 20/6/21.

RESULTS: A total of 213 AIACs were compared with 213 CCs. Baseline patient age, gender, indication for procedure, bowel preparation scores and specialty of proceduralist (gastroenterologist or surgeon) were well matched (p>0.05). The withdrawal time was significantly longer in the AIAC group compared to CC controls (15 vs 13 minutes; p<0.001). The adenoma detection rate (ADR) was significantly higher in the AIAC group compared to CC group (47.9% vs 38.5%; odds ratio 1.59; 95% CI [1.05–2.41]; p=0.03). The overall polyp detection rate (PDR) was similar between groups (70% vs 70%; p=0.79). Analysis by polyp size, location and other histology was not significant between groups.

CONCLUSION: AI-assisted colonoscopy significantly improved ADR compared with conventional colonoscopy. Further research is required to understand its utility and impact on long-term clinical outcomes.

In New Zealand and internationally, demand for colonoscopy has steadily increased over recent years.[1] A national bowel screening programme was introduced in 2018, and there has been significant expansion in studies performed for symptomatic indications.[1,2] This growing demand has placed pressure on providers to improve the scale and quality of these services, whilst maximising efficiency. Innovations which improve these metrics are therefore desired, considering the high local incidence of colorectal cancer (CRC).[3]

Computer-aided polyp detection tools (CADe) utilising artificial intelligence (AI) and deep-learning software have come to attention in recent years with several trials showing promise.[4,5] The primary role of these tools is the automated detection of polyps, indicating the presence and location of lesions in real time.[6] By drawing the endoscopist's attention to AI-recognised polyps, the software provides visual support and an additional mechanism that may help reduce the frequency of overlooked polyps. CADe software may also improve consistency and procedural efficiency across different colonoscopy providers, as it operates independently of endoscopists' experience level.[7]

The adenoma detection rate (ADR) is a key quality indicator in colonoscopy as it is inversely related to the incidence of post-colonoscopy interval CRC and CRC-related mortality.[8,9] Approximately 85% of interval cancers are thought to develop because of previously missed adenomas or incomplete polyp resection.[10] When comparing conventional colonoscopy (CC) with artificial intelligence-assisted colonoscopy (AIAC), seven randomised trials have been conducted to date with an overall suggestion of increased ADR.[11–17] To this end, AIAC has already been adopted into international guidelines.[18] Only one abstract from a single user has been published using the Olympus Endo-AID module,[19] which gained regulatory approval in Europe in 2020. No studies have been published from New Zealand, with few studies of AI utilisation in healthcare at all.[20] Due to the novelty of the technology, limited publications and short research periods clinical equipoise remains. We sought to study AIAC using Endo-AID to provide further perspective of this.

Method

A single-centre retrospective study was performed at Waitematā Endoscopy, a private endoscopy centre in Auckland. The Endo-AID (Olympus Corporation) module was introduced and utilised for the first time by 13 experienced consultant endoscopists (four surgeons, nine gastroenterologists). These endoscopists with at least five years of independent endoscopy experience each perform at minimum 300 colonoscopies per year, with an average caecal intubation rate of 99.2%, polyp detection rate (PDR) of 73% and ADR of 42% over the preceding two years (2019 and 2020).[21]

The Endo-AID module is designed to process colonoscopy images in real time and superimpose a green box over suspected polyps on the endoscopy display (see Figure 1). Detection Type A preset (sensitive) was used.

The primary endpoint for assessment was the ADR (proportion of patients who had one or more adenomas resected) for consecutive patients attending over a six-week period between 10 March 2021 to 23 April 2021, compared to procedures without its use (control group) from 27 April 2021 to 20 June 2021. The secondary outcomes included polyp detection rate (PDR, proportion of patients who had one or more polyp of any histology removed), sessile serrated lesion detection rate (SSLDR, proportion of patients who had one or more SSL removed), assessment of differences in size, location and morphology. Total withdrawal time from caecum to completion of procedure and caecal intubation rate were compared.

All consecutive patients were included and only those with a history of previous colorectal resection were excluded. Patients were classified as having their procedure for surveillance (i.e., colonoscopy performed to further evaluate an asymptomatic patient with a previous history of polyps or increased risk of colorectal cancer) or symptoms (i.e., colonoscopy performed to investigate intestinal symptoms or signs). No screening patients were included in this study.

