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Seminars in ULTRASOUND CT and MRI

Training in Computed Tomographic Colonography Interpretation: Recommendations for Best Practice

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The value of computed tomographic colonography (CTC) as a sensitive diagnostic investigation for colorectal cancer is well established. However, there is lack of consensus in the best way to achieve expertise in interpreting these studies. In this review we discuss the value of CTC training, accreditation and performance monitoring; the qualities of good CTC interpretation training, and specific training cases with associated learning points.

Introduction

First described in 1994,[1] computed tomographic colonography (CTC) uses two-and three-dimensional (2D, 3D) CT images of the gas-distended colon, after bowel cleansing and oral contrast medium to "tag" residual faeces. It allows the detection of intraluminal colonic cancers and polyps and has comparable sensitivity to colonoscopy for detection of colorectal cancer (CRC) and large (10mm+) polyps,[2,3] and slightly lower sensitivity for small (6 to 9 mm) polyps.[4] An objective clinical measure of reader sensitivity is the interval or 'missed' cancer rate following the investigation. For colonoscopy, this is referred to as the post colonoscopy colorectal cancer rate (PCCRC), and the equivalent for CTC is the post imaging colorectal cancer rate (PICRC). A recent systematic review of published research articles showed an average PICRC rate at 36 months of 4.4% for CTC, similar to the range previously published for colonoscopy (2.9 to 8.6%).[5,6] Importantly, at CTC more than half of post-investigation cancers are visible in retrospect and due to perceptual errors.[5,7] It is therefore critical that readers interpreting CTC in clinical practice are adequately trained so that they are able to match the high diagnostic accuracy and low cancer miss rates reported in research trials.

Worryingly, some evidence suggests that CTC performance in a real-world setting may be worse than expected from the research literature. For example, in the English national bowel cancer screening programme, CTC achieved only 50% of the detection rates of colorectal cancer and advanced neoplasia achieved by colonoscopy,[8] and missed cancer rates were twice as common at 3 years,[9] although data are not randomised and thus heavily influenced by selection bias.

Given the large impact of perceptual error on neoplasia detection rates, appropriate training for CTC interpretation must be improved. In our previous article, we demonstrated that there is considerable variation in the training recommendations made by international bodies. The relatively small body of research literature investigating optimal methods for CTC interpretation training generally show a positive impact on performance although the precise methods used for training and feedback are variable. In this article, we aim to summarise methods for CTC training and accreditation, and make recommendations for best practice training, using clinical case examples.

What are Training, Accreditation and Performance Monitoring?

Training in CTC reporting involves teaching on how to interpret cases and may be delivered locally, 'on-the-job', or at a structured workshop or course. Such training does not lead to a recognised qualification and is frequently performed ad hoc. This contrasts with accreditation, which is a formal process leading to the achievement of a recognised set of objectives or standards. It almost always includes some form of

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training prior to the accreditation being awarded. The accredited individual has been assessed and deemed to fulfil the requirements of the accrediting body. As a condition of accreditation, there may be a requirement for repeat "refresher" or "update" training, and periodic or continuous monitoring of performance to ensure the individual continues to maintain an appropriate skill level.

In most jurisdictions, there is no mandatory training, accreditation process or standardised performance monitoring for CTC readers. This is in contrast to the evidenced-based accreditation and performance monitoring processes in place for colonoscopists in many regions; and for other imaging modalities in cancer screening services (eg, mammography interpretation in breast cancer screening). Lack of standardised training, accreditation and performance monitoring could contribute to poor performance and variability among readers. In addition, the absence of centralised, evidenced-based CTC interpretation training is likely to contribute to lower interpretation accuracy in clinical practice. These concepts are summarised in Figure 1.

Recommendations for Best Practice

Training in CTC can be broadly categorised into 2 groups: (i) training in CTC technique and (ii) training in CTC interpretation. In our experience, the most accurate CTC readers also have a good understanding of how the investigation is performed, allowing them to troubleshoot image acquisition and ensure high quality data are captured for interpretation. We recommend adequate training in both areas according to a dedicated syllabus with clear learning objectives. Further discussion will focus on CTC training related to interpretation.

Clinically Relevant Content

Test cases and ideally all training cases should have endoscopic (or follow up CTC) validation and where possible histological confirmation of the findings. We advocate for a consensus opinion from a panel of experts on CTC findings prior to using cases for training and testing readers. Fundamental learning principles for CTC interpretation include the methodical and systematic use of 3D endoluminal navigation with 2D multiplanar reformatting for lesion perception followed by a rigorous method for lesion characterisation incorporating a sound knowledge of interpretation pitfalls (Fig. 2).

