

CT COLONOGRAPHY RECOMMENDED READING LIST

Bibliographies

- 1: **Pickhardt et al.** *Small and diminutive polyps detected at screening CT colonography: a decision analysis for referral to colonoscopy.* AJR Am J Roentgenol. 2008 Jan; 190(1):136-44.
- 2: **Pickhardt et al.** *Primary 2D versus primary 3D polyp detection at screening CT colonography.* AJR Am J Roentgenol. 2007 Dec; 189(6):1451-6.
- 3: **Knechtges et al.** *National and local trends in CT colonography reimbursement: past, present, and future.* J Am Coll Radiol. 2007 Nov; 4(11):776-99. Review.
- 4: **Kim DH, et al.** *CT colonography versus colonoscopy for the detection of advanced neoplasia.* N Engl J Med. 2007 Oct 4; 357(14):1403-12.
- 5: **Rockey et al.** *Standards for gastroenterologists for performing and interpreting diagnostic computed tomographic colonography.* Gastroenterology. 2007 Sep; 133(3):1005-24. No abstract available.
- 6: **Pickhardt PJ.** *Screening CT colonography: how I do it.* AJR Am J Roentgenol. 2007 Aug; 189(2):290-8.
- 7: **Copel et al.** *CT colonography in 546 patients with incomplete colonoscopy.* Radiology. 2007 Aug; 244(2):471-8.
- 8: **Dachman et al.** *CT colonography: visualization methods, interpretation, and pitfalls.* Radiol Clin North Am. 2007 Mar; 45(2):347-59. Review.
- 9: **Friedman et al.** *AGA position statement of computed tomographic colonography.* Gastroenterology. 2007 Apr; 132(4):1632-3; author reply 1633. No abstract available.
- 10: **Fajardo et al.** *Business plan to establish a CT colonography service.* J Am Coll Radiol. 2006 Mar; 3(3):175-86. Review.
- 11: **Iafrate et al.** *Spectrum of normal findings, anatomic variants and pathology of ileocecal valve: CT colonography appearances and endoscopic correlation.* Abdom Imaging. 2007 Sep-Oct; 32(5):589-95.
- 12: **Kim et al.** *Characteristics of advanced adenomas detected at CT colonographic screening: implications for appropriate polyp size thresholds for polypectomy versus surveillance.* AJR Am J Roentgenol. 2007 Apr; 188(4):940-4.

- 13: **Zalis et al.** CT colonography reporting and data system: a consensus proposal. *Radiology*. 2005 Jul;236(1):3-9. Review. No abstract available.
- 14: **Levin et al.** *Screening and Surveillance for the Early Detection of Colorectal Cancer and Adenomatous Polyps, 2008: A Joint Guideline From the American Cancer Society, the US Multi-Society Task Force on Colorectal Cancer, and the American College of Radiology*. *CA Cancer J Clin*. 2008 Mar 5; [Epub ahead of print]
- 15: **Pickhardt et al.** Computed tomographic virtual colonoscopy to screen for colorectal neoplasia in asymptomatic adults. *N Engl J Med*. 2003 Dec 4;349(23):2191-200. Epub 2003 Dec 1.

Abstracts

1: AJR Am J Roentgenol. 2008 Jan;190(1):136-44.

Small and diminutive polyps detected at screening CT colonography: a decision analysis for referral to colonoscopy. Pickhardt PJ, Hassan C, Laghi A, Zullo A, Kim DH, Iafrate F, Morini S.

