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Rationalizing polyp matching criteria in colon capsule endoscopy: an international expert consensus through RAND (modified DELPHI) process

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Abstract

Background: Colon capsule endoscopy (CCE) has gained momentum as an alternative modality for the investigation of the lower gastrointestinal tract. Of the few challenges that remain, the comparison and – eventually – matching of polyps at different timestamps leads to the potential for double reporting and can contribute to false-positive findings and inaccuracies. With the impending artificial intelligence integration, the risk of double reporting the same polyp due to the lack of information on spatial orientation underscores the necessity for establishing criteria for polyp matching.

Objectives: This RAND/University of California, Los Angeles (modified Delphi) process aims to identify the key factors or components used to match polyps within a CCE video. This involves exploring the attributes of each factor to create comprehensive polyp-matching criteria based on international expert consensus.

Design: A systematic qualitative study using surveys.

Methods: A panel of 11 international CCE experts convened to assess a survey comprised of 60 statements. Participants anonymously rated statement appropriateness on a 1–9 scale (1–3: inappropriate, 4–6: uncertain and 7–9: appropriate). Following a virtual group discussion of the Round 1 results, a Round 2 survey was developed and completed before the final analysis.

Results: The factors that were agreed to be essential for polyp matching include (1) timestamp, (2) polyp localization, (3) polyp vascular pattern, (4) polyp size, (5) time interval of the polyp appearance between the green and yellow camera, (6) surrounding tissue, (7) polyp morphology and (8) polyp surface and contour. When five or more factors are satisfied, it was agreed that the comparing polyps are likely the same polyp.

Conclusion: This study has established the first complete criteria for polyp matching in CCE. While it might not provide a definitive solution for matching difficult, small and common polyps, these criteria serve as a framework to guide and facilitate the process of polyp-matching.

Plain language summary

Creating criteria and standards for matching polyps (abnormal growth in the bowels) on colon capsule video analysis: an international expert agreement using the RAND (modified Delphi process) process

Background: Doctors often use colon capsule endoscopy (CCE), a high-tech capsule with two cameras, to record and check for diseases in the small and large bowels as the capsule travels through the intestines. One of the most common conditions in the large bowel is

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polyps, which are abnormal growths in the lining of the bowel. Comparing and matching polyps in the same video from the capsule can be tricky as they look very similar, leading to the possibility of incorrectly reporting the same polyp twice or more. This can lead to wrong results and inaccuracies. The literature did not have any criteria or standards for matching polyps in CCE before.

Aim: Using the RAND/UCLA (modified Delphi) process, this study aims to identify the key factors or components used to match polyps within a CCE video. The goal is to explore each factor and create complete criteria for polyp matching based on the agreement from international experts.

Method: A group of 11 international CCE experts came together to evaluate a survey with 60 statements. They anonymously rated each statement on a scale from 1 to 9 (1-3: inappropriate, 4-6: uncertain, and 7-9: appropriate). After discussing the Round 1 results virtually, a Round 2 survey with the same but revised questions was created and completed before the final analysis of their agreement.

Results: The main factors for matching polyps are 1) the timing when the polyp was seen, 2) where it is in the bowel, 3) its blood vessel pattern, 4) size, 5) the timing of its appearance between cameras, 6) surrounding tissue features, 7) its shape, and 8) surface features. If five or more of these factors match, the compared polyps are likely the same.

Conclusion: This study establishes the first complete criteria for matching polyps in CCE. While it may not provide a definitive solution for matching challenging and small polyps, these criteria serve as a guide to help and make the process of polyp matching easier.

Keywords: capsule endoscopy, colon capsule endoscopy, colorectal polyp, polyp, colorectal cancer, CCE, polyp matching

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Background

Colorectal cancer (CRC) ranks as the third most common cancer worldwide, constituting approximately 10% of all cancer diagnoses. This places CRC as the second leading cause of cancer-related deaths worldwide.[1] In recent years, colon capsule endoscopy (CCE) has gained significant popularity as one of the modalities for lower gastrointestinal investigations, a trend that has been notably embraced since the COVID-19 pandemic. As a result, CCE has witnessed widespread acceptance in the Scottish, English and Danish healthcare systems. Interim findings from the NHS England pilot study show that CCE identified 95% of patients with polyps >10 mm, while 70% of those undergoing CCE were spared a conventional colonoscopy.[2]

CCE aligns with a widespread growing emphasis on sustainability, eco-friendly endoscopy and reducing environmental impact. However, despite its possible favourable cost-effectiveness and carbon footprint profile, CCE faces several challenges in becoming the mainstream investigational modality.[3] These stem from CCE's limitations, including long reading times, poor localization of anatomical landmarks, inaccurate polyp differentiation, inability to provide therapy, interobserver variability in reporting and decision-making, and long procedural times with a relatively low completion rate.[4–6] One of the common observations is the difficulty in detecting CCE-reported polyps in subsequent optical colonoscopy (OC). This issue primarily arises for two reasons: (1) false-negative findings by OC and (2) false-positive findings by CCE.

