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Effect of a tele-training programme on radiographers in the interpretation of CT colonography

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Objective: To assess the performance of radiographers in CT colonography (CTC) after a tele-training programme, supervised by 2 experienced radiologists.

Materials and methods: Five radiographers underwent training in CTC using a tele-training programme mainly based on the interpretation of 75 training cases performed in the novice department. To evaluate the educational performance, each radiographer was tested on 20 test cases with 27 lesions ≥6 mm (12: 6–9 mm; 15: >10 mm). Sensitivity, specificity and PPV for polyps ≥6 mm and ≥10 mm were calculated with point estimates and 95% confidence interval (95% CI). The results were compared by comparing 95% CI with a 5% significance level.

Results: In the training cases overall per-polyp sensitivity was 57% (95% CI 46.1–67.9) and 69.1% (95% CI 50.6–87.5) for lesions ≥6 mm and ≥10 mm, respectively. Overall per patient sensitivity, specificity and PPV were 86.4% (95% CI 76.7–96.1), 85.4% (95% CI 77–93.9) and 78.3% (95% CI 64.9–91.7), respectively.

In the test cases overall per-polyp sensitivity was 80.7% (95% CI 69.5–92) and 94.7% (95% CI 85.6–100) for lesions ≥6 mm and ≥10 mm, respectively. Overal per patient sensitivity, specificity and PPV were 92.9% (95% CI 83.1–100), 64% (95% CI 13.1–100) and 87.8% (95% CI 71.7–100), respectively. There was a statistically significant improvement in per-polyp sensitivity for lesions ≥6 mm in the test cases. No statistically significant differences were found in per patient sensitivity, specificity and PPV, but there was an improvement.

Conclusion: This training programme based on tele-training obtained good performance of radiographers in detecting tumoral lesions in CTC.

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1. Introduction

CT colonography (CTC) has now reached a high performance level in detecting tumoral lesions in the colon. Indeed, several large trials could demonstrate very good results of polyp detection [1–4]. These good results are only obtained if state-of-the-art technique and interpretation are applied by experienced teams being adequately trained in CTC. All experts [5–7] agree that this adequacy level is hard to reach, as CTC has a long and steep learning curve. This was demonstrated in the large trial performed by Rockey et al. [8]. Indeed, a review of this trial showed that technical failure and observer perceptual errors were by far the major cause of false negative results [9]. Whereas training in the practical aspects seems straightforward, only needing some short theoretical training and practical demonstration, acquiring sufficient experience and confidence in CTC interpretation is a rather arduous task. To date numerous efforts are being made to build up an efficient CTC training programme.

Furthermore, despite good sensitivity for polyp detection using state-of-the-art CTC technique, the recent ACRIN 6664 trial [3] was inflicted with positive predictive values as low as 40% and 23% for polyps ≥6 mm and ≥10 mm, respectively, indicative of a high false positive rate. Hence, improving CTC technique and interpretation through adequate training is deemed mandatory.

The combination of interpreting 50–75 cases validated by optical colonoscopy (OC) with the participation in a hands-on CTC workshop is considered a solid basis for starting to read CTC exams [10,11].
It is generally accepted [12] that the training process can be improved by augmenting the interaction with and feedback from the teachers. This type of mentored training has been proposed in the ACR Colon Cancer Committee’s white paper [10].

Tele-training or tele-medicine, which is now widely available and easy to apply, could be a promising companion in achieving these goals [13].

Likewise, this premise makes the establishment of a structured CTC education a priority and yet induces additional problems. Population-based training for colorectal cancer would encompass a large number of radiologists participating in the screening process possibly increasing their workload to unacceptable levels.

It may be supposed that a reduction of radiologist hours and costs could probably be accomplished by working with a team of radiographers supervised by one radiologist. With a sufficient level of experience for the radiographers, the interpretation time for the radiologist can be reduced significantly with the ultimate goal being the radiologist only checking the findings of the radiographers. This would allow supervision and validation of a substantial daily number of examinations per radiologist, reducing the total number of staff radiologists needed for population-based screening.

