Optimizing Computer Aided Detection for CT Colonography: Understanding Stand Alone Software Accuracy

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Learning objectives

• To demonstrate the critical detection and classification parameters for CTC CAD and apply them to a cohort of proven cases
• We emphasize the importance of rigorous definition of truth and correlation with polyp morphology, histopathology and size
Background

- CAD for CT Colonography (CTC or virtual colonoscopy) has been investigated as a way to improve reader performance, in particular to reduce errors of omission and accelerate learning.
- CAD provides locations of suspicious regions, and/or quantitative analysis of these regions.
- Several CAD programs have been developed and some have undergone observer testing.
- Each CAD program has a unique polyp detection rate, false-positive rate, and display of the CAD output.
- Stand alone performance means analysis of how well the software finds the polyps (i.e., no human blinded reading of the case).
Imaging findings OR Procedure details

Expected Benefits of CAD

• Improve lesion detection/diagnosis
• Increase sensitivity and specificity
• Decrease inter- and intra-reader variability
• Improve confidence of interpretation
• Improve productivity - Read more cases without significantly increasing interpretation time and potentially reduce reading time for some
• Reliable polyp measurement for follow up

Application to a case cohort

• Main aim: To determine by polyp sensitivity for 6-9 mm and > 10 mm polyps and average number of false-positive (FP) marks per view
• Secondary aims: Determine by polyp true positive (TP) rate stratified by polyp morphology and histology; Determine by patient sensitivity at the > 6 mm and > 10 mm thresholds

Truthing process

• A rigorous truthing process was used.
• 5 experts performed truthing using 3D+2D (500 case experience and involved in either CTC research and/or education)
• Truthing radiologists were unblinded to all data and finalized classification of each case as positive, negative or excluded from the study
• Established ground truth for localization of polyps and polyp morphology (sessile, pedunculated or flat)
• Designated largest linear dimension of the polyp on CTC
• Initial independent review by 2 of 5 radiologists
• 3rd radiologist arbitrated in few cases with disagreement.
• Majority opinion considered truth

Additional Truther Analysis

• All CAD TPs verified visually by a truthing radiologist
• Assessment of CAD FP marks was performed in 50 cases (25 positive, 25 negative)
• Judge whether hit may actually be a TP or is clearly a FP and search for potential cause of FP (e.g. colonic fold, stool, ICV, small bump < 6 mm, or other causes)
• Polyp candidate deemed a FP hit was rated on a 3-point scale whether it was easy, moderate or hard to dismiss by a reader

Patient Population
CTCs of 355 patients from three institutions
Average age of selected patients was 58.7 years (range 27-95)
197 male and 149 female
All patients had screening supine & prone CTC with saline cathartic prep, oral contrast for fluid and stool tagging, and insufflation with room air.
171 patients had no polyps 6mm or larger confirmed at truthing

Positive patient Characteristics
- CTCs from 184 patients had polyps 6mm or larger confirmed by at least 2 out of 3 highly experienced truthing radiologists
- 112 patients with small (6-9 mm) polyps
- 72 patients with large (≥ 10 mm) polyps
- 107 patients with adenomas

Polyp Characteristics
- 76 small and 59 large adenomatous polyps
- 179 small polyps
- 92 large polyps
- Polyps ranged in size from 6 - 51 mm
- 180 sessile polyps
- 51 pedunculated polyps
- 36 flat polyps
- 4 masses

Results
- Sensitivity of polyp detection by CAD without a radiologist was assessed in 184 patients with 271 polyps 6-51mm or larger in size, including 135 adenomas in 107 patients.
- Sensitivity was calculated by patient and by polyp stratified by size, morphology and histology.
- The average number of false-positive CAD marks (FP rate) was calculated in all 355 patients.
- By patient CAD sensitivity was 92% (169/184) for all polyps ≥ 6 mm (95% CI [88%, 96%]), 90% (101/112) for polyps 6-9 mm and 94% (68/72) for polyps ≥ 10 mm.
- Per-polyp CAD sensitivity was 86% (234/271) for all polyps ≥ 6 mm, 85% (153/179) for polyps 6-9 mm, and 88% (81/92) for polyps ≥ 10 mm.
- Per-polyp CAD sensitivity was 88% (119/135) for all adenomas 6mm or larger, 84% (64/76) for adenomas 6-9 mm, and 93% (55/59) for adenomas ≥ 10 mm.
- Per-polyp CAD sensitivity was 90% (162/180) for sessile polyps, 90% (46/51) for pedunculated polyps, and 64% (23/36) for flat polyps.
- Average CAD FP rate was 4.6 FPs/series for all 355 patients.
Images for this section:

![Diagram](image)

**Fig. 0:** A Step wise depiction of image processing by CAD

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Fig. 0: Characterization of Colonic Lumen by Shape Index
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Fig. 0: Examples of Polyps color-coded by CAD 2D axial and 3D colorized endoluminal images (arrow = polyp)
**Fig. 0:** Reducing CAD False Positives: How does the computer tell a fold (linear) from a polyp (round)? One Method: Gradient Concentration of HU density
**Fig. 0:** Additional methods: three-dimensional (3D) massive-training artificial neural network (MTANN) reduced FPs from rectal tubes and other artifacts

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**Fig. 0:** CAD System

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**Fig. 0:** The "Truther's Job" - Truther determines what is really a polyp
<table>
<thead>
<tr>
<th>Case</th>
<th>Exam Polyp Detected</th>
<th>Directed CTC Read</th>
<th>Full CTC Read</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive</td>
<td>CTC and OC</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Positive</td>
<td>OC only</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Positive</td>
<td>CTC only (and no OC performed)</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Negative</td>
<td>N/A</td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

**Fig. 0:** Truthing of Cases Contributed Prior to Commencing the Trial
Full read = 2 experts read entire case. Directed read = confirm presence, location and size of polyps

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**Fig. 0:** Folds and stool are the most common FPs

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**Fig. 0:** Examples of CAD False Positives: Flexural pseudotumor (left) and stool (right)

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**Fig. 0:** Impact of CAD FPs: Subjective Grading (based on time to dismiss the FP. N=90 FPs). 88% of the "difficult" FPs due to solid stool
Fig. 0: FROC Curve for Polyp-Level Sensitivity
Fig. 0: FROC Curve for Patient-Level Sensitivity

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Conclusion

- Each CAD software has a unique performance profile
- In developing and testing CAD, expert readers must rigorously define "truth" by identifying all pixels containing polyp
- CAD system performs at a level of high stand-alone sensitivity and specificity when tested in a large diverse case cohort
References