Interpretation technique forms the foundation of accurate CTC interpretation. Familiarity with local CTC software allows manipulation of acquired images to maximise chances of polyp detection. Interpretation should be performed methodically using 3D endoluminal reformats and standard 2D images (in at least 2 different planes) (Figs. 3 and 4). A suggested approach for lesion detection is sequential review

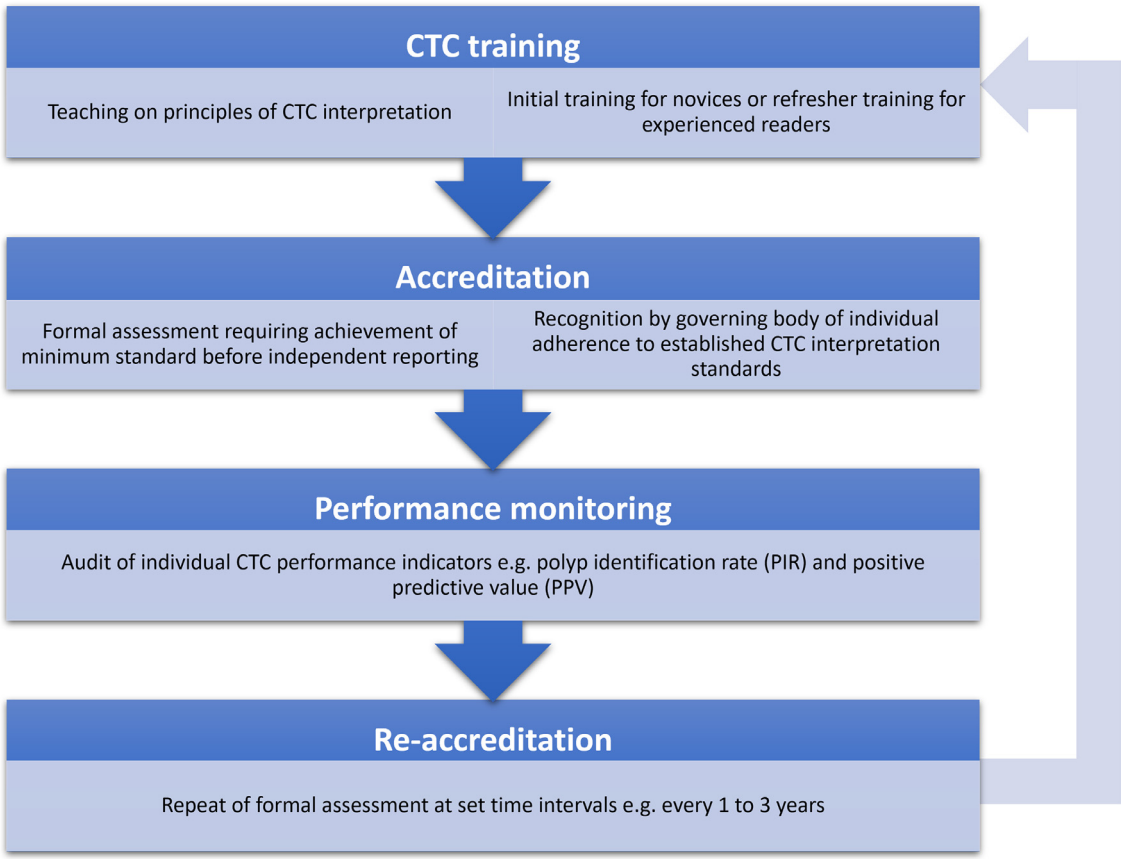

Figure 1 Suggested model of CTC training, accreditation and performance monitoring. Periods of refresher training can be performed after re-accreditation.