Keeping this in mind the purpose of this study was to assess the efficacy of radiographers interpreting CTC after a tele-radiology based training.

2. Materials and methods

The study was started in May 2008 and ended in October 2009. An IRB approval was not needed according to the Committees on Biomedical Research Ethics in Denmark. The study was granted by Metropolitan University College (DK), University College North Jylland (DK), Odense University Hospital (DK), Copenhagen University Hospital Herlev (DK) and the Danish Association of Radiographers.

2.1. Radiographers and tutors

Five radiographers (1 male, 4 females) participated in this study on a voluntary basis. Their age varied between 30 and 59 (mean age 50 years). They had no experience with CTC, and only very basic experience with colonic anatomy and pathology. They had practical experience with numerous abdominal CT and Barium enema examinations. CTC training of the radiographers was performed by two expert radiologists with an experience of ≥6000 CTC (with ≥800 validated by optical colonoscopy) and with great experience with the organisation of CTC-workshops. This training exclusively focused on the colon and did not consider the extracolonic structures.

2.2. Training

The training programme consisted of different stages:

2.2.1. Workshop

A 3-day workshop was organized in the teaching centre introducing the radiographers to CTC and to the normal and pathological conditions in the colon. The workshop consisted of a mix of theoretical presentations dealing with all technical and interpretational aspects of CTC and hands-on sessions. In total, 50 CTC cases were interpreted.

2.2.2. Reading material

After the workshop, a book on CTC was administered to the radiographers to refine the knowledge and experience obtained during the workshop. A CTC course was also available on the website of the teaching centre. This web-course focused on CTC imaging characteristics from normal to pitfalls. The web-course was concluded by a large Q/A section.

2.2.3. Training cases

75 randomly selected cases performed after incomplete colonoscopy in the local department were used for further training. The cases were interpreted by the radiographers at a rate of four cases/two weeks in a period of 34 weeks (holidays excluded) between July 2008 and June 2009. The use of CAD (computer aided detection) was not allowed. Colorectal polyps ≥6 mm were reported and classified in two size categories (≥6 mm and ≥10 mm). Tumours were included in the calculations and analysed as polyps, but were described separately as well. The C-RADS classification was used [14].

All observers read the examinations independently and were blinded to all clinical findings, the colonoscopic results and each other’s findings.

Image processing and interpretation in the novice department were performed with the use of a CT-workstation (Extended Brilliance workspace 3.5, Philips, The Netherlands) provided with dedicated CTC software and allowing primary two-dimensional and three dimensional reading of the colon.

During this tele-training, all observers continued their normal professional activity and interpreted the examinations during their spare time. Due to technical limitations of the workstation, simultaneous projection of the supine and prone acquisition, allowing fast comparison between both acquisitions, was impossible. Polyps were measured with electronic calipers on the two dimensional view and recorded according to the segment (cecum, ascending colon, transverse colon, descending colon, sigmoid colon or rectum).

Per polyp detected, the radiographers annotated the segmental location, the size, the attenuation, the slice numbers per acquisition, and the distance to the anal margin of the polyp in a report including a snapshot per polyp.

The anonymized examinations were sent in DICOM format to the teaching centre using secured ultrafast lines for interpretation by both experts. The experts interpreted the cases on a Vitrea workstation (Vital Images, Minnetonka, USA) and made a report based upon consensus reading. The results from the two experts were considered as the gold standard except for parts of the colon where optical colonoscopy (OC) was performed.

All CTCs were performed after incomplete OC. The reports from the radiographers were corrected by one of the experts and returned with comments. There was an active communication via e-mail for answering questions concerning CTC and the examinations at regular intervals, group discussions were performed via tele-conference. The use of CAD was not allowed.