CCE has shown high sensitivity (87%) and specificity (88%) in detecting polyps >6 mm.[7] Kobaek-Larsen *et al.*[8] also demonstrated that CCE might be superior to colonoscopy in polyp detection, especially in per-patient sensitivity for polyps >9 mm. Another study also showed a higher diagnostic yield of CCE (compared to OC) in identifying polyps ⩾6 mm, although statistical significance was not reached.[9,10] Polyps reported on CCE but not detected in subsequent colonoscopies may be due to non-detection during the

OC. This is supported by the extensive literature showing a considerable miss rate of OC for polyps. It was also validated by a back-to-back OC study, conducted by Heresbach *et al.*,[11] with a 28% miss rate for polyps measuring ⩾5 mm.

Another contributing factor is the possibility of duplicate reporting of the same polyp in CCE. Since the capsule does not move in a smooth and unidirectional manner, the back-and-forth movement of the device could capture the same polyp numerous times from different angles, potentially leading the reader to identify these images as distinct polyps. This may lead to false-positive results. To prevent duplicate reporting, it is crucial to establish a method for mapping features of the identified polyps to determine with confidence if the two polyps are, in fact, the same polyp. To our knowledge, there has been no literature addressing the matching of polyps in CCE videos.

In addition, the time-consuming aspect of CCE reading can potentially be alleviated through the utilization of machine learning algorithms, this can filter out the significant findings only for clinician validation. The stages of integrating artificial intelligence (AI) into the CCE process detailed by Robertson *et al.* propose a scenario where AI could initially replace the pre-reading process and eventually take on the responsibility for analysing the entire CCE video prior to the clinician's validation and reporting.[12–14] This proposal comprises of different stages. It suggested that the clinician would be presented with all the polyps' images without a comprehensive review of the whole CCE video.[15]

However, without evaluating the entire CCE video, the risk of duplicate reporting is significant due to the lack of spatial orientation gained from the complete video inspection. Consequently, establishing criteria for polyp matching between polyp images is imperative and, ultimately, reducing duplicate reporting and improving the overall accuracy of CCE reporting in the future. Moreover, the absence of a current polyp-matching benchmark makes it challenging to develop new AI algorithms for the polyp-matching process. These criteria may serve as a new standard for future AI algorithm development and validation. It may also act as a target for comparison and evaluation of the AI.

This RAND/University of California, Los Angeles (UCLA) methodology (modified Delphi decision process) aims to identify the key factors used to match polyps within the same colon capsule video. This also involves further investigation into the deciding component(s) associated with each factor. This is achieved through consensus from a panel of international CCE experts with the ultimate objective of compiling the results into comprehensive polyp-matching criteria.

Methods

Modified RAND appropriateness method

The RAND/UCLA appropriateness method incorporates a modified Delphi panel approach and combines expert opinions with the best available evidence and clinical guidance to establish the appropriateness of specific practices in well-defined clinical situations (https://www.rand.org/topics/methodology.html).[16] This method is particularly valuable in areas of uncertainty, where existing evidence may be insufficient to guide decision-making. The principal difference from a Delphi model is that the RAND process does not seek to force consensus and instead depicts and details agreement and disagreement as primary results of the method. This method entails conducting a systematic review to find all the relevant literature, contributing to the essential insights for designing the questionnaires. To reach a consensus, two rounds of the survey and a meeting will be conducted to formulate findings and collaborative agreements. Prospective registration of this study was not undertaken. This paper adheres to the Accurate Consensus Reporting Document guideline, a structured and comprehensive framework for studies using consensus methods.[17]

Identification of the potential factors and components

A systematic review was conducted by IL, with the search process detailed in the Supplemental Appendix. The inclusion of 14 relevant papers helps design and some of them serve as references during the scoring process (see Figure 1 in the Supplemental Appendix). The core group (consisting of IL, RPA and AK) designed and iteratively refined a web-based questionnaire to address the key challenges and uncertainties associated with polyp matching in CCE. Prior to commencing the RAND process, a

pre-round questionnaire was sent to all the panellists to capture a comprehensive list of key challenges and factors to be incorporated into the design of the survey. The factors and components are further refined and agreed upon by the core group.

