CT Colonography Reporting and Data System (C-RADS): Benchmark Values From a Clinical Screening Program

B. Dustin Pooler[1]
David H. Kim
Vu P. Lam
Elizabeth S. Burnside
Perry J. Pickhardt

OBJECTIVE. The CT Colonography Reporting and Data System (C-RADS) is a well-recognized standard for reporting findings at CT colonography (CTC). However, few data on benchmark values for clinical performance have been published to date, especially for screening. The purpose of this study was to establish baseline C-RADS values for CTC screening.

SUBJECTS AND METHODS. From 2005 to 2011, 6769 asymptomatic adults (3110 men and 3659 women) 50–79 years old (mean [± SD] age, 56.7 ± 6.1 years) were enrolled for first-time CTC screening at a single center. CTC results were prospectively classified according to C-RADS for both colorectal and extracolonic findings. C-RADS classification rates and outcomes for positive patients were analyzed.

RESULTS. C-RADS classification rates for colorectal evaluation were C0 (0.7%), C1 (85.0%), C2 (8.6%), C3 (5.2%), and C4 (0.6%). Overall, 14.3% of subjects were positive (C2–C4), and positive findings were more frequent among men (17.5%) than women (11.6%; $p < 0.0001$). Positivity also increased with age, from 13.4% of patients 50–64 years old to 21.8% of patients 65–79 years old ($p < 0.0001$). Regarding extracolonic evaluation, 86.6% of patients were either negative for extracolonic findings or had unimportant extracolonic findings (E1 or E2). Likely unimportant but indeterminate extracolonic findings where further workup might be indicated (E3) were found in 11.3% of patients, whereas 2.1% had likely important extracolonic findings (E4). Overall, E3 and E4 rates were increased for older ($p < 0.0001$) and female ($p = 0.008$) cohorts.

CONCLUSION. C-RADS results from our initial experience with CTC screening may serve as an initial benchmark for program comparison and quality assurance measures.

Keywords: C-RADS, colorectal cancer, CT colonography, screening, virtual colonoscopy

DOI:10.2214/AJR.13.11272

Received May 22, 2013; accepted after revision October 11, 2013.

Presented at the 2013 annual meeting of the ARRS, Washington, DC (recipient of the President's Award for Radiology Residents). This research was supported in part by the National Institutes of Health (National Cancer Institute grant 1R01CA144835-01).

[1]All authors: Department of Radiology, University of Wisconsin School of Medicine and Public Health, E3/311 Clinical Science Center, 600 Highland Ave, Madison, WI 53792-3252. Address correspondence to P. J. Pickhardt (ppickhardt2@uwhealth.org).

AJR 2014; 202:1232–1237

0361–803X/14/2026–1232

Standardized reporting systems for screening examinations promote quality and consistency in diagnostic performance and offer a means for providing quality improvement and enhanced patient care for clinical screening programs [1]. In addition, such systems facilitate reporting and communication of examination findings and allow appropriate triage of patients after screening. This has been well illustrated by the use of BI-RADS for breast cancer screening, and extensive research has shown the benefits of this construct [2, 3]. In 2005, the CT Colonography Reporting and Data System (C-RADS) was established [4] to provide a means of classifying findings of CT colonography (CTC) and of applying the advantages of structured reporting to the setting of colorectal cancer screening.

Since the initial publication of the C-RADS consensus proposal, C-RADS has become the standard for reporting of both colorectal and extracolonic findings at CTC and for classifying patients for the purposes of guiding management following screening. However, to date, there has been no large-scale study published to serve as a reference for the distribution of C-RADS categorization within a clinical screening program. We describe a large series of nearly 7000 patients undergoing first-time colorectal cancer screening with CTC at our single academic center who were prospectively categorized using C-RADS. Given the lack of large multicenter population-based data in the literature, the purpose of this study is to provide initial benchmark values for C-RADS classification scores that may be used by other screening programs for the purpose of comparison and generation of quality assurance measures.