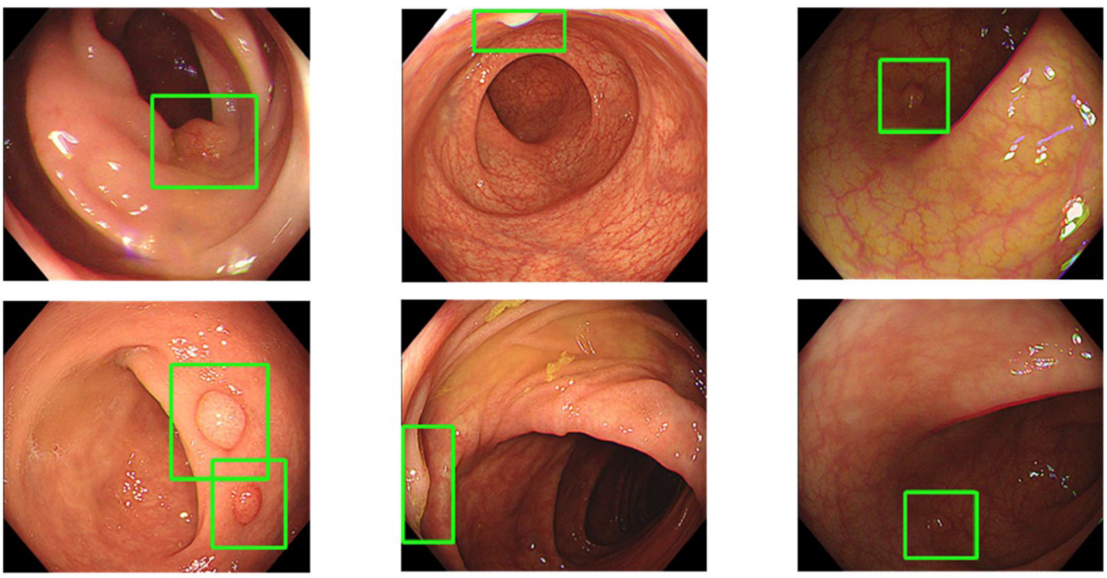
Endoscopists were able to toggle AI on-and-off at their discretion. Additional use of techniques to enhance polyp detection such as use of a distal cap, narrow band imaging, chemical chromoendoscopy, or anti-spasmodics remained at users' discretion.

All patients used split bowel preparation. Bowel preparation was evaluated and graded by the endoscopist performing the exam using the Boston Bowel Preparation Scale (BBPS).[22] All colonoscopies were performed using conscious sedation only (combination fentanyl and midazolam). Withdrawal time was measured by nursing staff from the time of caecal intubation to removal of the colonoscope from the colon. Polyps were classified by endoscopist estimation of size, location and morphology (polypoidal: Paris 0-Ip or non-polypoidal: Paris 0-IIa, Paris 0-IIb, Paris 0-Is).[23] Location was considered proximal if proximal to the splenic flexure. Final decision for polyp resection was at the discretion of the endoscopist.

All procedures were completed in the same endoscopy room with the same equipment, including high definition colonoscopes (HQ 190 with EVIS X1 video column; Olympus, Tokyo, Japan). Histopathology was assessed using standard methods at a single laboratory.

No funding was received. The Endo-AID equipment from Olympus was loaned free of charge. Standard written consent was gained from all patients prior to colonoscopy.

Figure 1: Endo-AID module with green boxes highlighting potential lesions.



Statistics

Sample size calculations for per patient multivariate logistic regression were conducted using the detection rate of tubular adenoma use as the primary outcome, and showed that a minimum of 150 patients were required for a model incorporating up to six predictor variables, with the adverse event rate being estimated to be approximately 40%, and the number of events per variable (EPV) value being 10.[24]

Statistical analysis was performed using IBM SPSS Statistics version 26.0 (New York, USA). Univariate comparisons of baseline parameters were conducted using the unpaired t-test, where normal distribution had been confirmed by the Kolmogorov–Smirnov test (p>0.05).

Non-normally distributed data were analysed using the Mann–Whitney U test, and categorical data using the Chi-squared or Fisher's exact test. Per patient multivariate logistic regression of detection rate by intervention group was performed with adjustment for confounding variables including age, sex, interventionist, colonoscopy indication, and the Boston Bowel Preparation Scale. All tests were two-tailed, and p<0.05 was considered statistically significant.

