



Effectiveness of Training in CT Colonography Interpretation: Review of Current Literature

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International guidance recommends that readers be specifically trained before embarking on independent interpretation of CT colonography (CTC) examinations. Systematic comparison of both international training requirements and the effectiveness of CTC training is lacking in the published literature. Therefore, we identified available international training standards for CTC and performed a review of studies published in the last 20 years to assess the impact of CTC interpretation training on reader diagnostic accuracy. A wide variation in training requirements was observed. Studies of the effectiveness of CTC reader training were heterogeneous in methodology, with large variation in sample size and the type of training administered. Although training in CTC interpretation improves reader sensitivity overall, it has varying impact on specificity. Consensus agreement on the best way to train and assess readers in CTC interpretation may lead to lasting improvements in reader performance.

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Introduction

CT colonography (CTC) is a whole-colon investigation commonly used in the detection of colorectal cancer and precursor polyps. Patients drink an oral cathartic agent to cleanse the bowel, with oral contrast medium used to tag any residual stool; these can be combined using a single agent with osmotic laxative effect, such as Gastrografin (diatrizoate meglumine and diatrizoate sodium solution, Bracco Imaging, USA).¹ High-resolution 2- and 3-dimensional (2D, 3D) CT images of the gas-distended colon are then obtained. Interpretation of these CTC images is time-consuming and differs from routine abdominopelvic CT. It therefore requires additional skills and training for adequate diagnostic accuracy. As such, it is recognized that specific training in CTC interpretation is necessary for accurate independent reporting.

Lack of training in CTC interpretation will lead to perceptual errors when detecting colorectal polyps and cancers, which in turn contributes to poorer outcomes.² There is currently no consensus on the most effective method to train

readers in CTC interpretation. Many current guidelines and standards for the practice of CTC advocate a minimum case number as the main training requirement.³⁻⁵ However, they do not provide details regarding the distribution or abnormalities that should be included. Moreover, there is wide variation in the number of training cases that is regarded as a suitable basic training requirement, with no clear logic as to why these numbers were selected. Although many studies have been conducted to assess the impact of interpretation training on CTC readers, these have not been comprehensively reviewed or incorporated into societal guidelines for CTC training. Here, we (a) review current international consensus guidance for CTC training prior to independent practice and (b) review the published literature regarding training methods for CTC interpretation. In a subsequent article, we draw on these data and the educational literature to make recommendations for best practice in CTC interpretation training.⁶

Methods

Ethical permission is not required by our institution for literature review or subsequent data synthesis.

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Current International CTC Training Guidelines

We performed an internet search for training guidelines from the 10 most populous countries according to the World Bank.⁷ Search terms included the country name and variations of “CT colonography”, “CTC”, “CTC training”, “CTC accreditation”, “CTC guidelines”, and “radiology society” or “college”. In addition, where they could be identified, we searched individual country or region websites, as well as regional or international radiology organizations which were known to have previously published guidance regarding CTC. Where references were identified regarding CTC training guidelines or minimum standard stipulations for radiologists, these were retrieved, and the source information interrogated.

Literature Review of Training Methods for CTC Interpretation

We searched PubMed using the following Medical Subject Headings (MeSH) and free-text terms: (1) (CT OR comput* AND tomogra*) AND (colonograp* OR virtua* AND colono*); (2) train* OR test* OR perform* OR experien* OR error*; (3) 1 AND 2; relating to CT colonography training and performance and examined reference lists from relevant articles. Inclusion criteria were any type of reader performance or diagnostic accuracy study assessing radiologist diagnostic accuracy or yield either before and after an interpretation training intervention, or simply after interpretation training. The search was restricted to dates January 1, 2001 to December 31, 2021, and only articles published in English were eligible. Excluded studies were those that assessed reader sensitivity without a training intervention of any kind, those that only assessed the performance of computer-aided detection (CAD) and those that did not involve CTC interpretation or report sensitivity. Abstracts were screened by a single researcher (AEO) and the full text of potentially eligible studies was retrieved for further assessment.