Recruitment of experts

An 11-member panel comprising international CCE experts with a special interest in the CCE was assembled. The experts were identified through a combination of their original research publications and recommendations from our study core group. Due to the specialized technical nature of this study, the panel included gastroenterologists, colorectal surgeons, CCE researchers and internal medical practitioners with additional gastroenterology qualifications from countries including the USA, England, Scotland, Denmark, Sweden, Germany and Spain. These experts were selected based on their extensive experience with CCE, and their participation was not influenced by any financial incentives. This aligns with the recommendations in the RAND manual, suggesting a panel size ranging from 7 to 15 members.[16] One of the core group members, AK, also had voting rights within the panel.

The definition of experts was defined using two criteria:

1. Experienced CCE readers who have reviewed and reported on 500 or more CCE videos, providing them with the necessary experience to participate in this study.
2. An annual volume of at least 200 CCE reads to demonstrate their reading competency. The average annual CCE reads of the panel is 341 ± 153.

The first round survey, the panel meeting and the second round survey

A web-based questionnaire, crafted and revised by the core group (IL, RPA and AK), was developed following the systematic review and the pre-round online survey after being circulated to the panellists. The questionnaire was distributed to the panellists to rate the appropriateness of each item regarding polyp matching in CCE (see the Supplemental Appendix for the example of the online survey).

The overall results from the first-round survey were shared with the panellists, followed by a virtual teleconference to discuss the appropriateness of the items. In this meeting, the areas of disagreement were identified and examined, allowing for an in-depth discussion among panellists to elucidate the rationale behind their initial responses. It is important to reiterate that no attempt was made to compel the panel to reach a consensus.

A final survey was designed, implementing the suggestions from the discussion, with a particular focus on identifying sources of disagreement. The results of this survey were summarized to yield the final recommendations to formulate the criteria. The timeline was summarized in Figure 2 in the Supplemental Appendix.

Analysis

Standardized RAND appropriateness methodology categorized each item as appropriate, uncertain or inappropriate for use in polyp matching in CCE based on the median panel rating and degree of panel disagreement. Items with a median panel rating of 1–3 without disagreement were classified as inappropriate, those with a rating of 4–6 or any median with disagreement were classified as uncertain and the items with a rating of 7–9 without disagreement were deemed appropriate. The level of disagreement was calculated based on the disagreement index (DI) calculation provided below. If the DI is $\geqslant 1$, this indicates uncertainty in the item. Conversely, a $DI < 1$ signifies the panel achieved agreement with the calculated panel median score (Table 1).

Experts' bias considerations

Each expert knows the identity of all the other experts on the panel. However, no one involved in the study will be made aware of the response of individual panellists, other than their response and the overall response from the previous round. The only exception is when the individual panellists choose to share their responses during the teleconference. Pseudonyms were also assigned to each expert as an option to

Table 1. Summary of RAND/UCLA appropriateness scale and DI for RAND process.[1]

DI	Panel median score								
	1	2	3	4	5	6	7	8	9
	Lower third (1–3)			Middle third (4–6)			Top third (7–9)		
<1 (Agreement)	Inappropriate			Uncertain			Appropriate		
⩾1 (Disagreement)									

$$\text{Disagreement index (DI)} = \frac{70\text{th} - 30\text{th centile}}{2.35 + (1.5 \times \text{abs}\left(5 - \frac{70\text{th} - 30\text{th centile}}{2}\right))}$$

[1]DI, disagreement index; UCLA, University of California, Los Angeles.

mitigate concerns about contributing without bias if the experts chose to remain anonymous.

Results

The factors that the panel reached a consensus on for consideration when matching two polyps on different thumbnails are listed below. These factors predominantly originate from the experience of lesion analysis in small bowel capsule endoscopy and polyp identification or matching in conventional colonoscopy, leveraging insights from these domains.

1. The location of the polyps
2. The distinct features of the surrounding tissue
3. The size of the polyps
4. The timestamp
5. The time interval between the polyp appearance in both cameras
6. The pit pattern of the polyps
7. The morphology of the polyps using the Paris classification
8. The surface contour and pattern of the polyps.