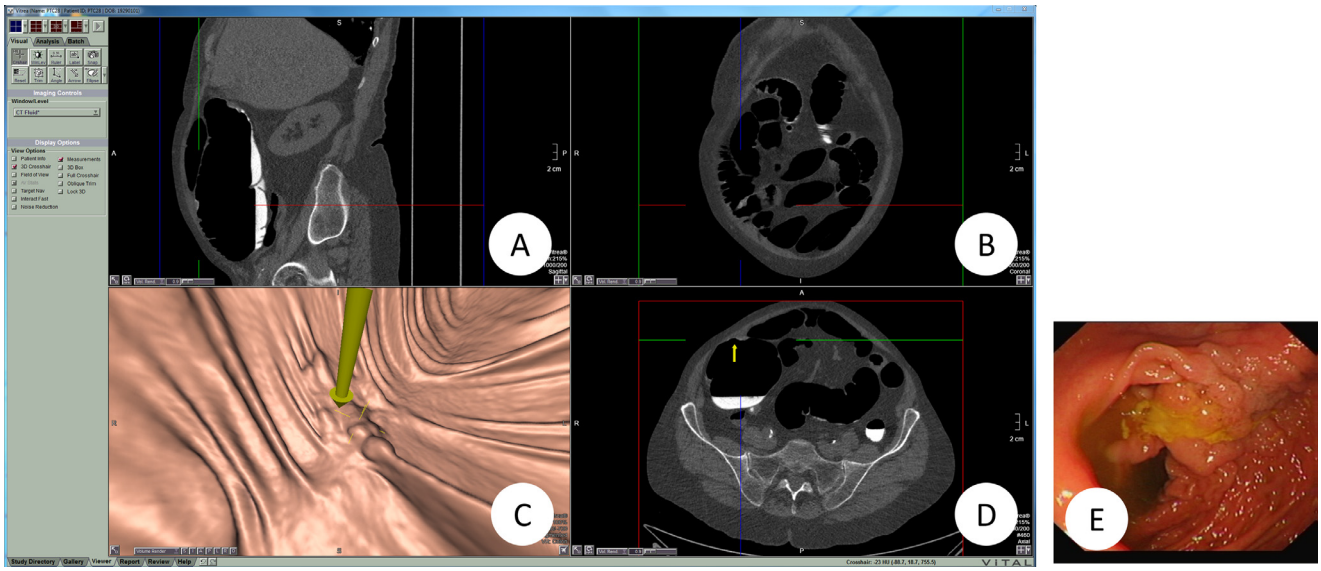

Figure 2 Screen capture from a CTC workstation showing correlation of the MPR 2D acquisition (A – sagittal, B – coronal, D – axial) and 3D endoluminal view (C). The yellow arrows (C, D) highlight a 22 mm nodular, sessile polyp in the ascending colon. Endoscopic view of the corresponding lesion (E), which is characterised as granular laterally spreading tumour. Histology confirmed a tubular adenoma with low grade dysplasia. MPR, multiplanar reformat. (Color version of figure is available online.)

of: (i) 3D axial supine acquisition, (ii) 2D axial prone or decubitus acquisition, (ii) 2D sagittal reformat of axial acquisition, and (iv) 2D coronal reformat of prone or decubitus acquisition. If a lesion is detected, characterisation should be performed by polyp matching between the two acquisitions to assess for movement (eg, to dismiss faecal residue) and use of CT windows to assess lesion density (eg, soft tissue vs lipoma or residue).

Training cases should be selected to present a spectrum of difficulty and disease, ranging from normal scans with non-neoplastic lesions (eg, lipoma, haemorrhoids, diverticular disease; Fig. 5) to scans with subtle, difficult to detect lesions (eg, flat lesions, Fig. 6). Differing morphologies for example pedunculated, sessile and malignant lesions should be highlighted.

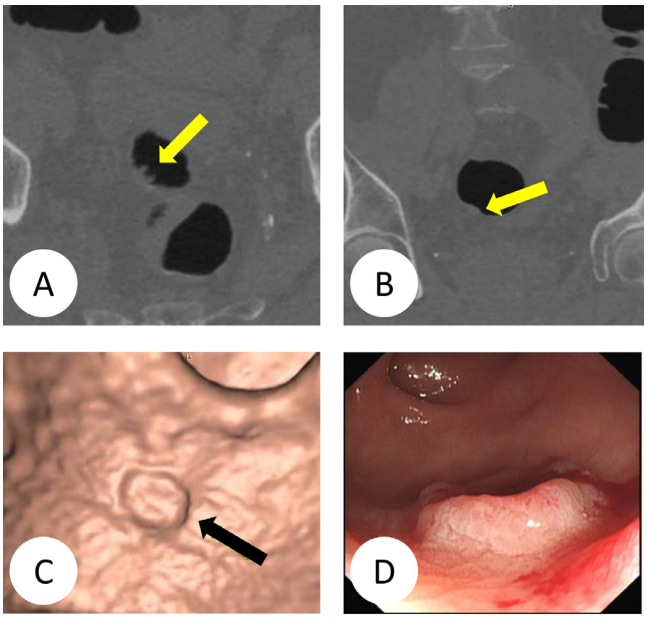

Figure 3 On careful inspect of the bone window, 2D axial views (A) a rectal lesion is visible; this is less conspicuous on the coronal view (B). The lesion is best appreciated on the 3D endoluminal view where it appears as a flat 12 mm rectal lesion with rolled edges (C). Colonoscopy confirmed a sessile lesion with depressed centre and the lesion was found to be a moderately differentiated adenocarcinoma on histology.