Subjects and Methods

This HIPAA-compliant study was approved by our institutional review board. The need for signed informed consent was waived.

Patient Population

From January 2005 through December 2011, we enrolled 7288 consecutive individuals referred from general medical practice for first-time CTC examination for the purpose of colorectal cancer screening. To obtain a typical screening population without a significantly increased risk for colorectal cancer, we excluded patients with a history of colorectal cancer, inflammatory bowel disease, polyposis syndromes, and colorectal surgery, as well as patients referred from incomplete optical colonoscopy or with suspicion of symptomatic colorectal cancer. A total of 6769 asymptomatic patients met inclusion criteria and composed the screening CTC cohort.

CT Colonography Technique

The CTC technique used in our screening program has been described in detail elsewhere [5–8]. Briefly, patients undergo a bowel preparation protocol beginning 1 day before CTC consisting of complete colonic catharsis and tagging of residual material. The cathartic cleansing agent was sodium phosphate before 2008 and magnesium citrate thereafter; polyethylene glycol was substituted as needed in a minority of patients. Contrast material tagging of residual fluid and fecal material was achieved with 2.1% weight/volume barium and diatrizoate meglumine (Gastrografin, Bracco Diagnostics). During the CTC examination, colonic insufflation was achieved and maintained throughout image acquisition using automated continuous carbon dioxide delivered through a rectal catheter [9]. Patients were routinely scanned in both supine and prone positions, with decubitus positioning as needed [10]. Images were acquired with 8- to 64-MDCT scanners using 1.25-mm collimation, 1-mm reconstruction interval, 120 kVp, and either a fixed tube current–time product (50–75 mAs) or tube-current modulation (range, 30–300 mA).

C-RADS

All screening CTC examinations were interpreted by a board-certified radiologist within our abdominal imaging section. All examinations were prospectively classified using C-RADS for both colorectal and extracolonic findings. The specific criteria for the various colorectal ("C") and extracolonic ("E") categories are listed in Table 1. If there were multiple lesions (either colorectal or extracolonic), the examination was scored by the most advanced finding. In our practice, slight modifications from the original C-RADS document were made. There were no CTC examinations in our study awaiting prior comparison; thus, in our experience, C0 represents a true nondiagnostic examination. In a similar fashion, all examinations for which polyps 6 mm or larger could not be excluded were considered technically inadequate and were coded as C0; thus, all examinations coded as C2 were positive for nondiminutive polyps.

Individual polyps were identified using a combination of 3D reconstructions and 2D cross-sectional images; 3D renderings were used primarily for polyp detection (supplemented by 2D detection), and 2D images were used for confirmation in all cases [6, 11]. The maximum linear diameter (excluding the stalk, if pedunculated) of each polyp was measured in both 3D and 2D projections using electronic calipers [12]. The morphologic features (sessile, pedunculated, flat, mass, or submucosal or extrinsic) and segmental location (rectum, sigmoid, descending, transverse, ascending, or cecum) of each polyp were determined and recorded. Of note, the submucosal or extrinsic category is not explicitly described in the original C-RADS publication, but we have found this useful to describe some lesions. Furthermore, we categorize likely diverticular strictures with a masslike appearance as a benign C4 subcategory, because no C-RADS classification yet exists. For each polyp, a diagnostic confidence score of 1 (least confident) to 3 (most confident) was also recorded, as described in the text of the C-RADS publication [4] and elsewhere [13, 14]. For evaluation of extracolonic findings, 5 × 3-mm axial reconstructions of the supine series were primarily used, supplemented by the prone images as needed. The results of colonoscopy and polypectomy, as well as the final histologic result at pathologic analysis, were recorded for all patients undergoing polypectomy.