Once eligibility was confirmed, a single researcher (AEO) extracted the following characteristics for each article: (a) author and publication year; (b) number of sites, readers and faculty participating in the training intervention; (c) training components of the intervention; (d) background of readers undergoing training (eg, radiologist or radiographer/technician); (e) reader and trainer career CTC experience; (f) number of test cases completed per reader; (g) number of lesions (polyps and/or colorectal cancers) assessed in test(s) both pre- and post-training intervention; (h) characteristics of such lesions; and (i) summary measures of the effect of training on reader diagnostic accuracy, including sensitivity and specificity where available. If data were not available in the original research article report, supplementary materials were examined, but no additional data was sought from primary research authors.

The data were extracted to a Microsoft Excel spreadsheet and summarized with descriptive statistics. Due to

considerable heterogeneity of initial reader experience and pre-training diagnostic accuracy, quantitative synthesis (meta-analysis) was not attempted.

Results

International CTC Training Guidelines

We identified several national and international regulatory bodies that have established training recommendations and guidelines for CTC readers (Table 1). These include standards which refer to both the CTC service (“service level guidance”), and the competency and performance of CTC readers (“reader level guidance”).

Although the importance of training in CTC interpretation prior to independent practice is recognized, none of these bodies mandate the completion of a specific program or training package prior to independently reporting CTC. The Royal Australian and New Zealand College of Radiologists (RANZCAR) is the only body to accredit (or certify) “CTC specialists”, a status achieved by (a) fulfilling minimum CTC training requirements stipulated by the College, and (b) maintaining an audited CTC logbook. The Joint Guidance from the British Society of Gastrointestinal and Abdominal Radiology (BSGAR) and the Royal College of Radiologists (RCR) is the only guidance to stipulate objective, quantitative performance indicators for CTC readers, including targets for polyp identification rates and positive predictive values. However, this primarily applies to readers who have already been trained and are reporting in routine practice, rather than those undergoing initial basic training.

There is no consensus on the minimum number of validated scans to be interpreted before achieving reporting competency, and recommendations vary widely between published guidelines. For example, the ACR, CAR and RANZCR all suggest a minimum of 50 training cases, whereas the ESGAR were unable to form a consensus recommendation, and the BSGAR-RCR recommends a minimum of 175 validated cases (by endoscopy or surgery), with over 300 training cases as an “aspirational” standard.

CTC Training Literature: Study and Reader Characteristics

Initial searching identified 987 abstracts, which was subsequently refined to 27 full text studies for further analysis (Fig. 1). Of these, 8 did not include a training intervention or were focused on CAD performance and were excluded, leaving 19 articles for data extraction and analysis. Table 2 provides a summary of the included articles, involving 372 readers at 143 centers interpreting 1183 lesions.

Where specified, most (85%; 11/13) of these studies were focused on training novice or inexperienced readers (0-500 CTC cases),⁸⁻²⁴ apart from 2 multi-center studies, which trained experienced readers who had reported more than 500.^{2,25} Accordingly, most of these studies only assessed diagnostic accuracy after the training intervention (rather

Table 1 Comparison of International CTC Interpretation Training Guidelines for Gastrointestinal Radiologists

| Metric | | International Guideline | | | | |
|-----------------------|---|--|---|--|--|---|
| | | BSGAR-RCR (2021) ²⁸ | ESGAR (2013) ¹ | ACR (2019) ⁴ | CAR (2010) ²⁹ | RANZCR (2013) ⁵ |
| Performance indicator | Interpretation time | Min > 20 min Asp > 25 min | NS | NS | NS | NS |
| | Polyp identification rate (PIR) | Min 6mm+ polyps identified in > 13% patients Asp PIR > 16% | NS | NS | NS | NS |
| Training | Positive Predictive value | Min > 80% Asp > 90% | NS | NS | NS | NS |
| | Same day CT staging | Min > 50% Asp > 80% | NS | NS | 'Majority' | NS |
| | Training prior to independent reporting | Min > 175 validated cases. Asp > 300 validated cases | No consensus but recognise that 175 validated cases may be insufficient | Min > 50 validated cases. Training on examination technique, pitfalls | Min > 50 validated cases. Training on technique, anatomy, pitfalls, complications, pathogenesis, epidemiology | Min > 50 validated cases and 10 live cases Training on technique, anatomy, limitations, pathogenesis |
| | Interpretation method | Competence in 2D and 3D techniques. Double reading as needed* | Competence in 2D and 3D techniques | Competence in 2D and 3D techniques. Double reading* | Competence in 2D and 3D techniques. Consider double reading* | Competence in 2D and 3D techniques |
| | Maintenance of competence | Min > 100/y Asp > 175/y | NS | Supervision and double reading by expert. Testing with feedback 25 cases/y | 100 cases/y | 30/y (recorded in RANZCR CTC logbook) |
| | Audit requirement | Every 2 y | NS | NS | 'Regular' | Every 3 y |
| CTC accreditation | No | No | Contributes to National Radiology Data Registry (NRDR) | No | Yes: CTC Specialist Register | |