OBJECTIVE: The objective of this study was to assess the clinical and economic impact of colonoscopic referral for small and diminutive polyps detected at CT colonography (CTC) screening. **MATERIALS AND METHODS:** A decision analysis model was constructed incorporating the expected polyp distribution, advanced adenoma prevalence, colorectal cancer (CRC) risk, CTC performance, and costs related to CRC screening and treatment. The model conservatively assumed that CRC risk was independent of advanced adenoma size. The number of diminutive (< or = 5 mm), small (6-9 mm), and large (> or = 10 mm) CTC-detected polyps needed to be removed to detect one advanced adenoma or prevent one CRC over a 10-year time horizon was calculated. The cost-effectiveness of polypectomy was also assessed. **RESULTS:** The estimated 10-year CRC risk for unresected diminutive, small, and large polyps was 0.08%, 0.7%, and 15.7%, respectively. The number of diminutive, small, and large polyps needed to be removed to avoid leaving behind one advanced adenoma was 562, 71, and 2.5, respectively; similarly, 2,352, 297, and 10.7 polypectomies would be needed, respectively, to prevent one CRC over 10 years. The incremental cost-effectiveness ratio of removing all diminutive and small CTC-detected polyps was \$464,407 and \$59,015 per life-year gained, respectively. Polypectomy for large CTC-detected polyps yielded a cost-saving of \$151 per person screened. **CONCLUSION:** For diminutive polyps detected at CTC screening, the very low likelihood of advanced neoplasia and the high costs associated with polypectomy argue against colonoscopic referral, whereas removal of large CTC-detected polyps is highly effective. The yield of colonoscopic referral for small polyps is relatively low, suggesting that CTC surveillance may be a reasonable management option.

Publication Types: Evaluation Studies

2: AJR Am J Roentgenol. 2007 Dec;189(6):1451-6.

Primary 2D versus primary 3D polyp detection at screening CT colonography. Pickhardt PJ, Lee AD, Taylor AJ, Michel SJ, Winter TC, Shadid A, Meiners RJ, Chase PJ, Hinshaw JL, Williams JG, Prout TM, Husain SH, Kim DH.

OBJECTIVE: Disparate results from the existing large CT colonography (CTC) trials suggest that 2D polyp detection is less sensitive than 3D detection, but no direct evidence exists to support this claim. Our goal was to assess the sensitivity of primary 2D polyp detection with cases from the Department of Defense CTC screening trial and compare results with the primary 3D evaluation and previous 2D CTC trials. **MATERIALS AND METHODS:** Ten radiologists, blinded to polyp findings, retrospectively interpreted 730 consecutive colonoscopy-proven CTC cases in asymptomatic adults using a primary 2D approach, with 3D reserved for problem

solving. Primary 2D CTC performance was compared with the primary 3D CTC results from the original trial of 1,233 asymptomatic adults. The 10 2D reviewers were significantly more experienced in CTC interpretation (> 100 cases interpreted) than the six reviewers from the original 3D trial. **RESULTS:** Primary 2D CTC sensitivity for adenomas > or = 6 mm was 44.1% (56/127), compared with 85.7% (180/210) at 3D ($p < 0.001$). Sensitivity of 2D CTC for adenomas > or = 10 mm was 75.0% (27/36) compared with 92.2% (47/51) at 3D ($p = 0.027$). Similar sensitivity trends were seen for the by-patient analysis and for all polyps at the 6-mm and 10-mm thresholds. By-patient specificity for 2D evaluation at the 10-mm threshold was 98.1% (676/689), compared with 97.4% (1,131/1,161) at 3D evaluation ($p = 0.336$). **CONCLUSION:** Primary 2D CTC is less sensitive than primary 3D CTC for polyp detection in low-prevalence screening cohorts. The disappointing 2D sensitivity in this study was very similar to results obtained with primary 2D evaluation in previous CTC trials.

Publication Types: Comparative Study

3: J Am Coll Radiol. 2007 Nov;4(11):776-99.

National and local trends in CT colonography reimbursement: past, present, and future. Knechtges PM, McFarland BG, Keysor KJ, Duszak R Jr, Barish MA, Carlos RC.