Results

A total of 213 consecutive AIACs were compared with 213 CCs (control arm). The mean age of patients was 56 years old in both cohorts, with 48% male (see Table 1). Indication for procedure, bowel preparation scores and performing specialist (gastroenterologist or surgeon) were well matched (p>0.05). The withdrawal time was longer in the AIAC group compared to controls (15 vs 13 minutes; p<0.001). Caecal intubation was achieved in all cases. No complications were reported for any of the procedures.

The adenoma detection rate (ADR) was significantly higher in the AIAC group compared to CC group (47.9% vs 38.5%; odds ratio (OR) 1.59; 95% confidence interval (CI) [1.05–2.41]; p=0.03). The polyp detection rates (PDR) were no different between groups (70% vs 70%; p=0.79). Sessile serrated lesion detection was also similar (20% vs 24%; p=0.56). Further analysis by polyp size, location, other histological features and morphology did not reveal any significant difference between the two groups (see Table 2).

Discussion

We demonstrate that the addition of Endo-AID artificial intelligence-assisted colonoscopy resulted in a 59% relative increase (9.4% absolute increase) in ADR compared to conventional colonoscopy. ADR is an established performance indicator in colonoscopy, validated as a predictor of cancer occurring after colonoscopy.[25] It is estimated that for every 1% increase in ADR, a patient's risk

Table 1: Characteristics of patients by intervention group. Data are presented as mean ± SD, median (IQR), or number of participants (% of participants).

Parameter	AIAC group (n=213)	Control group (n=213)	p-value
Age (years)	56 ±15	56±16	0.60
Male sex	103 (48.4%)	103 (48.4%)	>0.99
Interventionist			
Gastroenterologist	154 (72.3%)	169 (79.3%)	0.11
Surgeon	59 (27.7%)	44 (20.7%)	
Indication for colonoscopy			
Symptoms	122 (57.3%)	104 (48.8%)	0.19
Surveillance	79 (37.1%)	92 (43.2%)	
Symptoms and surveillance	12 (5.6%)	17 (8.0%)	
Boston Bowel Preparation Scale	8.3±1.3	8.3±1.3	0.91
Withdrawal time	15 (11–15)	13 (9–14)	<0.001
Total number of polyps	1(0–2)	1 (0–3)	0.19

Table 2: Detection rate according to intervention arm, as well as "per patient" multivariate logistic regression of detection rate by intervention group adjusted for confounding variables including age, sex, interventionist, colonoscopy indication, and the Boston Bowel Preparation Scale. Data are presented as number of patients (% of patients).

Parameter	AIAC group (n=213)	Control group (n=213)	Odds Ratio (95%CI)	p-value
All polyps	149 (70.0%)	149 (70.0%)	1.06 (0.69–1.64)	0.79
Size of polyp				
≤ 5mm	149 (70.0%)	136 (63.8%)	1.42 (0.92–2.18)	0.12
6-9 mm	33 (15.5%)	33 (15.5%)	1.03 (0.60–1.77)	0.91
≥ 10 mm	22 (10.3%)	26 (12.2%)	0.88 (0.48–1.63)	0.69
Location of polyp				
Proximal colon	123 (57.7%)	108 (50.7%)	1.46 (0.98–2.19)	0.07
Distal colon	109 (51.2%)	104 (48.8%)	1.14 (0.77–1.69)	0.51
Histology				
Tubular adenoma	102 (47.9%)	82 (38.5%)	1.59 (1.05–2.41)	0.03
Tubulovillous adenoma	7 (3.3%)	7 (3.3%)	0.95 (0.33–2.78)	0.93
Sessile serrated lesion	43 (20.2%)	51 (23.9%)	0.87 (0.55–1.39)	0.56
Hyperplastic polyp	63 (29.6%)	57 (26.8%)	1.21 (0.79–1.86)	0.39
High-grade dysplasia	0 (0.0%)	2 (0.9%)	-	-
Carcinoma	1 (0.5%)	2 (0.7%)	0.40 (0.03–4.62)	0.46
Morphology				
Polypoidal	9 (4.2%)	14 (6.6%)	0.59 (0.24–1.41)	0.23
Non-polypoidal	144 (67.6%)	146 (68.5%)	1.01 (0.65–1.55)	0.98

of developing colon cancer over the next year decreases by 3%.[8]