2.2.4. Test cases

Finally, the radiographers underwent a test of 20 cases validated by optical colonoscopy. This test was composed by the teaching centre. These cases were sent in DICOM format to the novice department using secured ultrafast lines allowing for interpretation of the cases on the local workstation.

The test consisted of five normal cases and 15 cases with colonic polyps.

There were a total of 27 polyps ≥6 mm with 12 and 15 polyps 6–9 mm and ≥10 mm, respectively. According to the C-RADS classification, 10 polyps had a sessile morphology, 11 were pedunculated, three were flat polyps, and three were masses with malignant characteristics. There was one lipoma.

All the cases were interpreted by the radiographers at a rate of four cases/two weeks in a period of 10 weeks (holidays excluded).

between August 2009 and October 2009. The use of CAD was not allowed. The interpretation and reporting was performed the same way as the training cases mentioned above.

The outcome measure of the test was to achieve a per-polyp sensitivity per radiographer at 80% for polyps ≥6 mm.

2.3. Statistical analysis

Sensitivity, specificity, and PPV were evaluated by means of point estimates and respective 95% confidence intervals (95% CI). The results were given both on patient basis and on polyp basis, stratified according to the respective size categories, i.e. polyps ≥6 mm and ≥10 mm, respectively. Assuming a prevalence of 33% and a true (but unknown) sensitivity on per patient-basis of 0.85, 75 patients included in the study were sufficient for an expected width of a 95% Wilson-score confidence interval of 0.27. The success criterion for the single reader is an estimated per patient sensitivity of at least 0.8. For per polyp-based analyses, bootstrapping [15] was applied as supplementary sensitivity analysis (results not shown here). For polyp-based analyses as well as for average reader analyses on patient-basis, linear regression models were used with the constant term as only explanatory variable and clustered sandwich estimators of variance to allow for intra group correlation (due to several polyps in the same patient) Confidence intervals which emanate from these linear regression models are Wald-type confidence intervals. These may exceed the boundaries of 0% or 100%, and were therefore truncated and indexed with an asterisk where required. Patient-based analyses by reader were carried out by means of 95% CI based on the Wilson-score method [16]. Group comparisons were performed by comparing the respective 95% confidence intervals, hence, significance level was 5%.

All results were kept on a worksheet (Microsoft Excel version 2007, Microsoft Corporation, Redmond, Wash., USA) and analysed by using Stata 11 (StataCorp, TX 77845, USA).

3. Results

3.1. Training cases

The training cases presented 69 polyps ≥6 mm, with 47 and 22 polyps 6–9 mm and ≥10 mm, respectively. Nine cases were excluded and considered as inadequate exams due to insufficient distension or incomplete preparation. The polyps were detected in 25 of 66 patients (39.4%).

Two colorectal carcinomas were detected and were categorized as polyps ≥10 mm. Overall per-polyp sensitivity was 57.0% (95% CI 46.1–67.9) and 69.1% (95% CI 50.6–87.5) for polyps ≥6 mm and ≥10 mm, respectively. Individual per-polyp sensitivity with 95% CI is shown in Fig. 1 and ranged between 54.7% and 61.7% and between 61.1% and 78.9% for polyps ≥6 mm and ≥10 mm, respectively.

The overall per-polyp sensitivity analysis for polyps ≥6 mm and ≥10 mm using bootstrapping was 56.3% (95% CI 37.2–76.1) and 69.1% (95% CI 33.3–100), respectively.

Overall per-patient sensitivity was 86.4% (95% CI 76.7–96.1) for polyps ≥6 mm. Individual per patient sensitivity with 95% CI is shown in Fig. 2a and ranged between 76.0% and 92.0% for polyps ≥6 mm.

Overall per-patient specificity was 85.4% (95% CI 77.0–93.9) for polyps ≥6 mm. Individual specificity with 95% CI is shown in Fig. 2b and ranged between 75.6% and 90.2%.