BSGAR-RCR: Joint Guidance from the British Society of Gastrointestinal and Abdominal Radiology and The Royal College of Radiologists. Standards of practise for computed tomography colonography

ESGAR, European Society of Gastrointestinal and Abdominal Radiology; ACR, American College of Radiology; CAR, Canadian Association of Radiologists; RANZCR, The Royal Australian and New Zealand College of Radiologists; Min, minimum; Asp, aspirational. NS: not specified

*Double reading suggested for inexperienced readers. Min, minimum target; Asp, aspirational target

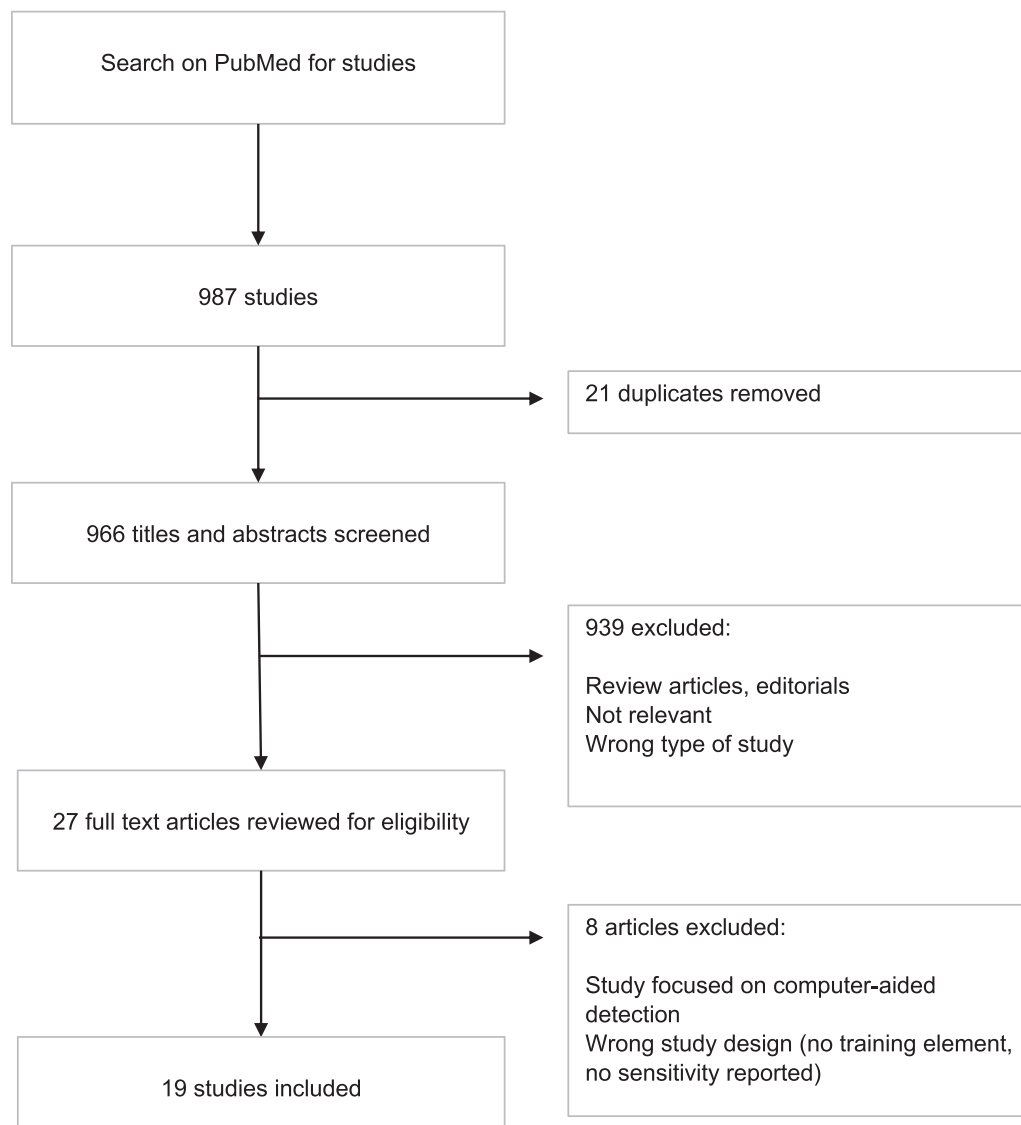


Figure 1

than pre- and post-training). Three studies assessed the effect of training with and without CAD used concurrently during interpretation, and all observed some benefit of CAD use.^{15,22,23} Five studies measured interpretation times before and after training, and all except one,¹⁵ observed a decrease in interpretation time.^{8,10,12,16}

CTC Training Literature: Training and Testing Methods Employed

Several different training components are described, which can be broadly categorized into (a) hands-on training workshops; (b) trainee-directed independent reading of relevant CTC literature; (c) didactic lectures on CTC-related topics (technique, software applications, interpretation, and pitfalls); and (d) reading of practice cases (independently or supervised; whole data sets or partial studies).

Most studies (79%; 15/19) contained passive, standardized (ie, non-tailored) teaching components for example, lectures, self-directed reading, or case review, and were heavily trainer focused. Seven studies used only a single expert trainer. Only 1 study emphasized individualized feedback on reader performance which was provided by a panel of experts.²

Where used, the format of the training workshops varied according to study design, but was typically 1 or 2 days (ranging from half a day to 4 days), with teaching delivered by several expert faculty in 1:1, 2:1 or small group tutorial setting.^{2,8,11,15,20,23,25} If specified, definitions of a faculty expert again varied, but were usually a board-certified abdominal or gastrointestinal radiologist with a career experience of ≥ 300 CTC cases. Only one study described training given to expert faculty in how to specifically train readers in CTC.²

All studies incorporated an element of CTC interpretation testing in either a formative (throughout the training) or

Table 2 Summary of CT Colonography Interpretation Training and Testing Studies Between Jan 2001 and Dec 2021