Computed tomographic colonography (CTC) was first introduced in the mid-1990s as a minimally invasive technology for colorectal cancer screening. Given its potential to significantly change colorectal cancer screening practices in the United States, it has attracted widespread multidisciplinary interest among radiologists, gastroenterologists, colorectal surgeons, and primary care physicians. Because of its potential for widespread utilization and the potential associated costs, it has also attracted much scrutiny from payers. The authors discuss the coding and reimbursement history of CTC, outline strategies for obtaining local coverage for CTC, and attempt to outline some of the possible future influences on CTC reimbursement.

Publication Types: Review

4: N Engl J Med. 2007 Oct 4;357(14):1403-12.

CT colonography versus colonoscopy for the detection of advanced neoplasia. Kim DH, Pickhardt PJ, Taylor AJ, Leung WK, Winter TC, Hinshaw JL, Gopal DV, Reichelderfer M, Hsu RH, Pfau PR.

BACKGROUND: Advanced neoplasia represents the primary target for colorectal-cancer screening and prevention. We compared the diagnostic yield from parallel computed tomographic colonography (CTC) and optical colonoscopy (OC) screening programs. **METHODS:** We compared primary CTC screening in 3120 consecutive adults (mean [\pm SD] age, 57.0 \pm 7.2 years) with primary OC screening in 3163 consecutive adults (mean age, 58.1 \pm 7.8 years). The main outcome measures included the detection of advanced neoplasia (advanced adenomas and carcinomas)

and the total number of harvested polyps. Referral for polypectomy during OC was offered for all CTC-detected polyps of at least 6 mm in size. Patients with one or two small polyps (6 to 9 mm) also were offered the option of CTC surveillance. During primary OC, nearly all detected polyps were removed, regardless of size, according to established practice guidelines. **RESULTS:** During CTC and OC screening, 123 and 121 advanced neoplasms were found, including 14 and 4 invasive cancers, respectively. The referral rate for OC in the primary CTC screening group was 7.9% (246 of 3120 patients). Advanced neoplasia was confirmed in 100 of the 3120 patients in the CTC group (3.2%) and in 107 of the 3163 patients in the OC group (3.4%), not including 158 patients with 193 unresected CTC-detected polyps of 6 to 9 mm who were undergoing surveillance. The total numbers of polyps removed in the CTC and OC groups were 561 and 2434, respectively. There were seven colonic perforations in the OC group and none in the CTC group. **CONCLUSIONS:** Primary CTC and OC screening strategies resulted in similar detection rates for advanced neoplasia, although the numbers of polypectomies and complications were considerably smaller in the CTC group. These findings support the use of CTC as a primary screening test before therapeutic OC. Copyright 2007 Massachusetts Medical Society.

Publication Types: Comparative Study

5: Gastroenterology. 2007 Sep;133(3):1005-24.

Standards for gastroenterologists for performing and interpreting diagnostic computed tomographic colonography. Rockey DC, Barish M, Brill JV, Cash BD, Fletcher JG, Sharma P, Wani S, Wiersema MJ, Peterson LE, Conte J.

Publication Types: Guideline

6: AJR Am J Roentgenol. 2007 Aug;189(2):290-8.

Screening CT colonography: how I do it. Pickhardt PJ.

OBJECTIVE: The purpose of this article is to detail an approach to CT colonographic screening that has evolved at one institution. **CONCLUSION:** CT colonography is a rapidly advancing technology that has great potential for addressing a deadly but preventable disease-colorectal carcinoma. CT colonography is ideally suited for widespread screening of asymptomatic adults and has become an integral component of the screening efforts at my institution since local third-party coverage was initiated.

7: Radiology. 2007 Aug;244(2):471-8.

CT colonography in 546 patients with incomplete colonoscopy. Copel L, Sosna J, Kruskal JB, Raptopoulos V, Farrell RJ, Morrin MM.