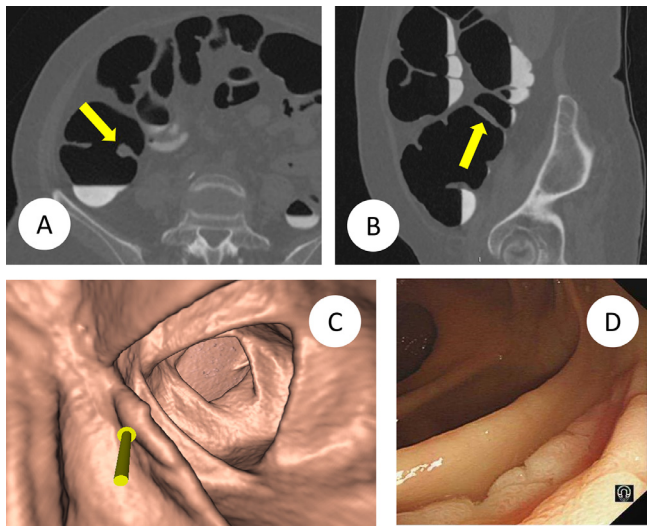

Figure 4 The 2D axial view on bone window, shows an abnormally thickened fold in the ascending colon (A – axial, B – sagittal), which is more obvious on the 3D endoluminal view (C). This was confirmed to be a 13 mm laterally spreading tumour on colonoscopy (D).

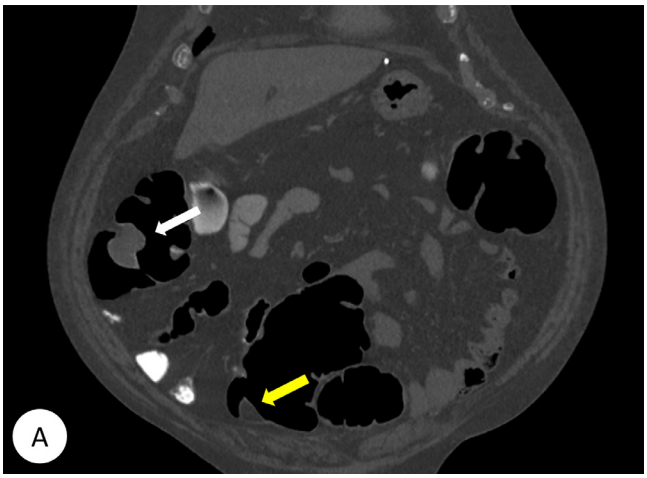

Figure 5 2D coronal view on bone window demonstrates a 17 mm lipoma in the proximal ascending colon (yellow arrow), compare with a 36 mm polyp in the ascending colon (white arrow) which has soft tissue attenuation. (Color version of figure is available online.)

Readers should be advised that some societal guidance recommends a CTC reporting time between 20 and 25 minutes per scan, ideally performed in dedicated/uninterrupted sessions.[10] Reporting too quickly and for too long is associated with reduced polyp detection, therefore a maximum of four sequential scans should be reported before taking a screen-break.[11]

We recommend establishing course objectives prospectively, and covering key topics in a structured, comprehensive fashion as described in Table, which are similar to those used in a recent randomised, multicentre trial.[12]

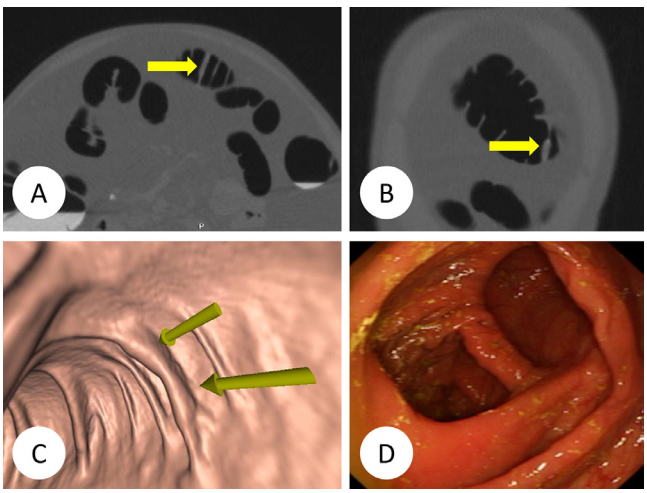

Figure 6 On the 2D, bone window, there is a flat lesion on a fold in the distal transverse colon (A – axial, B – coronal). This fold is abnormally thickened in comparison to adjacent folds, appearing more conspicuous on the 3D endoluminal view (C). Colonoscopy confirmed a 17 mm tubular adenoma with low grade dysplasia (D).