| Author | No. Sites | No. Readers | Training Components | No. Faculty (Experience) | Type of Readers (Experience) | No. Test Cases Per Reader | No. Lesions in Test (Characteristics) | Sensitivity (Sn) and Specificity (Sp) After Training* |
|------------------------------------|-----------|-------------|--|---|--|---|---|---|
| Arnesen et al. 2005 ¹⁸ | NS | 1 | Analysis of 12 CTCs and 12 colonoscopies and supervised visit to a CTC centre | - | 1 radiologist (NS) | 105 cases with sequential colonoscopy. Normal and 41 abnormal cases. | 90 lesions (1 cancer) | Sn: 67% for ≥ 5 mm; 75% for ≥ 10 mm Sp: 84% for ≥ 5 mm; 95% for ≥ 10 mm 55% of false positives due to perceptual error. |
| Bodily et al. 2005 ¹⁹ | NS | 7 | Independent review of teaching file of 61 partial CTC datasets focused on on lesion appearance/pitfalls. Didactic tutorials. | - | 5 medical students (0 cases) 2 technologists (0 cases) Compared to 15 radiologist controls in Fidler et al. 2004. ⁹ | 50 cases with sequential feedback. Technologists repeated test at 6 weeks. Normal and abnormal cases. | 35 lesions (8 cancers 20-50cm; 25 adenomas, 2 hyperplastic polyps 5-50mm) | Sn: 45% (non-radiologists) vs 63% radiologists for 5-9mm polyps. Sp: 79% (non-radiologists) vs 74% (radiologists). Similar Sn and Sp between radiologists and non-radiologists 5-9mm lesions. |
| Dachman et al. 2008 ⁸ | 1 | 7 | 1-day course - lectures on technique, hands-on teaching on 10 cases. 5-10 hrs self-directed reading. Self-study 61 partial cases Observe 3 cases 10 cases with sequential unblinding | 1 expert (≥ 500 cases) | 1 GI resident (0 cases) 6 medical students (0 cases) | 3 sets of 20 cases with sequential unblinding and post-case feedback over 5-8 weeks. Normal and abnormal cases. | 93 polyps (61 polyps 6-9mm; 32 polyps ≥ 10 mm) | Sn: 77% for 6-9mm polyps ($p > 0.05$); 93% for ≥ 10 mm polyps Sp: 92%. FPs decreased with each 20-case set ($p=0.04$). Read time decreased ($p = 0.001$). |
| Fidler et al. 2004 ⁹ | 12 | 15 | Independent review of 61 partial CTC datasets focused on on lesion appearance/pitfalls | - | 15 GI radiologists (0 to 'limited' cases) | 50 cases with sequential review of colonoscopy/histology report. Normal and abnormal cases. | 35 lesions (8 cancers 20-50cm; 25 adenomas; 2 hyperplastic polyps 5-50mm) | Sn: 76% for sessile polyps; 63% for pedunculated; 32% for flat. Sp: 80%. More errors of detection (55%) than characterisation (45%). |
| Fletcher et al. 2010 ²⁵ | 15 | 15 | 1-day course - hands-on teaching on 15 cases and 27 partial | 2 experts (NS) 1 app specialist (NS) | 4 readers (≥ 500 cases) | Test 1: 20 cases after 1-day training. | Test 1: 25 polyps ≥ 5 mm (5 cancers; 19 | Sn: 16% difference between Test 1 vs Test 2 ($p < 0.001$). |