PURPOSE: To retrospectively evaluate the positive predictive value (PPV) of computed tomographic (CT) colonography performed in patients who were referred for further examination after incomplete colonoscopy. **MATERIALS AND METHODS:** This HIPAA-compliant retrospective study was approved by the institutional review board; informed consent was waived. We identified 546 consecutive patients (mean age, 64.1 years; 401 [73.4%] women) who underwent CT colonography after incomplete colonoscopy between November 1999 and December 2002. A retrospective chart review was performed if CT colonography depicted endoscopically nonvisualized lesions 6 mm or greater in diameter. Repeat colonoscopy rate, endoluminal findings, and PPV of CT colonography were determined. Subsequent colonoscopic findings were used as the reference standard. **RESULTS:** In 72 (13.2%) patients, CT colonography depicted 88 endoscopically nonvisualized lesions 6 mm or greater. Of 11 patients reported to have 12 masses (> or =20 mm), at subsequent colonoscopy, one patient had no mass. Eighteen patients had 23 large (10-19-mm) polyps that they were suspected of having, and 47 patients had 53 medium (6-9-mm) polyps that they were suspected of having. At a median follow-up of 31 months (range, 6-42 months), 45 (63%) of 72 patients underwent follow-up colonoscopy because of their CT colonographic findings. Rates of repeat colonoscopy for masses, large polyps, and medium polyps were 100%, 94%, and 45%, respectively. Per-patient and per-lesion PPVs of CT colonography for masses, large polyps, and medium polyps were 90.9% and 91.7%, 64.7% and 70%, and 33.3% and 30.4%, respectively. **CONCLUSION:** CT colonography has the potential to become an accepted technique for evaluation of the nonvisualized part of the colon after incomplete colonoscopy, and it can increase the diagnostic yield of masses and clinically important polyps in this part of the colon.

8: Radiol Clin North Am. 2007 Mar;45(2):347-59.

CT colonography: visualization methods, interpretation, and pitfalls. Dachman AH, Lefere P, Gyspeerd S, Morin M.

Virtual colonoscopy interpretation is improving rapidly with the development of efficient software using two-dimensional, three-dimensional (3D) endoluminal, and 3D novel views such as those that seem to cut the colon open and lay it flat for interpretation. Comparison of these various views, comparisons of supine and prone positioning, and comparisons of lung and soft tissue windows aid in the recognition of various pitfalls of interpretation.

Publication Types: Research Support, Non-U.S. Gov't Review

9: Gastroenterology. 2007 Apr;132(4):1632-3; author reply 1633.

AGA position statement of computed tomographic colonography. Friedman A, Lance P.

Publication Types: Comment Letter

10: J Am Coll Radiol. 2006 Mar;3(3):175-86.

Business plan to establish a CT colonography service. Fajardo LL, Hurley JP, Brown BP, Summers RW, McDaniel RD Jr.

The authors describe the University Of Iowa Department Of Radiology's business planning process to initiate a new service in computed tomographic colonography (CTC). Also known as virtual colonoscopy, CTC is a noninvasive technology that offers less risk, and potentially similar sensitivity and specificity, than conventional optical colonoscopy (OC). Although not currently covered by all insurance payers, about a year ago, the Centers for Medicare and Medicaid Services instituted temporary Current Procedural Terminology codes (Category III) for CTC. In locales where the procedure is not covered by insurers, it is likely to be sought by patients willing to pay out of pocket to undergo noninvasive cancer screening as an alternative to OC. Thus, CTC could become the preferred method of colon cancer surveillance by insurance providers in the near future. In developing the business plan, the authors reviewed pertinent scientific and clinical data to evaluate the need for and efficacy of CTC. Local market data were used to estimate patient and procedure volumes and utilization. The authors modeled financial expectations with respect to return on investment on the basis of recently reported models specific to CTC, resource requirements, and the operational impact of the new service on existing hospital and departmental clinical functions. Because there are few local providers of CTC in the authors' region, the business plan also included a publicity campaign and plan to market the new service, stimulate general public interest early, and differentiate the program as a leader in applying this unique new technology to promote cancer screening. Finally, the planning committee acknowledged and accommodated needs specific to the missions of an academic medical center with respect to research and education in designing the new service.