The agreed components of each factor by the expert panel are summarized in the Colon Capsule Endoscopy Polyp Matching Criteria (CCE PM criteria) in Table 2, presented as a comprehensive framework. The key consensus includes reviewing the whole section of the colon capsule video between the polyps timestamps (1. Timestamp), considering polyps within or near the same anatomical landmarks (2. Localization), agreement on similar vascular patterns on the polyp surface and interrupted by the polyp (3. Vascular pattern), acceptable polyp size discrepancy ±30% (4. Polyp size), a 30-s difference for polyps' appearance between the green and yellow camera which are the two opposite cameras in CCE (5. Time interval of polyps' appearance between cameras). The outcome also highlights using the adjacent small sentinel polyps and diverticulum/diverticula (6. Surrounding tissue), differentiation using polyp morphology: pedunculated, flat, malignant and lateral spreading appearance (7. Morphology). Finally, distinctive polyp surfaces and contours, including ulceration, distinctive shape, eroded polyp surfaces and special surface colour (8. Polyp surface and contour), were also areas of agreement among the experts.

Whereas, areas of disagreement among the experts include (1) considering debris around the polyp as a decisive factor for matching, (2) regarding a timestamp interval of more than 30 min between polyps as indicative of being the same polyp, (3) asserting that a time interval between the appearance of the polyp in the green and yellow camera exceeding 30 min is suggestive of the same polyp and (4) suggesting that scoring only 1 or 2 out of 8 factors would support the impression that the polyps are the same.

Discussion

The time interval between the polyps

Rationally, the timestamp of the polyps being compared should significantly influence the determination of whether they are indeed the same polyp or not. Logically, the closer the timestamps are, the higher the probability that the two

Table 2. The summary of the CCE PM criteria.

CCE PM criteria **Each item is scored with equal weight (1 point each)**		
Factor number	**Component(s) within each factor**	**Score**
1.	Timestamp – Within any time interval, consider two polyps as the same if they appear to be so after reviewing the whole section of the colon capsule video between their timestamps.	
2.	Localization – either or: a. Both polyps are within the anatomical landmarks (appendiceal orifice, ileocaecal valve, anal cushions, hepatic flexure and splenic flexure) b. Both polyps are near the same anatomical landmarks.	
3.	Vascular pattern – either or: c. Both polyps have similar vascular patterns on the polyp surface only d. Both polyps have similar vascular patterns interrupted by the polyp.	
4.	Polyp size – both polyps are within a 30% size difference.	
5.	The time interval of the polyps' appearance between the green and yellow camera – both polyp images have to be within 30-s difference between its appearance between the green and yellow camera.	
6.	Surrounding tissue – either or e. Adjacent small sentinel polyps f. Adjacent diverticulum/diverticula.	
7.	Polyp morphology – one of the following g. Both polyps have a 'pedunculated' appearance h. Both polyps have a 'flat' appearance i. Both polyps have a 'malignant' appearance j. Both polyps have a 'lateral spreading' appearance.	
8.	Polyp surface and contour – one of the following k. Ulceration on both polyps l. Shape, for example, oval or irregular of both polyps m. Eroded polyp surfaces on both polyps n. The distinctive surface colour of both polyps.	
	Total number of scores out of 8: (If five or more factors are satisfied during the matching process, it is highly probable that the comparing polyps are the same polyp.)	

CCE PM, colon capsule endoscopy polyp matching criteria.

polyps are the same polyp. However, this factor consistently raised concerns of uncertainty among the experts, mainly due to the unpredictability of the erratic capsule movement in the colon. The see-saw swirl of the capsule in the caecum, the rocking movement of the capsule in the splenic flexure and also the brief sweeps up the ascending colon contribute to the uncertainty and disagreement regarding the reliability of using timestamps for polyp matching.

Nonetheless, there was a consensus on one aspect related to the timestamp: it was consistently agreed that reading the entire section of the colon capsule video between the timestamps of the two polyps, regardless of the time interval, serves as a reliable factor for polyp matching. In terms of the threshold for the time interval between the polyps, there was consistent consensus achieved when the polyps' timestamps are more than 30 min apart, the polyps are much less likely to be the same polyp.

The location of the polyps

There was agreement that the location of the polyps plays a pivotal role in polyp matching.

However, there were significant hesitations in using colonic segments such as caecum, ascending, transverse and left-sided colon as reliable references for polyp mapping. This is mainly because of concerns about the accuracy of the flexure landmarks that delineate these segments. In contrast to OC, where a scoping guide could be used to help in locating pathologies, a lack of localization guidance in CCE complicates the determination of segment locations.