Table 1 Suggested CTC Training Topics

Interpretation technique
- Use MPR and 3D endoluminal views for both primary detection and problem solving
- Principles of 2D scrolling focused on the colon and polyp matching between scan positions
- Awareness of advanced 3D visualisation tools (eg, panoramic, unfolded cube and virtual dissection)
- Employ techniques that improve detection of difficult lesions
- Develop a process for evaluating review areas
- Employ techniques to avoid 'satisfaction of search'
Non-neoplastic abnormalities
- Differentiate non-neoplastic abnormalities from neoplastic pathology
- Features of haemorrhoids, diverticular change and colonic anastomoses
- Characteristics of benign and malignant strictures
- Hernia
Flat and/or fold-related lesions
- Develop strategy to detect subtle, fold-related lesions more easily
- Develop strategy to detect flat lesions more easily
- Use techniques that improve detection of difficult lesions
Small/irregular polyps
- Develop strategy to detect small (6 to 9mm) lesions more easily
- Characterisation of polyp candidates with an irregular or atypical morphology
- Understand the Paris Polyp Classification System
Pitfalls
- Anorectal junction lesions
- Ileocaecal valve variations and lesions
- Spasm and under-distension
- Artifact and foreign bodies
- Tagging and faecal residue
- Appendix and appendiceal orifice

3D, three-dimensional; MPR, multiplanar reformat.

Expert Training Faculty

There is a clear difference between being an expert in CTC interpretation and being an expert CTC trainer. Most radiologists acting as trainers in CTC will not have received any guidance or teaching on how to deliver CTC training, invariably leading to variation in practice and skills acquisition between centres. Beyond commercially available short courses, often designed and delivered by CTC software companies, much CTC training has traditionally been accomplished by informal "on the job" teaching in local radiology units. Such an approach lacks standardisation and is dependent on local caseload and radiologist availability.

Similar observations in colonoscopy led to the development of the 'Training the Colonoscopy Trainer' (TCT) course.[13] Recognition that being able to perform a skill does

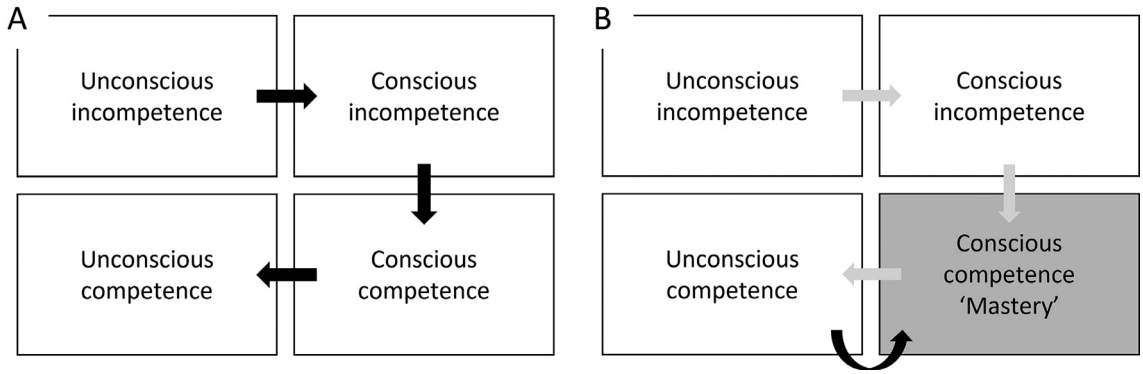

Figure 7 Peyton's model of procedural skills acquisition (A). Effective teaching of procedural skills requires moving from unconscious to conscious competence, 'mastery' (B).

not explicitly result in an individual also being an effective trainer is based on the concept of Peyton's model of procedural skills acquisition.[14] According to this model, individuals progress through stages of unconscious incompetence to unconscious competence (Fig. 7A). Beginners are initially in the unconscious incompetence phase (unaware of what they do not know) and over time their ability develops into conscious incompetence (aware of limitations). If a task is simply learned from experience, without the component elements explained then the learner may bypass conscious competence directly to unconsciously competent, where the task is automated and habit-like. The unconsciously competent have mastered a technique, allowing it to be performed quickly and efficiently. However, effective teaching requires the ability to deconstruct actions and techniques, thus requiring trainers to move from unconscious competence to 'enlightened' conscious competence or mastery (Fig. 7B). Effective CTC interpretation training therefore requires the trainer to possess explicit knowledge of 'how to interpret' CTC but also 'how to teach' CTC interpretation. When a CTC trainer is consciously competent, they are able to verbalize specific steps for example how to distinguish a polyp from faecal residue, which facilitates the skills acquisition of the learner.