Several factors have been linked with variable ADRs including training related factors,[26–28] specialist scope of practice, and differing levels of endoscopy experience.[29] Additional techniques such as chromoendoscopy, water-aided colonoscopy and patient position change have improved rates in some studies, but are variably adhered to, inconsistent between users, require interpretation, and are challenging to maintain and implement.[30–33] Mechanical adjuncts such as distal attachments and Third Eye have been developed to overcome these challenges, with only mixed success to date.[33–36] AI is the latest attempt to improve this procedure uniformly and consistently, which is otherwise substantially operator dependent.

To date AIAC trials have been limited by methodological issues, including lack of blinding and incomplete relevant data. Six of the seven studies to date assessed AI where they were developed, with proprietary modules not commercially available. Studies corroborating these findings in other users and populations have therefore not been possible with no trials to compare different systems.

Our study joins the limited but growing number of trials demonstrating consistent benefits for this technology,[11–17] with an estimated 44% relative increase in ADR averaged across five randomised control trials.[5] This was found in a cohort with a relatively low control ADR of 22.9% and a mean PDR of 30.7%, considerably lower than our averages of 44% and 70%, respectively. Current recommended minimal thresholds for ADR in screening colonoscopies are 25% overall, 30% in men and 20% in women aged over 50 years.[9] It is postulated that endoscopists with lower baseline ADRs might benefit most from AI assistance,[11] with a trial currently underway to investigate outcomes of using Endo-AID in trainees.[16] However, our study also supports the findings from one published abstract that even in "high detectors", AIAC can improve polyp detection, with gains in ADR demonstrated from 61% to 69%.[37]

Improving detection of SSLs remains a challenge due to their often subtle, non-polypoid appearance. SSLs may account for up to 30% of colorectal cancer[38] including interval cancers, particularly, in proximal locations.[39,40] SSLs are difficult to detect using conventional methods,[41] with unfortunately limited improvement with current studied AI modules. Our study likewise did not demonstrate any improvement in SSL detection, although our average detection rate of 23% is appreciably higher than those in other studies ranging from 4–6%.[11,13,16] Only one recent study utilising a novel AI module reported a reduced SSL miss rate, although overall detection rates were low.[17] Unlike ADR, no benchmark detection rate has been set. Ongoing work to improve AI in this important area is underway,[42] yet clearly reservations still exist with current technologies.[17]

Within our cohort, analysis of polyp-specific characteristics did not reveal any significant differences for polyps of different sizes or locations within the colon. This contrasts with both meta-analyses by Ashat and Hassan et al., which demonstrated superiority of AIAC over CC for polyps of all sizes, with greatest benefit shown for the smallest <5mm adenomas, and those in the proximal colon.[4,5] In our study controls, adenomas <5mm constituted 64% of the total polyps compared with a mean of 19% across the RCT controls.[4] Similarly, 50% of the total adenomas detected in our study were located in the proximal colon compared with 14.5% average in other controls.[4] In conjunction with the aforementioned high ADR and SSL detection rates, this may reflect the experienced cohort of endoscopists in this study, utilising all available techniques to expose mucosa and inspect carefully. Large population-based trials are required to establish whether these increased detections translate into improvements in important clinical outcomes for patients.

Withdrawal time has been extensively investigated in colonoscopy and is a critical quality factor with a strong relationship to ADR.[43] The mean withdrawal time increased by two minutes to a total of 15 minutes in our AI cohort. This is considerably longer compared to other trials with a grouped average of 6.9 minutes and 6.4 minutes in AI and control groups, respectively.[4] Prolongations in endoscope withdrawal may be a by-product of improved adenoma detection and time to resect these, increased vigilance, or increased time assessing activations from the AI module, including false positive signals. It is possible with more practice and experience using AI that withdrawal times become equivalent as in other trials, with endoscopists able to more quickly recognise, characterise and disregard non-neoplastic signals detected by AI.