This issue was also examined by Schelde-Olesen *et al.*,[4] who illustrated only 51% agreement on all landmarks. Remarkably, the interobserver agreement for hepatic flexure and splenic flexure was as low as 29% and 22%, respectively, which is indeed concerning. Given this variability and uncertainty associated with these landmarks, relying on them as references for locating polyps might not be a dependable approach.[4]

However, the confidence in localization experiences a substantial boost when the polyp is situated within or near readily identifiable landmarks such as the appendiceal orifice, ileocaecal valve, anal cushions and even within the flexures. This increased confidence arises from the visual confirmation of the polyp's presence alongside these landmarks, providing the reader with confidence and eliminating guesswork. Undoubtedly, it was agreed that when a polyp is within or near the landmarks, confidence in the matching process improves.

The vascular pattern of the polyp

Studying polyp vascular patterns has been extensively published in the realm of OC. Beyond its utility in polyp matching in colonoscopy, it further characterizes the nature of the polyp through narrow-band imaging. The vascular pattern on the polyp is recognized as a dependable marker to match the polyp when it comes to subsequent polyp assessment and endoscopic mucosal resection on an interventional colonoscopy list.[18] Buoyed by the insights gained from OC, the vascular pattern of the polyp is equally perceived to be a trustworthy feature for polyp mapping in CCE. From the consensus, this only applies specifically to the vascular pattern on the polyp or interrupted by the polyp, as opposed to the vascular pattern in the surrounding tissue or folds. This is related to the unreliability of similar vascular patterns in the surrounding tissue, particularly when viewed from different angles.

The surrounding tissue

When considering the use of surrounding tissue as a reference for polyp matching, there was sufficient consensus in favour of using adjacent small sentinel polyps and diverticulum/diverticula could yield positive polyp mapping results. These distinctive findings are also more commonly observed on the left side of the colon and can sometimes serve as a confirmation that the capsule is in the left colon. Remarkably, there was also a collective agreement that using the debris around the polyps as a reference, even within a close time interval, is inappropriate.

Size of the polyps

The size of the polyps is one of the most important deciding factors in polyp mapping. Despite a size overestimation observed in CCE polyp measurement, as shown in a study led by Blanes-Vidal *et al.*[19] with an overall discrepancies of 2.7 and 4.3 mm when compared CCE to OC and histopathology, respectively, it still remains one of the most influential determinants for polyp mapping.[19] The acceptable threshold for a size discrepancy varies with the polyp's dimensions, allowing for more flexibility as the polyp size increases or decreases. Hence, the criteria for size difference was modified from a fixed numerical value, such as ± 2 mm, to a percentage of the original size of the polyp, for example, $\pm 20\%$ of the measured polyp size. The consensus indicated that if the size discrepancy is within 30% of the measured polyp size, it would be acceptable to consider the two polyps to be the same polyp, accounting for the inherent inaccuracy of the polyp measuring tools within the current capsule reading software (RAPID Medtronic).[19,20]

The time interval between the polyp appearance between the green and yellow cameras

To accurately identify and count polyps, it is essential to observe a polyp with one camera head and then follow the polyp appearance in the other camera head shortly before or after based on the capsule's orientation.[21] However, the definition of 'shortly' remains unclear. The threshold of the time interval between the appearance of the same polyps between each camera head was also explored.

It was collectively agreed that if polyps appear within a time interval of approximately ± 30 s, it is

highly likely that these polyps are the same polyp. Beyond this specific time interval, significant uncertainty arises, depending on the movement of the capsule at the time. However, it is important to be mindful of the instances where a polyp seen on one camera is not captured on the second camera, and there may be multiple polyps within that same area of the colon, even within the 30-s interval between the cameras. When the interval extends beyond ±30 min, a consensus was also achieved that it is inappropriate to consider the two polyps as being likely the same polyp.

The morphology of the polyps

The morphology of the polyps is defined using the Paris classification, adopted from the OC practice due to the absence of formal polyp classification in CCE. However, there is a caveat with the flat polyp, as most flat lesions might appear to be polypoidal or protruding when the lumen is not insufflated or distended underwater in CCE.[22] In addition, a small study suggested that CCE has a high diagnostic yield for flat polyps with per polyp sensitivity and specificity of 90% and 96%, respectively, when compared to OC as the gold standard.[23] While a study with a small number of superficial colorectal lesions was examined by Otani *et al.*, it showed a sensitivity of only 78% in diagnosing superficial polyps compared to 88% of the protruded lesions, even though there were no statistically significant differences.

Despite the limited evidence above, there was agreement that the classification of 'flat' morphology is highly appropriate as a criterion for polyp matching if it is visible on CCE, which is due to its distinctiveness. The more distinctive the morphology of a polyp, the more reliable it is for use in polyp mapping. The only two uncertain morphologies were sessile and hyperplastic polyp due to the non-specific nature of these features and the characterization challenges in CCE. From the experts' consensus, the appearance associated with malignant lesions is considered the most reliable marker for mapping polyps.