Publication Types: Review

11: Abdom Imaging. 2007 Sep-Oct;32(5):589-95.

Spectrum of normal findings, anatomic variants and pathology of ileocecal valve: CT colonography appearances and endoscopic correlation. Iafrate F, Rengo M, Ferrari R, Paolantonio P, Celestre M, Laghi A.

Knowledge of the potential variants of ileocecal valve, the most frequent pathologic conditions as well as some pitfalls encountered during the analysis of CT Colonography images are thus indispensable for radiologists who perform and interpret such examinations and for general practitioners who are approaching this technique. Awareness of these different diagnostic possibilities is mandatory for radiologists evaluating CT Colonography datasets. Combined analysis of 2D axial and reformatted slices and 3D endoluminal views provides the highest level of diagnostic accuracy. We present the multidetector CT Colonography findings with endoscopic correlation and discuss the possible pathologies and the practical implications.

12: AJR Am J Roentgenol. 2007 Apr;188(4):940-4.

Characteristics of advanced adenomas detected at CT colonographic screening: implications for appropriate polyp size thresholds for polypectomy versus surveillance. Kim DH, Pickhardt PJ, Taylor AJ.

OBJECTIVE: Advanced adenomas are the primary target in colorectal screening. The purpose of this study was to delineate the prevalence and imaging characteristics of advanced adenomas detected at screening CT colonography (CTC) and the rates of invasive carcinoma and high-grade dysplasia for various polyp size categories. These observations may be a basis for formulation of polypectomy thresholds and CTC surveillance strategies. **MATERIALS AND METHODS:** The imaging and pathologic findings for polyps measuring 6 mm or more obtained from a CTC screening population of 3,536 persons during a 32-month period were retrospectively reviewed. From this group, prevalence, size, histologic features, morphologic features, and location of advanced adenomas were tabulated. Advanced adenomas were defined by size (> or = 10 mm) and/or histologic findings (prominent villous component or high-grade dysplasia). **RESULTS:** A total of 123 (38.3%) of 321 adenomas measuring 6 mm or more were classified as advanced, the overall prevalence being 3.1% (111 of 3,536 patients). The mean size of advanced adenomas was 16.6 +/- 11.6 mm; most of the lesions (116/123, 94.3%) qualified as advanced on the basis of the size criterion alone. The seven lesions measuring 6-9 mm constituted 3.4% (7/205) of all medium-sized adenomas. The largest percentage (65/123, 52.8%) of the advanced adenomas had tubular histologic features, followed by tubulovillous (50/123, 40.6%), villous (5/123, 4.1%), and serrated (3/123, 2.4%) histologic features. High-grade dysplasia was uncommon (6/123, 4.9%), typically occurring in large lesions. Seven cases of cancer were detected, all lesions measuring 10 mm or more in size. The majority of advanced adenomas were classified as sessile (57/123, 46.3%) or pedunculated (57/123, 46.3%); a small percentage were flat (9/123, 7.3%). Advanced adenomas were located in the proximal colon in 43.9% (54/123) and distal colon in 56.1% (69/123) of the cases. **CONCLUSION:** Advanced adenomas were generally large (> or = 10 mm in size); only a small percentage were medium sized (6-9 mm). There was a very low prevalence of high-grade dysplasia and invasive carcinoma in this series, particularly in the medium-sized group of lesions. These findings lend support to the practice of CTC screening in which large polyp size is used as a surrogate measure for the possible presence of advanced histologic features and medium-sized lesions are followed with noninvasive surveillance protocols.