Implications of AI for training endoscopists is considerable. There may be a risk that endoscopists become complacent, assuming AI to detect polyps, with a loss of conventional skills and reliance on these technologies. Within New Zealand, there has been discussion of AI within the medical field and implications with regard to negligence law.[44] Reassuringly, one study has compared colonoscopy outcomes using AI and noted PDR remained elevated two months after the module was intentionally switched off suggesting a learning effect.[37] It is likely that wider utilisation and addition of greater imaging inputs into deep learning algorithms will improve the accuracy and usefulness of AI with time as has been demonstrated in other health use cases.[45–47] It may be that our positive result, despite no prior experience or learning represents an underestimation of what is possible, even within a cohort with high pre-existing ADR.

The strength of this study is its real-world setting, with less risk of operator bias that may change practice within a trial setting.[48] However, we acknowledge that behavioural changes may occur with introduction of any new technology. It is further limited by its retrospective nature and the lack of randomisation. Nonetheless by enrolling consecutive patients we achieved well matched baseline variables. Only a single AI module, Olympus Endo-AID, was used which makes comparisons with other modules difficult. There was no prior experience or training provided for the software, which although intuitive, may change over time. The AI assistance mode could be toggled on and off generating an additional variable of "on time" for the intervention, which was not recorded. We did not perform a cost analysis which in the future must consider establishment costs, training, procedural times, and laboratory resources. The postulated up-front increases in cost must be weighed against potential reduced incidence of CRC in the long run.[49]

There is evidence that AI-assisted classification to aid interpretation of polyp histology may reduce colonoscopy-related costs by up to 7–20% with implementation of a resect and discard strategy.[50] Lastly, connection between longer-term outcomes of improved ADRs to important patient benefits, such as reduction in incidence of colorectal cancer, is not established here.

In conclusion, AI-assisted colonoscopy significantly improved ADR compared with conventional colonoscopy in a cohort of experienced endoscopists. Further research is required to understand its complete utility, including longitudinal changes with time, its application for endoscopists with lower baseline ADRs and, above all, the impact on long-term clinical outcomes.

COMPETING INTERESTS
Nil.

ACKNOWLEDGMENTS
We are grateful to the outstanding nursing team at Waitematā Endoscopy for their assistance and data collection during these procedures.

AUTHOR INFORMATION
Cameron Schauer: Waitematā Endoscopy, 53 Lincoln Road, Henderson, Auckland; Faculty of Medicine, The University of Auckland, Auckland, New Zealand.
Michael Chieng: Faculty of Medicine, The University of Auckland, Auckland, New Zealand.
Michael Wang: Faculty of Medicine, The University of Auckland, Auckland, New Zealand.
Michelle Neave: Waitematā Endoscopy, 53 Lincoln Road, Henderson, Auckland.
Sarah Watson: Waitematā Endoscopy, 53 Lincoln Road, Henderson, Auckland.
Marius Van Rijnsoever: Waitematā Endoscopy, 53 Lincoln Road, Henderson, Auckland.
Russell Walmsley: Waitematā Endoscopy, 53 Lincoln Road, Henderson, Auckland; Faculty of Medicine, The University of Auckland, Auckland, New Zealand
Ali Jafer: Waitematā Endoscopy, 53 Lincoln Road, Henderson, Auckland.

CORRESPONDING AUTHOR
Dr Cameron Schauer: C/O Waitematā Endoscopy, 53 Lincoln Road, Henderson, Auckland, New Zealand. E: cameron.schauer@gmail.com