Development of a 'Training CTC Trainers Course' (TC3) allows the teaching process to be formalised, with due consideration given to preparation, learning objectives, cognitive overload, performance feedback, critical reflection, and take-home messages. In turn a faculty of 'enlightened' CTC trainers who have undertaken such a course are well equipped to share best practice CTC training tips and tricks and thus improved trainee performance. This model was used during the PERFECTS trial,[12] where expert faculty delivered a 1-day CTC training workshop to experienced CTC reporting radiologists after attending a specially designed TC3 course. Faculty were equipped to train radiologists according to an agreed syllabus and best practice learning principles. This study observed a 16.7% improvement in sensitivity among radiologists who had received this training. Widespread implementation of this model will improve CTC training and is the rationale for a national training programme in its early stages of development.[15]

Individualised Training and Performance Feedback

While any reader can be trained to become a good CTC interpreter, a distinction must be made between the requirements of a novice learning to interpret CTC scans for the first time and an experienced reader; each of which will have different learning needs. However, many previous models of CTC training operate on a 'one size fits all' assumption, offering the same

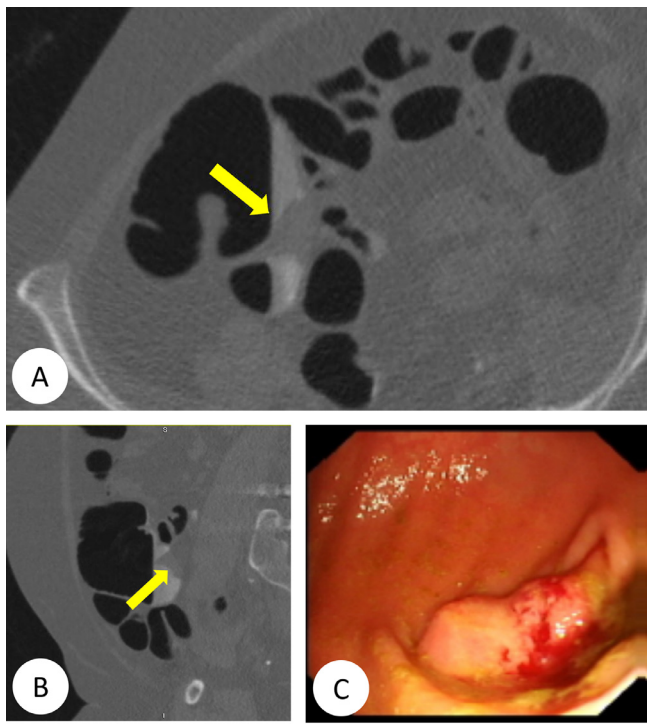

Figure 8 2D images on bone window (A – axial, B – sagittal) demonstrate a 23 mm caecal polyp submerged under tagged fluid (arrow) and corresponding endoscopic view (C). In cases with retained tagged fluid, the window level should be widened to increase conspicuity of lesions. Care should be taken to specifically interrogate the colonic segments with retained fluid to maximise lesion detection. The patient underwent a right hemicolectomy and histology confirmed a T2V0N2 adenocarcinoma.

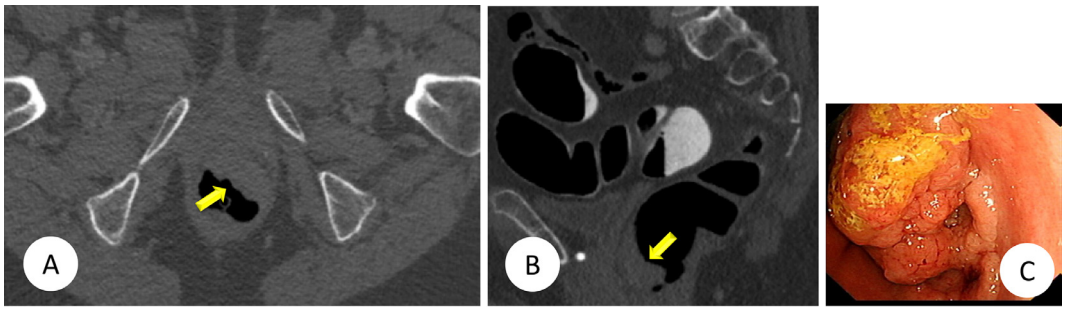

Figure 9 2D images on bone window (A – axial, B – sagittal) demonstrate a 6.5 cm polyp in the low rectum adjacent to the rectal balloon. This is confirmed on colonoscopy (C) and histology as a tubulovillous adenoma. The rectum should be assessed with particular care since the presence of the inflated rectal balloon can obscure low lesions. The sagittal view is helpful to identify these.

training to all readers. Several studies have observed that this approach has limited impact on improving reader sensitivity.[16]

Interestingly, Fletcher et al (2010) found that acceptable reader sensitivity could be achieved after reviewing only 45 training cases; notably, 30 of these cases were tailored to individual reader weaknesses.[17] This contrasts with observations by Liedenbaum et al (2011), who found that although novice readers reached the sensitivity of experienced readers after 164 cases, one third of readers did not reach competency even after 200 cases.[18] Their training model comprised self-directed reading, lectures, and training on pitfalls, however, independent hands-on practise was only delivered on 4 CTC cases.