Table 2 (Continued)

| Author | No. Sites | No. Readers | Training Components | No. Faculty (Experience) | Type of Readers (Experience) | No. Test Cases Per Reader | No. Lesions in Test (Characteristics) | Sensitivity (Sn) and Specificity (Sp) After Training* |
|--|-----------|-------------|---|-------------------------------|---|---|---|---|
| | | | cases then Test 1. Optional second day if Test 1 failed, with retraining on 30 cases | | 11 readers (<500 cases) | Test 2: 8 individualised cases including up to 6 missed cases from Test 1. Normal and abnormal cases in both tests. | adenomas; 1 NS) Test 2: individualised | Sp: 1.5x increase in odds of detecting an abnormal case for every 50-case increase in experience and formal training ($p = 0.025$). |
| Gluecker et al. 2002 ¹⁰ | 1 | 4 | 24 cases read followed by review of endoscopy results | - | 2 radiologists (NS) 2 gastroenterologists (NS) | 26 cases. Normal and abnormal cases. | 29 lesions (18 polyps ≤ 5 mm; 5 polyps 6-9mm; 6 polyps >9mm) | Sn: 63% to 45-64% for >5mm polyps, post-training. Sp: improved from 42-58% to 79%; improved with increasing experience ($p = 0.02$). Read time decreased ($p = 0.002$). |
| Halligan (ESGAR) et al. 2007 ¹⁷ | 9 | 28 | Local training of 19 novices with interpretation of 50 cases and feedback | 9 experts (median 750 cases) | 9 GI radiologists (≤ 10 cases) 10 technologists (≤ 10 cases) | 40 cases over 2 days individualised per centre. Normal and abnormal cases. | 24 lesions (8 cancers; 12 polyps ≥ 10 mm; 4 polyps 6-9mm) | Sn: 51% (trained radiologists) vs 66% (experts), $p = 0.007$, all lesion sizes. Sp: Accuracy- 67% (trained radiologists) vs 74% (experts), $p = 0.17$. |
| Haycock et al. 2010 ²⁰ | NS | 49 | 4-day course with small group lectures, hands-on training on technique and interpretation | 2 experts (> 1500 cases) | 49 radiographers (NS) | 5 baseline and 5 post-training cases. All abnormal cases. | 24 lesions (6 cancers; 2 ≤ 5 mm; 7 6-9mm; 9 10mm+) | Sn: 49 to 60% improvement for ≥ 10 mm polyps/cancers ($p = 0.002$) post-training. Sp: 55% to 71% improvement ($p < 0.001$) |
| Heresbach et al. 2011 ¹¹ | 26 | 28 | 2-day course - lectures/hands-on teaching on 52 cases with 'hard- | 3 experts (≥ 300 cases) | 28 GI radiologists (NS) | Median case volume: 18 Normal and | Median # polyps for detection: 19 | Sn: 62% for ≥ 6 mm lesions. Baseline Sn of ≥ 6 mm polyps in |