REFERENCES

1. Stamm, R., et al., Challenges for the future: the gastroenterology specialist workforce in New Zealand. N Z Med J, 2020. 133(1519): 32-40.
2. Ministry of Health New Zealand - National Bowel Screening Programme. 2021. [Available at: http://www.health.govt.nz/our-work/preventative-health-wellness/screening/bowel-screening-pilot].
3. Bowel Cancer New Zealand - Bowel cancer symptoms and statistics 2021. [Available at: https://bowelcancernz.org.nz/?wpdmdl=10906].
4. Ashat, M., et al., Impact of real-time use of artificial intelligence in improving adenoma detection during colonoscopy: A systematic review and meta-analysis. Endoscopy International Open, 2021. 9(04):E513-E521.
5. Hassan, C., et al., Performance of artificial intelligence in colonoscopy for adenoma and polyp detection: a systematic review and meta-analysis. Gastrointestinal endoscopy, 2021. 93(1):77-85.e6.
6. Misawa, M., et al., Current status and future perspective on artificial intelligence for lower endoscopy. Digestive Endoscopy, 2021. 33(2):273-284.
7. Olympus, Setting the foundation for a new era of endoscopy: Olympus launches ENDO-AID, an AI-Powered Platform for Its Endoscopy System. 2020. [Available at: https://www.olympus-europa.com/company/media/en/content/news/msd/071020-endo-aid/endo-aid_global-launch_media-release_en.pdf].
8. Corley, D.A., et al., Adenoma detection rate and risk of colorectal cancer and death. New england journal of medicine, 2014. 370(14):1298-1306.
9. Rex, D.K., et al., Quality indicators for colonoscopy. Gastrointestinal endoscopy, 2015. 81(1): 31-53.
10. Pohl, H. and D.J. Robertson, Colorectal cancers detected after colonoscopy frequently result from missed lesions. Clinical Gastroenterology and Hepatology, 2010. 8(10):858-864.
11. Wang, P., et al., Effect of a deep-learning computer-aided detection system on adenoma detection during colonoscopy (CADe-DB trial): a double-blind randomised study. The lancet Gastroenterology & hepatology, 2020. 5(4):343-351.
12. Wang, P., et al., Real-time automatic detection system increases colonoscopic polyp and adenoma detection rates: a prospective randomised controlled study. Gut, 2019. 68(10):1813-1819.
13. Repici, A., et al., Efficacy of real-time computer-aided detection of colorectal neoplasia in a randomized trial. Gastroenterology, 2020. 159(2):512-520. e7.
14. Su, J.-R., et al., Impact of a real-time automatic quality control system on colorectal polyp and adenoma detection: a prospective randomized controlled study (with videos). Gastrointestinal endoscopy, 2020. 91(2):415-424. e4.
15. Gong, D., et al., Detection of colorectal adenomas with a real-time computer-aided system (ENDOANGEL): a randomised controlled study. The lancet Gastroenterology & hepatology, 2020. 5(4):352-361.
16. Liu, W.N., et al., Study on detection rate of polyps and adenomas in artificial-intelligence-aided colonoscopy. Saudi J Gastroenterol, 2020. 26(1):13-19.
17. Brown, J.R.G., et al., Deep Learning Computer-aided Polyp Detection Reduces Adenoma Miss Rate: A United States Multi-center Randomized Tandem Colonoscopy Study (CADeT-CS Trial). Clinical Gastroenterology and Hepatology, 2021.
18. Bisschops, R., et al., Advanced imaging for detection and differentiation of colorectal neoplasia:

