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Computer-aided quality assessment (CAQ): the next step for artificial intelligence in colonoscopy?

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Abstract

Recent developments and breakthroughs in artificial intelligence (AI) for colonoscopy have the potential to improve the quality of colonoscopy. Computer-aided detection for colorectal polyps has been shown to increase the adenoma detection rate by more than 10%. Furthermore, recently developed computer-aided quality assessment (CAQ) systems, such as real-time withdrawal speed monitoring, are expected to provide additional gain in colonoscopy practice. However, the added clinical value of combining AI techniques is uncertain. This paper provides an overview of the latest evidence on CAQ systems and identifies knowledge gaps that need to be filled before widespread implementation.

Keywords: Artificial intelligence (AI), computer-aided quality assessment (CAQ), computer-aided detection (CADe), computer-aided diagnosis (CADx)

INTRODUCTION

Colorectal cancer (CRC) is the third most common cancer and the second leading cause of cancer death worldwide[1]. Colonoscopy screening with detection and removal of neoplastic, precancerous polyps such as adenomas is performed in many countries for the prevention and early detection of CRC[2,3]. The effectiveness of colonoscopy screening depends on a high adenoma detection rate (ADR), which is the

proportion of colonoscopies where at least one adenoma is detected[4].

Cause of missing adenoma

Although detection of adenomas is key for cancer prevention, almost one-fourth of adenomas are missed at CRC screening. Missed adenomas at screening are a main reason for CRC after screening with colonoscopy, so-called interval cancer[5,6], of which 89% are deemed avoidable[7]. Missed adenomas can be either the result of recognition failures, such as when endoscopists fail to recognize adenomas that are visualized on the screen (cognitive errors), or due to blind spots and incomplete mucosal exposure that is related to the speed during colonoscopy withdrawal, endoscopists' skill, degree of bowel cleansing, and other factors (exposure errors)[5,7,8].

Computer-aided detection

Artificial intelligence (AI) by computer-aided detection (CADe) aims at improving ADR by reducing cognitive errors of endoscopists and thus reducing the rate of missed polyps[9,10]. Since ADR is known to be inversely associated with the risk of interval CRC[11], there is hope that AI reduces cancer incidence after colonoscopy. However, clinical trial evidence is currently lacking to support this claim.

CADe systems based on deep learning identifiy polyps in real time and display visual alerts on the monitor for the endoscopist. CADe systems showed an increase in ADR of 10% compared to colonoscopies done without CADe[9,10]. A recent randomized tandem study found that the adenoma miss rate with CADe was significantly lower compared to standard colonoscopy (13.89% *vs.* 40.00%, $P < 0.0001$)[12]. Furthermore, CADe does not reduce the miss rate of advanced adenomas[12], those with the highest immediate impact on colorectal cancer risk. The incremental benefit of CADe on CRC incidence therefore remains to be investigated.

COMPUTER-AIDED QUALITY ASSESSMENT SYSTEM

Since CADe only addresses cognitive errors, recent developments in computer-aided techniques have focused on measures to overcome exposure errors [Figure 1]. These tools can be defined as computer-aided quality assessment (CAQ) systems and is a third group of computer-aided techniques in colonoscopy along with CADe and computer-aided diagnosis. CAQ is expected to increase mucosal exposure during colonoscopy and promote more careful visualization. Specific measures of CAQ include the withdrawal speed monitoring and blind spot detector, which warn the endoscopist whenever the speed limit has been exceeded and there is a blind spot during withdrawal of endoscopes, respectively[13-15].

Withdrawal time is considered a surrogate quality indicator of mucosal inspection, influencing ADR. A withdrawal time of at least 6 min is recommended and may indicate a more careful inspection of the colorectal mucosa during screening colonoscopy[16-18]. However, the recommended withdrawal time is sometimes ignored due to the busyness of clinical practice, the lack of knowledge on guidelines, or other reasons.

Apart from withdrawal time, it is also important to maintain a stable maneuvering and uniform speed throughout withdrawal. This is especially crucial when passing colonic flexures where the endoscopist can experience endoscope slipping, resulting in quickly changing frames and blurry images, reduced mucosal exposure, and increased blind spots. Therefore, identifying withdrawal speed and identifying blind spots during colonoscopy are considered two major goals of the CAQ systems. CAQ is especially expected to help less experienced endoscopists achieve a better ADR in this regard.

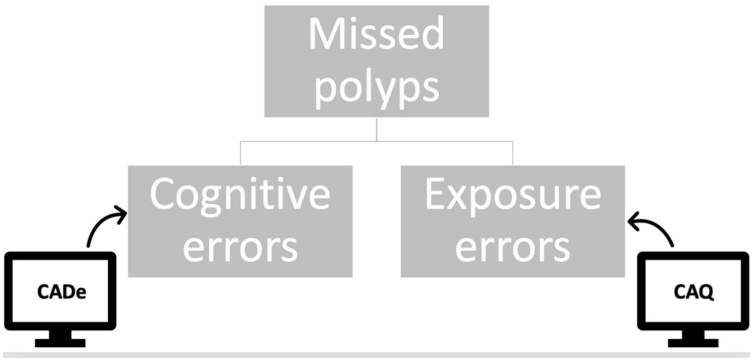

Figure 1. Missed polyps are caused by either cognitive errors or exposure errors. CADe: Computer-aided detection; CAQ: computer-aided quality assessment.