It is intuitive that training will have more impact when it is targeted to the trainees needs. Indeed, Fidler et al (2004) suggest that formal CTC training must provide enough cases for readers to learn their own idiosyncratic weaknesses in interpretation.[19] In the PERFECTS trial, readers were required to prospectively write individual personalised development plans (PDPs), which were used to identify areas of weakness that could be targeted during the training workshop.[12] These self-declared areas of weakness or difficulty were combined with observations from expert faculty to individualise readers' learning journey. This approach significantly improved reader sensitivity, which lasted for at least 12 months after the initial training.[12]

Pitfalls and Errors

Many pitfalls in CT colonography interpretation are well known and have been described previously.[20-22] CTC training cases should illustrate these pitfalls and provide troubleshooting mechanisms for avoiding them (Figs. 8 and 9). Subsequently, understanding should be assessed with discriminatory test cases.

Notably, the type of lesion which appropriately assesses the ability of novice vs experienced readers will be different. For novice readers, teaching the recognition of large, protuberant lesions will allow them to appreciate obvious abnormal findings, providing the opportunity to practise luminal navigation and interpretation technique. For more experienced readers, focus can be directed toward hard to detect lesions, especially if these readers are involved in reporting bowel cancer screening studies in which lesions are typically more subtle.[23]

Once a possible abnormality has been detected, it must then be accurately characterised. Errors of characterisation for example mistaking an abnormal fold for spasm (Fig. 10) or dismissing mucosal nodularity caused by a granular laterally spreading tumour (Fig. 11) are considered cognitive errors. Exposure to the spectrum of polyp and cancer morphology during teaching cases can mitigate against such errors (Fig. 12).

Discussion

If the full utility of CT colonography (CTC) as a sensitive diagnostic tool for colorectal cancer is to be established there must be high quality training in technique and interpretation. The current lack of standardised and formal CTC training undermines this. This review has focused on the importance of CTC interpretation and best practice principles of delivery.

Training cases should cover a spectrum of difficulty, with emphasis on recognising pitfalls and troubleshooting. Particular attention should be paid to developing methodical interpretation technique, with the opportunity to practise

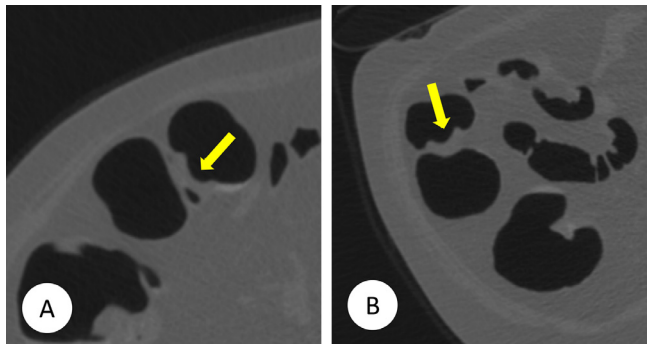

Figure 10 Supine (A) and prone (B) 2D axial images on bone window demonstrating a polyp with central depression on a fold in the transverse colon which was initially dismissed. The patient had a concurrent caecal polyp detected on this CTC and the additional transverse colon lesion was identified on colonoscopy and confirmed to be a malignancy. This case highlights cognitive errors of characterisation and satisfaction of search.