European Society of Gastrointestinal Endoscopy (ESGE) Guideline–Update 2019. Endoscopy, 2019. 51(12):1155-1179.
19. Wong, Y.T. and K.F. Wong, IDDF2021-ABS-0048 The study on artificial intelligence (AI) colonoscopy in affecting the rate of polyp detection in colonoscopy–a single-center retrospective study. 2021, BMJ Publishing Group.
20. Diprose, W. and N. Buist, Artificial intelligence in medicine: humans need not apply? The New Zealand Medical Journal (Online), 2016. 129(1434):73.
21. Jafer, A., 23.12.2020. Colonoscopy Audit Report, Personal Communication. 2015 - 2020, Waitemata Endoscopy. 1.
22. Lai, E.J., et al., The Boston bowel preparation scale: a valid and reliable instrument for colonoscopy-oriented research. Gastrointestinal endoscopy, 2009. 69(3):620-625.
23. Participants in the Paris, W., The Paris endoscopic classification of superficial neoplastic lesions: esophagus, stomach, and colon: November 30 to December 1, 2002. Gastrointestinal Endoscopy, 2003. 58(6):S3-S43.
24. Peduzzi, P., et al., A simulation study of the number of events per variable in logistic regression analysis. Journal of clinical epidemiology, 1996. 49(12):1373-1379.
25. Kaminski, M.F., et al., Quality indicators for colonoscopy and the risk of interval cancer. New England Journal of Medicine, 2010. 362(19):1795-1803.
26. Leyden, J., et al., Quality of colonoscopy performance among gastroenterology and surgical trainees: a need for common training standards for all trainees? Endoscopy, 2011. 43(11):935-940.
27. Coe, S.G., et al., An endoscopic quality improvement program improves detection of colorectal adenomas. Official journal of the American College of Gastroenterology| ACG, 2013. 108(2):219-226.
28. Kaminski, M.F., et al., Leadership training to improve adenoma detection rate in screening colonoscopy: a randomised trial. Gut, 2016. 65(4):616-624.
29. Rex, D.K., et al., Colonoscopic miss rates of adenomas determined by back-to-back colonoscopies. Gastroenterology, 1997. 112(1):24-28.
30. Akarsu, M. and C. Akarsu, Evaluation of new technologies in gastrointestinal endoscopy. JSLS: Journal of the Society of Laparoendoscopic Surgeons, 2018. 22(1).
31. Franco, D.L., J.A. Leighton, and S.R. Gurudu, Approach to incomplete colonoscopy: new techniques and technologies. Gastroenterology & hepatology, 2017. 13(8):476.
32. Rex, D.K., Polyp detection at colonoscopy: Endoscopist and technical factors. Best Practice & Research Clinical Gastroenterology, 2017. 31(4): 425-433.
33. Facciorusso, A., et al., Compared abilities of endoscopic techniques to increase colon adenoma detection rates: a network meta-analysis. Clinical Gastroenterology and Hepatology, 2019. 17(12): 2439-2454. e25.
34. Rondonotti, E., et al., The impact of hyoscine-N-butylbromide on adenoma detection during colonoscopy: meta-analysis of randomized, controlled studies. Gastrointestinal endoscopy, 2014. 80(6):1103-1112. e2.
35. Ng, S.C., et al., The efficacy of cap-assisted colonoscopy in polyp detection and cecal intubation: a meta-analysis of randomized controlled trials. Official journal of the American College of Gastroenterology| ACG, 2012. 107(8):1165-1173.
36. Mir, F.A., et al., Cap-assisted colonoscopy versus standard colonoscopy: is the cap beneficial? A meta-analysis of randomized controlled trials. Annals of gastroenterology, 2017. 30(6):640.
37. Patel, M., et al., Artificial intelligence increases adenoma detection even in 'high-detector'colonoscopy: early evidence for human: machine interaction. 2021, BMJ Publishing Group.
38. Rex, D.K., et al., Serrated lesions of the colorectum: review and recommendations from an expert panel. The American journal of gastroenterology, 2012. 107(9):1315.
39. Burgess, N.G., et al., Sessile serrated adenomas/ polyps with cytologic dysplasia: a triple threat for interval cancer. Gastrointestinal endoscopy, 2014. 80(2):307-310.
40. Sweetser, S., T.C. Smyrk, and F.A. Sinicrope, Serrated colon polyps as precursors to colorectal cancer. Clinical Gastroenterology and Hepatology, 2013. 11(7):760-767.
41. Lafeuille, P., et al., Flat colorectal sessile serrated polyp: an example of what artificial intelligence does not easily detect. Endoscopy, 2021.
42. Zhou, G., et al., Computer aided detection for laterally spreading tumors and sessile serrated adenomas during colonoscopy. PloS one, 2020. 15(4):e0231880.
43. Barclay, R.L., et al., Colonoscopic withdrawal times and adenoma detection during screening colonoscopy. New England Journal of Medicine, 2006. 355(24): 2533-2541.

44. Boniface, C., Medical negligence in the age of artificial intelligence. The New Zealand Law Journal 2020. NZLJ 136.
45. Dilsizian, S.E. and E.L. Siegel, Artificial intelligence in medicine and cardiac imaging: harnessing big data and advanced computing to provide personalized medical diagnosis and treatment. Current cardiology reports, 2014. 16(1): 441.
46. Jiang, F., et al., Artificial intelligence in healthcare: past, present and future. Stroke and vascular neurology, 2017. 2(4).
47. Bi, W.L., et al., Artificial intelligence in cancer imaging: clinical challenges and applications. CA: a cancer journal for clinicians, 2019. 69(2):127-157.
48. Rex, D.K., et al., The impact of videorecording on the quality of colonoscopy performance: a pilot study. Official journal of the American College of Gastroenterology| ACG, 2010. 105(11): 2312-2317.
49. Mori, Y., et al., Artificial intelligence in colonoscopy-Now on the market. What's next? Journal of Gastroenterology and Hepatology, 2021. 36(1): 7-11.
50. Mori, Y., et al., Cost savings in colonoscopy with artificial intelligence-aided polyp diagnosis: an add-on analysis of a clinical trial (with video). Gastrointestinal endoscopy, 2020. 92(4):905-911. e1.