The surface contour and pattern of the polyps

Despite advancements in camera technology and battery life, the resolution of the images provided by CCE remains insufficient for in-depth polyp characterization, especially when examining the pit pattern. CCE lacks the capabilities found in traditional colonoscopy, such as washing, suction, insufflation, moving the camera, magnification and using narrow-band imaging technology.[21] However, if the pit pattern on the image is of sufficient quality, the pit pattern can be a valuable feature for polyp matching, which is not always available. Other agreed surface and contour characteristics that could be considered useful by the expert panel include the presence of ulceration or erosion on the polyp surface and a distinct shape or colour of the polyp. By contrast, erythema on the polyp was considered to be too generic to be a reliable matching feature. Similar to the morphology of the polyps, the more distinct and specific the surface features, the easier it becomes to be used to accurately map polyps.

Uncertain factors – opportunities for further research

The uncertain factors from the panel included the size of the polyps in relation to the size of the lumen, the full or partial view of the polyps, application of different reading modes/filters including FICE1 or blue mode, the presence of blood, location estimated by the video tracer or guide and the use surrounding colonic fold as reference for polyp matching.

The size of the polyps in relation to the size of the lumen

As discussed before, the issue of overestimation in the CCE polyp sizing tool prompted the exploration of alternative approaches.[19] The utilization of the ratio between the polyp size and the luminal size of the colon was proposed in the pre-round questionnaire. After extensive discussion in the teleconference, it was determined that this approach was uncertain mainly due to the variations in the colon lumen resulting from colon contraction. Unlike colonoscopy, the colon is not fully distended in CCE, and the calibre of the lumen varies depending on its distension and the occurrence of colon contraction as the images were captured.

Due to the variability of the lumen calibre, it cannot serve as a reliable reference for polyp sizing and, hence, polyp matching. This has clearly demonstrated the pressing need for an accurate polyp sizing tool in CCE. In addition, there might be a possibility that AI could hold the potential to overcome this challenge in the future.

FICE and blue mode

Panel agreement was not reached when it came to the utilization of the Flexible spectral Imaging Color Enhancement (FICE) technique in polyp mapping, this is because of the general uncertainty surrounding the effectiveness of FICE in polyp detection and characterization in CCE.

FICE is a digital imaging post-processing technique aimed at augmenting the revelation of the vascular network and mucosal surface pattern of lesions.[24] In OC, FICE without magnification was also shown not to improve the adenoma miss rate or the detection rate of CRTs and adenomas compared to white light.[25] On the contrary, Kiriyama *et al.*[26] also reported that the miss rate for all polyps with FICE was significantly less than the white light in colonoscopy, especially in the right colon.

In CCE, a small study conducted by Omori *et al.* showed an increase in per-patient diagnostic accuracy for CCE-FICE when compared to CCE white light in colorectal polyps and cancer, especially in the 6–9 mm polyp and overall >6 mm colorectal tumour. However, the specificity of CCE-FICE was significantly lower than CCE white light, despite its significantly higher sensitivity. It also concluded that CCE-FICE could be superior in identifying smaller polyps than white light in CCE.[27] Another small study showed potential in differentiating between adenomatous and hyperplastic polyps using FICE, but it only included 52 lesions from 18 patients.[28] On the other hand, FICE was shown to be not a good adjunctive tool for the detection of polyps or tumours but may improve the visibility of pigmented vascular lesions and lesion delineation in a different study.[29]

Given the conflicting evidence, it is understandable that there was no agreement among the panellists. In addition, no study has specifically studied the effect of FICE on polyp matching within the same video, which might be an area for future study.

Video capsule tracer

The accuracy of video capsule tracers has not yet reached an acceptable level that allows widespread adoption in the medical field. Several hurdles must be overcome, including the reliability of the closed-loop control of active-locomotion capsules, interferences from the external environment and the challenges in capsule position and orientation accuracy.[30,31] These limitations create a significant level of uncertainty, which contributed to the poor uptake of this technology in the medical world. This was also reflected in the consensus of the expert panel.

The deciding number of factors

Following the scoring process, there was a consistent consensus in both rounds, suggesting that satisfying five out of eight factors instilled confidence and ease in the context of matching polyps. However, there was also a consistent disagreement that polyps meeting only two out of eight factors should be considered the same polyp.