Overall per-patient PPV was 78.3% (95% CI 64.9–91.7) for polyps ≥6 mm. Individual PPV with 95% CI is shown in Fig. 3 and ranged between 68.8% and 84.6%.

3.2. Test cases

Overall per-polyp sensitivity was 80.7% (95% CI 69.5–92.0) and 94.7% (95% CI 85.6–100) for polyps ≥6 mm and ≥10 mm, respectively. Individual per-polyp sensitivity with 95% CI is shown in Fig. 4 and ranged between 77.8% and 85.2% and between 93.3% and 100% for polyps ≥6 mm and ≥10 mm, respectively.

Compared to the training cases, there was a statistically significant improvement of sensitivity for polyps ≥6 mm in the test cases, since the respective confidence intervals did not overlap (Figs. 1 and 4).

The overall per-polyp sensitivity analysis for polyps ≥6 mm and ≥10 mm using bootstrapping was 86.4% (95% CI 73.5–96.9) and 95.8% (95% CI 87.0–100), respectively. The bootstrapping analysis of the data from the training cases for per-polyp sensitivity did not show any important difference.

Overall per-patient sensitivity was 92.9% (95% CI 83.1–100) for polyps ≥6 mm. Individual per-patient sensitivity with 95% CI is shown in Fig. 5a and ranged between 92.9% and 100%.

No significant difference in sensitivity was observed on a per-patient basis between the training cases and the test cases (Figs. 2a and 5a).

Overall specificity was 64.0% (95% CI 13.1–100) for polyps ≥6 mm. Individual specificity with 95% CI is shown in Fig. 5b and ranged between 40% and 100%.

In the overall specificity was higher in the training cases compared to the test cases (Figs. 2b and 5b).
This difference of specificity was probably due to the fact that the radiographers were more focused on finding polyps in the test cases, and due the low number of negative cases in the test.

Overall per-patient PPV was 87.8% (95% CI 71.7–100\%\times) for polyps ≥6 mm. Individual per-patient PPV with 95% CI for polyps is shown in Fig. 6 and ranged between 81.3% and 100%.

This high level of PPV on a per patient basis indicated a low number of false positives in the test cases compared to the training cases, however the difference is not statistically significant (Figs. 3 and 6).

All readers detected the three colorectal cancers.

4. Discussion

Using a tele-training programme, five radiographers were successfully educated in CTC. After initial training, good sensitivity and PPV for polyps ≥6 mm were obtained in a test with statistically significant improvement for sensitivity compared to the training cases. The training focused on both FN and FP findings. This was achieved by combining a workshop, reading material and interpretation of 75 cases. During this training period the radiographers could rely on the mentorship of two experienced CTC readers.

Compared to other studies this training method obtained good results. Jensch et al. [17] trained two radiographers with 20 cases with feedback. In 145 patients per-polyp sensitivity was 65% and 66% for polyps ≥6 mm and ≥10 mm, respectively. PPV was 37.5% and 59.5% for polyps ≥6 mm and ≥10 mm, respectively.
ESGAR CTC study [18], 10 radiographers without any previous experience were trained in 50 cases. In a test of 40 cases, per-polymp sensitivity was 63.5% after exclusion of six cases, where it was difficult to detect lesions. In another study, Burling et al. [19] obtained a per-polymp sensitivity of 76% for polyps $\geq 6$ mm with five radiographers. PPV for cancer was 74%. Bodily et al. [20] trained two radiographers with teaching files. One file provided the basic imaging characteristics of colonic lesions and imaging pitfalls. The second file consisted of interpreting 50 CTC cases. At the end they were tested on 56 cases. This test was repeated after six weeks of performing second reads. After this period of additional training, results improved from 61% to 79.5% for polyps $\geq 5$ mm. These results are comparable to the results of the present study and probably confirm the efficacy of this education method.