Table 2 (Continued)

| Author | No. Sites | No. Readers | Training Components | No. Faculty (Experience) | Type of Readers (Experience) | No. Test Cases Per Reader | No. Lesions in Test (Characteristics) | Sensitivity (Sn) and Specificity (Sp) After Training* |
|--------------------------------------|-----------|-------------|---|------------------------------|--|---|---|--|
| | | | to-detect' lesions and sequential feedback | | | abnormal cases. | | training set was only predictor of subsequent per-patient accuracy. Sp: 94% for average risk patients |
| Jensch et al. 2007 ²¹ | NS | 4 | 20 cases reviewed with feedback, for radiographers | 1 expert (NS) | 1 radiologist (>50 cases) 1 radiology trainee (>50 cases) 2 radiographers (0 cases) | 145 cases with sequential colonoscopy. Normal and abnormal cases. | 317 lesions (31 polyps \geq 10mm (including 2 cancers); 29 polyps 6-9mm; 257 polyps \leq 5mm) | Sn: 81% (radiologists) vs 87% (radiographers) for \geq 6mm. Sp: 71% (radiologists) vs 67% (radiographers) for \geq 6mm. Comparable Sn and Sp between radiologists and radiographers. |
| Liedenbaum et al. 2011 ¹² | 1 | 9 | Self-directed reading and lectures. Independent hands-on training on 4 cases with tutor for troubleshooting. Additional training on pitfalls with 40 images and MCQs for 5 readers. | 1 expert (\geq 400 cases) | 1 GI radiologists (0 cases) 3 radiology residents (0 cases) 2 non-radiology researchers (0 cases) 3 technicians (0 cases) | 4 sets of 50 cases over 4-6m. Sequential computer feedback after each of the first 25 cases. Normal and abnormal cases. | 160 lesions \geq 6mm (10 cancers; 62 pedunculated polyps; 74 sessile; 14 flat) | Sn: 91% for \geq 6mm lesions at 4th set post-training (p = 0.018). Sn of novice readers equalled experienced readers after 164 cases. Sp: 86% at fourth set post training. Read time decreased between 1st and 2nd sets (p < 0.001). |
| McFarland et al. 2001 ¹³ | 1 | 3 | Observed testing on 5 datasets (30 colonic segments) with coaching | 1 expert (NS) | 3 GI radiologists (NS) | Retesting on same 5 datasets 6 weeks later, using different 2D or 3D technique. Normal and abnormal cases. | 22 lesions (11 polyps 5-9mm (4 hyperplastic lesions, 5 adenomas, 2 unknown); 11 polyps \geq 10mm (3 cancers, 2 hyperplastic lesions, 2 adenomas)) | Sn: 89%-92%. No significant improvement at retesting. Sp: 72%-83%. |
| Neri et al. 2011 ²² | 1 | 27 | 9 h hands-on training over 3 days, including lectures, practise on 3 | 1 radiologist (NS) | 11 radiologists (0 cases) | 26 cases +/- CAD assistance with | 38 lesions (12 polyps \leq 5mm, 9 polyps 6-9mm; 12 polyps 10- | Sn: 29% (without CAD); 31% (with CAD), for 6-9mm polyps |