14: CA Cancer J Clin. 2008 Mar 5

Screening and Surveillance for the Early Detection of Colorectal Cancer and Adenomatous Polyps, 2008: A Joint Guideline From the American Cancer Society, the US Multi-Society Task Force on Colorectal Cancer, and the American College of Radiology. Levin B, Lieberman DA, McFarland B, Andrews KS, Brooks D, Dash C, Giardiello FM, Glick S, Levin TR, Pickhardt PJ, Rex DK, Smith RA, Thorson A, Bond J, Johnson D, Johnson CD, Winawer SJ; American Cancer Society Colorectal Cancer Advisory Group, the US Multi-Society Task Force, and the American College of Radiology Colon Cancer Committee.

In the United States, colorectal cancer (CRC) is the third most common cancer diagnosed among men and women and the second leading cause of death from cancer. CRC largely can be prevented by the detection and removal of adenomatous polyps, and survival is significantly better when CRC is diagnosed while still localized. In 2006 to 2007, the American Cancer Society, the US Multi-Society Task Force on Colorectal Cancer, and the American College of Radiology came together to develop consensus guidelines for the detection of adenomatous polyps and CRC in asymptomatic average-risk adults. In this update of each organization's guidelines, screening tests are grouped into those that primarily detect cancer early and those that can detect cancer early and also can detect adenomatous polyps, thus providing a greater potential for prevention through polypectomy. When possible, clinicians should make patients aware of the full range of screening options, but at a minimum they should be prepared to offer patients a choice between a screening test that primarily is effective at early cancer detection and a screening test that is effective at both early cancer detection and cancer prevention through the detection and removal of polyps. It is the strong opinion of these 3 organizations that colon cancer prevention should be the primary goal of screening.

15. N Engl J Med. 2003 Dec 4;349(23):2191-200. Epub 2003 Dec 1.

Computed tomographic virtual colonoscopy to screen for colorectal neoplasia in asymptomatic adults. Pickhardt PJ, Choi JR, Hwang I, Butler JA, Puckett ML, Hildebrandt HA, Wong RK, Nugent PA, Mysliwiec PA, Schindler WR.

BACKGROUND: We evaluated the performance characteristics of computed tomographic (CT) virtual colonoscopy for the detection of colorectal neoplasia in an average-risk screening population. **METHODS:** A total of 1233 asymptomatic adults (mean age, 57.8 years) underwent same-day virtual and optical colonoscopy. Radiologists used the three-dimensional endoluminal display for the initial detection of polyps on CT virtual colonoscopy. For the initial examination of each colonic segment, the colonoscopists were unaware of the findings on virtual colonoscopy, which were revealed to them before any subsequent reexamination. The sensitivity and specificity of virtual colonoscopy and the sensitivity of optical colonoscopy were calculated with the use of the findings of the final, unblinded optical colonoscopy as the reference standard. **RESULTS:** The sensitivity of virtual colonoscopy for adenomatous polyps was 93.8 percent for polyps at least 10 mm in diameter, 93.9 percent for polyps at least 8 mm in diameter, and 88.7 percent for polyps at least 6 mm in diameter. The sensitivity of optical colonoscopy for adenomatous polyps was 87.5 percent, 91.5 percent, and 92.3 percent for the three sizes of polyps, respectively. The specificity of virtual colonoscopy for adenomatous polyps was 96.0 percent for polyps at least 10 mm in diameter, 92.2 percent for polyps at least 8 mm in diameter, and 79.6 percent for polyps at least 6 mm in diameter. Two polyps were malignant; both were detected on virtual colonoscopy, and one of them was missed on optical colonoscopy before the results on virtual colonoscopy were revealed. **CONCLUSIONS:** CT virtual colonoscopy with the use of a three-dimensional approach is an accurate screening method for the detection of colorectal neoplasia in asymptomatic average-risk adults and compares favorably

with optical colonoscopy in terms of the detection of clinically relevant lesions.
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Publication Types: Comparative Study; Evaluation Studies; Research Support, U.S.
Gov't, Non-P.H.S.