Training in detecting polyps in a well distended colon could appear straightforward. Indeed, once a basic level of experience is reached and sufficient knowledge concerning pathologic conditions in the colon has been acquired, one would expect an adequate observer performance. However, several studies have shown that a basic experience does not guarantee performance in polyp detection [21,22]. Firstly, numerous errors of interpretation causing FN are made [23,24]. Secondly, erroneous characterization of luminal defects may result in disappointing PPV. This was demonstrated in the ACRIN trial (3) with a PPV of 40% and 23% for polyps $\geq 6$ mm and $\geq 10$ mm, respectively. Interpretation errors are not only caused by lacking experience in interpretation. Frequently, technical inadequacy is a major source of error as was the case in the Rockey trial with 26% of important lesions missed due to technical shortcomings in colonic preparation and distension (8). From this it has been learned that state-of-the-art application of CTC is mandatory [25].

This concept of good CTC technique was learned when interpreting the 75 training cases. We preferred not to use a predefined teaching file of 75 cases, as was done by Dachman et al. [6], but deliberately chose cases coming out of clinical practice performed in the novice centre. With nine out of 75 examinations considered inadequate for interpretation, we were able to show that state-of-the-art application of CTC technique needs special attention during CTC implementation in a novice centre. This approach also added a real time aspect to the training as the teachers were faced with unexpected problems enabling the novices to assess how they solved particular problems.

This training method based on mentored supervision with tele-training had some advantages. It allowed for continuous guidance during the training period and could be considered a virtual fellowship. The radiographers could compare their findings with the reports of the experienced CTC-readers. Feedback via e-mail and/or tele-conferences provided a continuous source of information. In that way, the radiographers not only learned the importance of good CTC technique, they were most of all faced with their own interpretational errors. During the group meetings each case was reviewed and an explanation was provided when a lesion was overlooked or incorrectly interpreted. This type of mentored supervision has been considered important for CTC-training in the White Paper on CTC published by the ACR colon cancer committee [10]. Tele-training also allowed the radiographers to integrate the training in normal daily activity and learning the technique on their own workstation. Finally, it can be expected that this mentored training would also be helpful for radiologists.

To our knowledge this is the first study assessing the effect of a mentored training performed with tele-education over several months. This method could be improved by organizing webinars for learning the basic CTC principles. The use of tele-radiology also allowed for fast and efficient communication with the experts and allowed the radiographers to learn the technique on their own workstation.
What was the rationale for educating radiographers? A team of radiographers under supervision of one radiologist could be helpful when screening for colorectal cancer, as this approach would reduce radiologist time and the procedural costs. Furthermore, it would also allow for double reading which has been proven to increase performance [10].

This training method had limitations. Firstly, the radiographers were tested on only 20 cases with a total of 27 polyps >6 mm. However the same number of cases was also used for testing the participants at the ACRIN trial [26].

This means that they were more alert for polyp detection compared to a screening setting with low disease prevalence. Together with a low number of normal cases, this probably explains the low specificity. Secondly, the gold standard for the training cases was the report after consensus reading by two CTC experts. This could have resulted in some false negative and false positive findings. However, this avoided the necessity of validating each CTC by optical colonoscopy and hence examining patients twice. Furthermore, the test cases had optical colonoscopy as ground truth. As mentioned above, we used clinical cases for CTC-training. A predefined set of CTC examinations would enable improved monitoring with assessment of progress in performance. This was not possible in this study, as the last 20 cases were presented with only two polyps.

Finally, the training was performed over a considerable time span of 34 weeks. This long period is probably not favourable for a focused assessment of progress in performance. This was not possible in this study, as the last 20 cases were presented with only two polyps. These results cannot be generalized because of the low number of radiographers educated. Further studies are required to prove this.

In conclusion, this training in CTC based on tele-training proved successful and could be a useful method in training radiographers in CTC.

Conflicts of interest

There are no conflicts of interest.

References