Limitations of this study

One of the limitations of this study is that all the items in the criteria are given equal weight, even though this is never the case in our day-to-day practice. We recognize that certain features hold more significance than others, such as pedunculated polyps weighing more than similar vascular patterns of the polyp. However, this study aims to create criteria that are clear and user-friendly.

Another potential drawback is the over-representation of experts from the UK, which might introduce potential bias in the method of assessing and matching polyp in CCE, particularly in the context of following the UK training and guidelines. Part of the rationale is UK has one of the largest CCE uptake rates over the past few years, including initiating two large studies from Scotland and NHS England. Given the novelty of CCE, it was challenging to identify experts who fulfilled the defined criteria in regions or countries with low CCE adoption. To improve future study's robustness and validity, it might be better to include a more diverse group of CCE experts from various countries to get additional insights in this area.

Finally, these criteria are primarily designed for positively identifying the same polyps at different time stamps when five or more factors are fulfilled. Conversely, this does not necessarily imply that the polyps failing to meet these criteria cannot be considered the same polyp. Given the common polyp morphology, such as sessile and hyperplastic, make up the majority of the polyps that we encounter on a day-to-day basis and these

features often carry a high degree of uncertainty when matching even when using the created criteria. This indicates that a significant number of polyps will still pose challenges to match, as they may not meet the currently defined criteria.

With the continuous advancement in artificial technology, further validation and refinement of this polyp matching criteria are suggested, particularly important when validating the findings of a complete independent AI read without manual video review. The continuous development of computer-aided diagnosis might potentially guide the likelihood of polyps being the same, assisting us in decision-making in the future.

Conclusion

This RAND consensus has established the first criteria for polyp matching in CCE, laying the essential foundation for addressing this substantial challenge in polyp matching. While it might not completely resolve the matching of difficult, small and common polyps, this criteria will offer a framework for guidance and consideration in polyp matching. Its implementation in daily practice will require further validation and its further development potentially assists us to validate the AI-processed findings in the near future.

Declarations

Author's note

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Ethics approval and consent to participate

All the experts consented to participate in the expert panel.

Consent for publication

Not applicable.

Author contributions

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Competing interests

The authors declare that there is no conflict of interest.

Availability of data and materials

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Supplemental material

Supplemental material for this article is available online.

References

1. World Health Organization. *Colorectal cancer*. https://www.who.int/news-room/fact-sheets/detail/colorectal-cancer (2023, accessed 15 November 2023).
2. James Turvill MM. Interim update on the NHS England colon capsule endoscopy evaluation. *Gut* ℐ 2023; 72: A1–A248.
3. Sebastian S, Dhar A, Baddeley R, *et al*. Green endoscopy: British Society of Gastroenterology (BSG), Joint Accreditation Group (JAG) and Centre for Sustainable Health (CSH) joint consensus on practical measures for environmental sustainability in endoscopy. *Gut* 2023; 72: 12–26.
4. Schelde-Olesen B, Bjørsum-Meyer T, Koulaouzidis A, *et al*. Interobserver agreement on landmark and flexure identification in colon capsule endoscopy. *Techniques in coloproctology*, 2023; 27: 1219–1225.
5. Buijs MM, Kroijer R, Kobaek-Larsen M, *et al*. Intra and inter-observer agreement on polyp detection in colon capsule endoscopy evaluations. *United European Gastroenterol* ℐ 2018; 6: 1563–1568.
6. MacLeod C, Hudson J, Brogan M, *et al*. ScotCap – a large observational cohort study. *Colorectal Dis* 2022; 24: 411–421.
7. Kjølhede T, Ølholm AM, Kaalby L, *et al*. Diagnostic accuracy of capsule endoscopy compared with colonoscopy for polyp detection: systematic review and meta-analyses. *Endoscopy* 2021; 53: 713–721.
8. Kobaek-Larsen M, Kroijer R, Dyrvig A-K, *et al*. Back-to-back colon capsule endoscopy and optical colonoscopy in colorectal cancer screening individuals. *Colorectal Dis* 2018; 20: 479–485.
9. Tai FWD, McAlindon M and Sidhu R. Colon capsule endoscopy – shining the light through the colon. *Curr Gastroenterol Rep* 2023; 25: 99–105.
10. Cash BD, Fleisher MR, Fern S, *et al*. Multicentre, prospective, randomised study comparing the diagnostic yield of colon capsule endoscopy *versus* CT colonography in a screening population (the TOPAZ study). *Gut* 2021; 70: 2115–2122.
11. Heresbach D, Barrioz T, Lapalus M, *et al*. Miss rate for colorectal neoplastic polyps: a prospective multicenter study of back-to-back video colonoscopies. *Endoscopy* 2008; 40: 284–290.
12. Lei II, Nia GJ, White E, *et al*. Clinicians' guide to artificial intelligence in colon capsule endoscopy-technology made simple. *Diagnostics (Basel)* 2023; 13: 1038.
13. Lei II, Tompkins K, White E, *et al*. Study of capsule endoscopy delivery at scale through enhanced artificial intelligence-enabled analysis (the CESCAIL study). *Colorectal Dis* 2023; 25: 1498–1505.
14. Jalayeri Nia G, Arasaradnam RP and Koulaouzidis A. Clinical utility of colon capsule endoscopy: a moving target? *Therap Adv Gastroenterol* 2023; 16: 17562848231195680.
15. Robertson AR, Segui S, Wenzek H, *et al*. Artificial intelligence for the detection of polyps or cancer with colon capsule endoscopy. *Ther Adv Gastrointest Endosc* 2021; 14: 26317745211020277.
16. Fitch K, Bernstein SJ, Aguilar MD, *et al*. *The RAND/UCLA appropriateness method user's manual*. UCLA: Library of Congress Cataloging-in-Publication Data, 2001.
17. Gattrell WT, Logullo P, van Zuuren J, *et al*. ACCORD (ACcurate COnsensus Reporting Document): a reporting guideline for consensus methods in biomedicine developed via a modified Delphi. *PLoS Med* 2024; 21: e1004326.
18. Wada Y, Kudo S-E, Misawa M, *et al*. Vascular pattern classification of colorectal lesions with narrow band imaging magnifying endoscopy. *Dig Endosc* 2011; 23(Suppl. 1): 106–111.
19. Blanes-Vidal V, Nadimi ES, Buijs MM, *et al*. Capsule endoscopy vs. colonoscopy vs. histopathology in colorectal cancer screening: matched analyses of polyp size, morphology, and location estimates. *Int* ℐ *Colorectal Dis* 2018; 33: 1309–1312.
20. Lei II, Shekhar C, Mannath J, *et al*. Matched analysis of colonic polyp characteristics between colon capsule endoscopy, lower GI endoscopy and histopathology. *Gut* 2023; 72: A185.
21. Koulaouzidis A, Dabos K, Philipper M, *et al*. How should we do colon capsule endoscopy