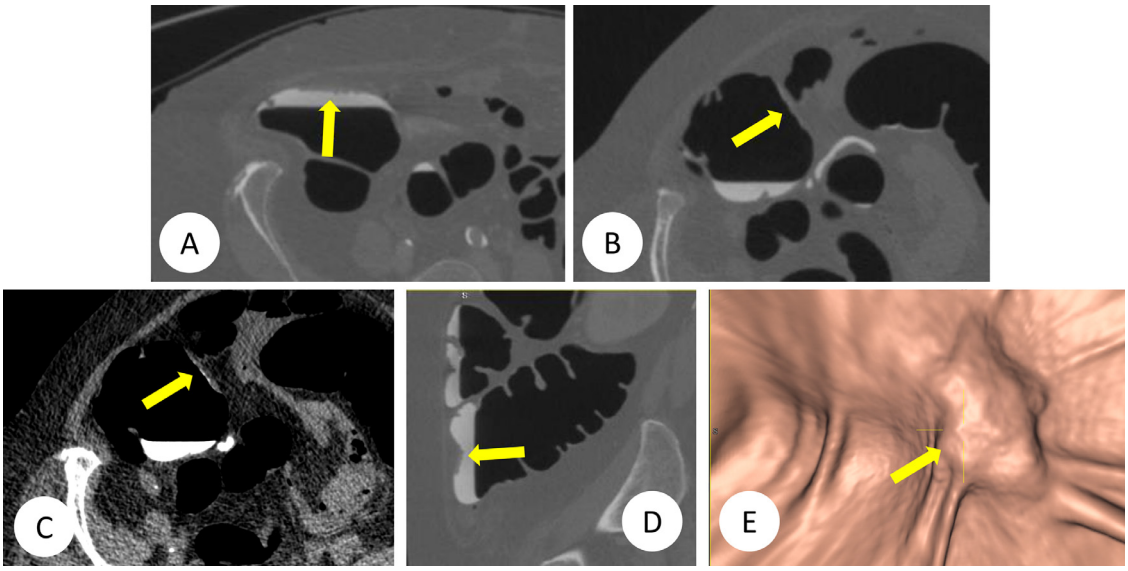

Figure 11 Prone (A), supine (B) axial and sagittal (D) 2D images on bone window demonstrating a histologically confirmed sessile caecal tubulovillous adenoma. On the prone images (A) the lesion is submerged under tagged fluid making detection more difficult. Compare with the 2D soft tissue window (C) which shows a small degree of oral contrast coating on the surface of the lesion. This characteristic can be used to aid detection of flat polyps. Corresponding 3D endoluminal view (E).

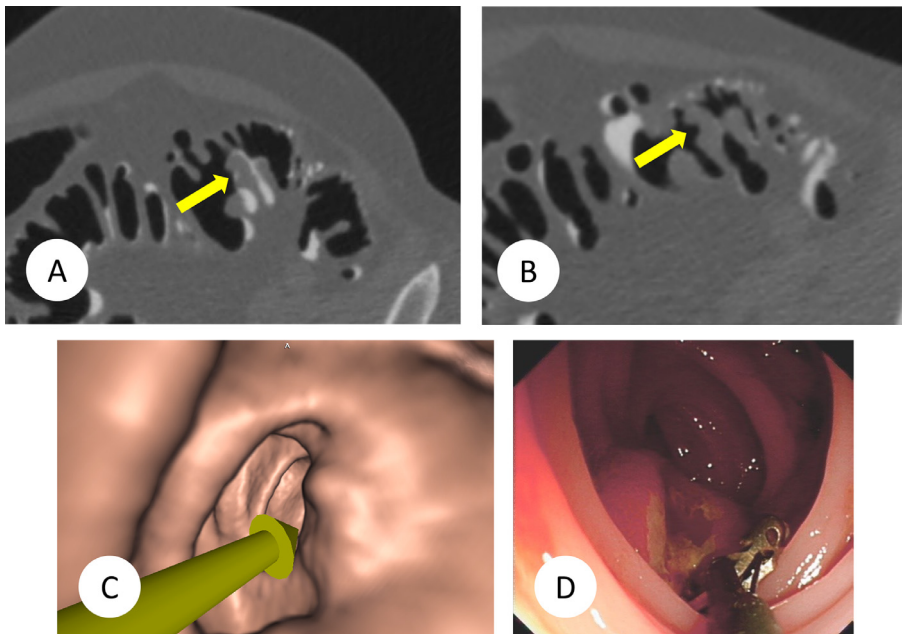

Figure 12 2D axial supine (A) and prone (B) images on bone window demonstrate a 10 mm sigmoid polyp with central depression in diverticular segment. The presence of central depression is in keeping with malignancy and this morphology is confirmed on the 3D endoluminal view (C) and colonoscopy (D). This was histologically confirmed as an adenocarcinoma.

reading a wide variety of cases. Furthermore, regular testing and performance feedback is essential to assessing understanding and embedding good practice.

Such CTC interpretation training should be delivered by experienced faculty, who have received specific guidance in how best to teach this subject. This may be difficult to achieve locally, therefore consideration must be given to the development and funding of national or international programmes which pool expertise and resource. Readers and services who have attained accreditation through completion of such a programme could benefit from better tariffs and reimbursement from insurance companies; thus, providing a financial incentive for participation.

Without a more considered approach to CTC interpretation training, readers will inevitably miss lesions which, if detected at an early stage, could prevent cancers. This observation should motivate regulating bodies to develop high quality teaching for those involved in delivering CTC services.

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