Added clinical value of CADe and CAQ

As described above, several randomized trials have shown that CADe during colonoscopy significantly increases ADR[9,10]. CAQ is also expected to improve ADR indirectly through slower, repetitive, and more conscious withdrawal. The added value of CADe combined with CAQ has recently been indicated in early studies from China investigating endoscopic AI-based monitoring of the withdrawal speed and blind spots and its efficacy to improve ADR [Table 1][13-15].

Studies where CAQ has been applied and investigated

Assessing the combined use of CAQ and CADe allows an evaluation of the incremental effect of the two computer-aided techniques, which is starting to gain more attention. Two studies[13,14] investigated the combined use of CAQ and CADe and compared it to standard colonoscopy with no involvement of CAD techniques. They found that ADR was significantly improved with the combined use of CAQ and CADe during colonoscopy, compared to non-AI colonoscopy.

Another study[15] investigated the efficacy of CAQ and CADe, comparing the combined use of CAQ and CADe with standard, non-AI colonoscopy, as well as with CADe or CAQ alone. Both CADe alone and CAQ alone showed a significantly increased ADR compared to non-AI colonoscopy, but when compared to each other, there was no significant difference in ADR. CAQ combined with CADe compared to CADe alone yielded an ADR of 30.6% *vs.* 21.3%. CAQ combined with CADe compared to non-AI colonoscopy yielded an ADR of 30.6% *vs.* 14.8%. However, there was no significant difference in ADR between CAQ combined with CADe compared to CAQ alone [Table 1]. Lastly, there was no significant difference in withdrawal time among any of the groups [Table 2].

Implementation of CAQ in colonoscopy: barriers and future

With only three studies, all performed in one country, investigating the added clinical value of applying CAQ alone and CAQ combined with CADe, there is a need for more studies such as these, especially from other countries, for external validation before implementation of CAQ can be recommended.

A concern with CAQ is the possibility that it can lead to an overload of information, especially when using two different monitors, and result in a negatively impacted ADR, longer withdrawal time without gains in ADR, or simply alert fatigue. Multiple alerts from more than one AI system during colonoscopy could exhaust endoscopists and reduce focus. These hurdles can be overcome by carefully finding the right sensitivity for alarm frequency and having all alerts on one monitor so that the endoscopist can focus on the same place rather than several.

Table 1. ADR comparison from studies investigating CADe and CAQ

Study	ADR in standard colonoscopy	ADR with CADe alone	ADR with CAQ alone	ADR with CAQ combined with CADe	*P*-value
Gong *et al.* (2020)[13]	27	N/A	N/A	58	$P = 0.001$
Su *et al.*(2020)[14]	16.5	N/A	N/A	28.9	$P < 0.001$
Yao *et al.* (2021)[15]	14.76	21.27	24.54	30.6	^$P = 0.045$ *$P = 0.004$ **$P = 0.52$ ***$P = 0.024$ ****$P = 0.21$

ADR: Adenoma detection rate; CADe: computer-aided detection; CAQ: computer-aided quality assessment. ^: standard colonoscopy *vs.* CADe alone; *: standard colonoscopy *vs.* CAQ alone; **: CADe alone *vs.* CAQ alone; ***: CAQ combined with CADe *vs.* CADe alone; ****: CAQ combined with CADe *vs.* CAQ alone.

Table 2. Withdrawal time comparison from studies investigating CADe and CAQ

Study	Withdrawal time in standard colonoscopy	Withdrawal time with CADe alone	Withdrawal time with CAQ alone	Withdrawal time with CAQ combined with CADe	*P*-value
Gong *et al.* (2020)[13]	4.76 min	N/A	N/A	6.38 min	$P < 0.0001$
Su *et al.* (2020)[14]	5.68 min	N/A	N/A	7.03 min	$P < 0.001$
Yao *et al.* (2021)[15]	9.71 min	10.52 min	10.14 min	10.17 min	^$P = 0.056$ *$P = 0.302$ **$P = 0.413$

CADe: Computer-aided detection; CAQ: computer-aided quality assessment. ^: Comparison (*t*-test) between standard colonoscopy and CADe alone; *: comparison (*t*-test) between standard colonoscopy and CAQ alone; **: comparison (*t*-test) between CADe and CAQ combined with CADe.

CONCLUSION

CAQ combined with CADe is an effective method to further increase ADR during colonoscopy without prolonging the withdrawal time. Artificial intelligence could contribute to post hoc auditing of the colonoscopy quality or other steps within the whole logistic process of CRC screening. It is likely that these computer-aided techniques will be implemented in colonoscopy procedures in the near future.

DECLARATIONS

Authors' contributions

Made substantial contributions to conception and design of the study and performed data analysis and interpretation; provided critical feedback and helped shape the research, analysis and manuscript: Barua I, Bretthauer M, Mori Y

Availability of data and materials

Not applicable.

Financial support and sponsorship
None.

Conflicts of interest
Barua I has received a travel grant from Olympus Norway. Mori Y has received consulting and speaking honorariums from Olympus Corp and has ownership interest in Cybernet Systems Corp. Bretthauer M has received consulting honorarium from Cybernet Systems Corp.

Ethical approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

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