reading: a practical guide. *Ther Adv Gastrointest Endosc* 2021; 14: 26317745211001983.

22. Spada C, Hassan C, Adler SN, *et al*. Flat colorectal lesions at pillcam colon capsule endoscopy. *United European Gastroenterol J* 2013; 1: A126–A127.
23. Spada C, Hassan C, Adler SN, *et al*. 857 Flat colorectal lesions at PillCam colon capsule endoscopy. *Gastrointest Endosc* 2013; 77: 58.
24. Omori T, Jodai Y, Maeda K, *et al*. Prospective study of diagnostic yields of flexible spectral imaging color enhancement installed in colon capsule endoscopy for colorectal polyps and tumors. *Gastrointest Endosc* 2024; 99: 245–253.e2.
25. Aminalai A, Rösch T, Aschenbeck J, *et al*. Live image processing does not increase adenoma detection rate during colonoscopy: a randomized comparison between FICE and conventional imaging (Berlin Colonoscopy Project 5, BECOP-5). *Am J Gastroenterol* 2010; 105: 2383–2388.
26. Kiriyama S, Matsuda T, Nakajima T, *et al*. Detectability of colon polyp using computed virtual chromoendoscopy with flexible spectral imaging color enhancement. *Diagn Ther Endosc* 2012; 2012: 596303.
27. Otani I, Oka S, Tanaka S, *et al*. Diagnostic yield of colon capsule endoscopy in detection of superficial colorectal lesions. *Digestion* 2020; 101: 262–269.
28. Nakazawa K, Nouda S, Kakimoto K, *et al*. The differential diagnosis of colorectal polyps using colon capsule endoscopy. *Intern Med* 2021; 60: 1805–1812.
29. Toskas A, Laskaratos F-M, Coda S, *et al*. Virtual chromoendoscopy in capsule endoscopy: a narrative review. *Diagnostics (Basel)* 2022; 12: 1818.
30. Bianchi F, Masaracchia A, Barjuei ES, *et al*. Localization strategies for robotic endoscopic capsules: a review. *Expert Rev Med Devices* 2019; 16: 381–403.
31. Mateen H, Basar R, Ahmed AU, *et al*. Localization of wireless capsule endoscope: a systematic review. *IEEE Sens J* 2017; 17: 1197–1206.