Table 2 (Continued)

| Author | No. Sites | No. Readers | Training Components | No. Faculty (Experience) | Type of Readers (Experience) | No. Test Cases Per Reader | No. Lesions in Test (Characteristics) | Sensitivity (Sn) and Specificity (Sp) After Training* |
|-------------------------------------|-----------|-------------|--|---|---|---|--|---|
| | | | normal and 3 abnormal scans | | 16 radiologists (<10 cases) | sequential feedback. All abnormal cases. | 30mm; 5 polyps > 3cm) | (p = 0.0027). Sp: unchanged (>96% for all sizes). Increased Sn for all polyp sizes with CAD except ≥30mm. Sn: 66.3% for ≥ 6mm polyps at 12m; improvement of 16.7% (p < 0.001) post-training. Sp: 80.6% at 1m, increasing to 89.3% at 12m. |
| Obaro et al. 2022 ² | 69 | 139 | 1-day course - 1:1 or 2:1 hands-on training on 50 cases with 'hard-to-detect' lesions after a baseline test | 13 experts (Trainer the trainers course attendance and: either ≥ 3000 cases or existing national CTC trainer or tertiary centre role) | 134 GI radiologists, 5 radiology residents (Median: 500-999 cases) | 4 unique sets of 10 cases over 1 y (read at baseline then 1m, 6m and 12m post-training) with individualised post-test feedback. Normal and abnormal cases. | 65 lesions ≥6mm (12 cancers; 5 serrated; 48 adenomas; 23 flat lesions) | Sn: 90% for 6-9mm polyps (radiology resident) Sp: Accuracy - 98.9% (radiology resident) No learning curve identified (p = 0.09-1.0). |
| Rosenfeld et al. 2014 ¹⁴ | 1 | 4 | 30 self-directed cases for the 3 novices | - | 1 experienced GI radiologist (NS) 1 radiology resident, 2 gastroenterology fellows (0 cases) | 90 cases with sequential review of colonoscopy report. Normal and abnormal cases. | 52 lesions ≥ 6mm (NS) | Sn: 83%-87% improvement with CAD (p= 0.021) and 74 to 83% without CAD (p < 0.001, for ≥6mm polyps). Sp: 81 to 86% improvement (p = 0.15). CAD alone had no impact on training. |
| Sali et al. 2018 ²³ | 3 | 20 | Half-day course (lectures, 5 case demo, individual training on 4 cases). Read 2 articles on pitfalls and lesions. 1:1 computer-based self training on 150 cases +/- CAD over 3-6m. | - | 17 radiology residents (0 cases) 3 radiologists (0 cases) | 37 cases at baseline (no feedback), repeated same test post-training. Normal and abnormal cases. | 24 lesions (2 cancers; 11 polyps 6-9mm; 11 polyps ≥ 10 mm) | Sn: 25%-58% for ≥ 10mm polyps. Trainee |
| | 1 | 3 | 50 cases read over 3-4 weeks, followed by | 1 expert (≥ 150 cases) | 1 GI radiologist (0 cases) | 50 test cases over 3-4 | 56 lesions (2 cancers; 42 polyps ≤5mm; 5 | |

Table 2 (Continued)

| Author | No. Sites | No. Readers | Training Components | No. Faculty (Experience) | Type of Readers (Experience) | No. Test Cases Per Reader | No. Lesions in Test (Characteristics) | Sensitivity (Sn) and Specificity (Sp) After Training* |
|-----------------------------------|-----------|-------------|--|-------------------------------|---|--|---|--|
| Taylor et al. 2004 ¹⁶ | | | individualised feedback and training | | 1 radiology fellow (0 cases) 1 radiology trainee (0 cases) | weeks. Normal and abnormal cases. | polyps 6-9mm; 7 polyps \geq 10mm) | significantly improved ($p = 0.007$). Sp: No significant difference in number of FPs after training. Read time reduced for GI radiologist ($p < 0.001$) and fellow ($p = 0.03$). |
| Taylor et al. 2008 ¹⁵ | 1 | 6 | 1-day course - lectures/hands-on teaching | 2 experts (≥ 300 cases) | 6 GI radiologist (107 cases read twice with no feedback) | 20 cases read concurrently with CAD All abnormal cases. | 55 polyps (22 polyps 1-5 mm; 33 polyps ≥ 6 mm) | Sn: 51% for 6-9mm polyps; improvement of 26% ($p < 0.001$) post-training with CAD. Sp: worsened after training ($p = 0.03$). Read time increased ($p=0.03$). |
| Thomsen et al. 2016 ²⁴ | 1 | 3 | Diagnostic training programme of 30 lessons (anatomy/pathology) Supervised interpretation of 50 cases E-learning cases | 1 radiologist (2 y) | 2 radiographers (NS) | 44 or 56 cases. Normal and abnormal cases. | 9 lesions (cancers; ≥ 6 mm polyps) | Sn: 100% for cancer, ≥ 6 mm polyps. Sp: 97% for cancer, ≥ 6 mm polyps. |

*p-values included where specified in original text 2D, two-dimensional; 3D: three-dimensional; FP, false-positive; GI, gastrointestinal; m, month; wks, weeks; No., number; NS, not specified; Sn, per-lesion sensitivity. Sp, per-case specificity

summative (at the end of the course) format; one tested only on partial datasets that is, isolated colonic segments;¹³ while most studies (84%; 16/19) used a combination of normal and abnormal cases.

CTC Training Literature: Effect on Reader Diagnostic Accuracy

Post-training per-lesion sensitivity for ≥ 6 mm lesions varied widely between studies, from 51%, up to 100%,^{16,17,24} and can be attributed to differing sample sizes (number of readers, test cases and lesions), reader experience and difficulty of the lesions selected for testing. Generally, studies which included 'hard-to-detect' lesions (eg, those assessing the impact of CAD on radiologist interpretation, or recruiting experienced readers being trained on subtle cases) observed lower sensitivities compared to those that did not.^{2,9,11,17} All studies where pre- and post-training assessments were administered observed a significant improvement in reader sensitivity,^{2,12,15,16,20,23,25} except 2.^{10,13}

The impact of training on specificity was varied, with some studies reporting reduced specificity after training.^{2,15} Other studies found an improvement in specificity as reader experience increased;^{8,10,25} one study observed a trend towards improving specificity in the 12 months after training, implying a gradual improvement in lesion characterisation.²

Discussion

CT colonography (CTC) is highly sensitive for large (≥ 10 mm) polyps and colorectal cancers and has good sensitivity for 6 to 9 mm polyps.²⁶ Accurate interpretation of these studies in routine clinical practice is essential if the outstanding diagnostic accuracy demonstrated in research studies is to be translated to the real world. Earlier CTC training studies advocated focusing on a minimum number of CTC cases read prior to independent reporting; however, simple case review, even with endoscopic correlation, does not necessarily lead to improved sensitivity, as the same errors may be perpetuated.¹⁰ Accumulation of CTC caseload has a differing effect on reader sensitivity, with a third of readers not reaching competency even after reviewing 175 CTC cases.¹² Studies which have focused on delivering feedback to readers, with or without specific individualized training, have observed significant gains in reader sensitivity.^{2,8,9,25} Therefore, the development of expertise requires training and feedback in addition to clinical experience.²⁷

In this study, we found that various institutions globally have provided recommendations for radiologist training prior to independent practice, but these recommendations are highly variable. The minimum number of cases varies from >50 to (under ideal circumstances) >300 , with limited detail regarding what these cases should be composed of, other than that they should be validated endoscopically (or via surgery). This heterogeneity in recommendations is perhaps due to the relatively small number of published articles

investigating the topic of CTC reader training. Our literature review identified only 19 such articles, with variable study designs and training interventions.

Although, in general, reader training was associated with superior detection rates, several early studies found no effect on reader sensitivity.^{10,13} Larger, more recent studies which focused on a broad selection of relevant cases and careful targeted feedback to those undergoing training have shown greater benefits.^{2,12,25} Several studies have shown a considerable difference in pre-training ability to interpret CTC; Here-sbach et al.¹¹ found that the best predictor of final accuracy was initial reader sensitivity at the start of training, and Liedenbaum et al.¹² found that some readers were unable to achieve adequate diagnostic accuracy despite prolonged training. The number of cases to which a reader is exposed is only a single facet of training, and a combination of an individual's aptitude, CTC case mix, training and feedback methods are all important to maximize performance. Generally, although specificity may reduce immediately after training, this tended to improve over time as skills of lesion characterization are being developed and refined.

In summary, we found considerable variability in national and international guidance recommendations for CTC training prior to independent practice. The published literature shows there is a clear benefit of training, which can be maximized through individualization and reader feedback. Optimizing reader training in CTC will require a more sophisticated program that should ideally be standardized to ensure all those learning how to interpret CTC can achieve the high accuracy that the technique has obtained in research trials.

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