Criteria for colorectal classification by C-RADS are summarized in Table 1. Positive cases were defined as patients with a C-RADS score of C2 through C4. In accordance with C-RADS, patients with a score of C3 or C4 were referred for colonoscopy with polypectomy, whereas patients with a score of C2 were given the option of either colonoscopy with polypectomy or CTC polyp surveillance. Patients with a score of C1 were considered to have a negative examination and were recommended to un-

TABLE 1: Summary of CT Colonography Reporting and Data System Colorectal and Extracolonic Classification Scores

Score	Description
Colorectal	
C0, inadequate study	Inadequate preparation; inadequate insufflation
C1, normal colon or benign lesion	No polyp ≥ 6 mm; recommend routine screening with CT colonography or colonoscopy in 5 years
C2, intermediate polyp or indeterminate finding	Polyps 6–9 mm, < 3 in number; recommend CT colonography polyp surveillance or colonoscopy with polypectomy
C3, polyp, possibly advanced adenoma	Polyps ≥ 10 mm; ≥ 3 polyps, each 6–9 mm; recommend colonoscopy with polypectomy
C4, colorectal mass, likely malignant	Lesion compromises bowel lumen, shows extracolonic invasion; recommend surgical consultation
Extracolonic	
E0, limited examination	Compromised by artifact; evaluation of extracolonic tissues severely limited; not used in practice by our program
E1, normal examination or anatomic variant	No extracolonic abnormalities visible; no workup indicated
E2, clinically unimportant finding	Examples: simple liver or kidney cyst, cholelithiasis without cholecystitis; no workup indicated
E3, likely unimportant, incompletely characterized	Example: minimally complex or homogeneously hyperattenuating kidney cyst; workup may be indicated; dependent on specific clinical scenario
E4, potentially important finding	Examples: solid kidney mass, aortic aneurysm; workup generally indicated, but dependent on specific clinical scenario; communicate to referring physician as per accepted practice guidelines

Note—Table is based on data published elsewhere [4].

TABLE 2: CT Colonography Reporting and Data System Colorectal and Extracolonic Classification Distribution by Age and Sex

Classification Score	All Patients (50–79 Years Old)			Patients 50–64 Years Old			Patients 65–79 Years Old		
	Overall (*n* = 6769)	Men (*n* = 3110)	Women (*n* = 3659)	Overall (*n* = 6043)	Men (*n* = 2741)	Women (*n* = 3302)	Overall (*n* = 726)	Men (*n* = 369)	Women (*n* = 357)
Colorectal									
C0	49 (0.7)	22 (0.7)	27 (0.7)	41 (0.7)	17 (0.6)	24 (0.7)	8 (1.1)	5 (1.4)	3 (0.8)
C1	5751 (85.0)	2543 (81.8)	3208 (87.7)	5191 (85.9)	2274 (83.0)	2917 (88.3)	560 (77.1)	269 (72.9)	291 (81.5)
C2	579 (8.6)	323 (10.4)	256 (7.0)	508 (8.4)	279 (10.2)	229 (6.9)	71 (9.8)	44 (11.9)	27 (7.6)
C3	351 (5.2)	209 (6.7)	142 (3.9)	278 (4.6)	163 (5.9)	115 (3.5)	73 (10.1)	46 (12.5)	27 (7.6)
C4	39 (0.6)	13 (0.4)	26 (0.7)	25 (0.4)	8 (0.3)	17 (0.5)	14 (1.9)	5 (1.4)	9 (2.5)
Extracolonic									
E1	2416 (35.7)	1051 (33.8)	1365 (37.3)	2266 (37.5)	988 (36.0)	1278 (38.7)	150 (20.7)	63 (17.1)	87 (24.4)
E2	3445 (50.9)	1689 (54.3)	1756 (48.0)	3003 (49.7)	1455 (53.1)	1548 (46.9)	442 (60.9)	234 (63.4)	208 (58.3)
E3	764 (11.3)	305 (9.8)	459 (12.5)	660 (10.9)	252 (9.2)	408 (12.4)	104 (14.3)	53 (14.4)	51 (14.3)
E4	144 (2.1)	65 (2.1)	79 (2.2)	114 (1.9)	46 (1.7)	68 (2.1)	30 (4.1)	19 (5.1)	11 (3.1)

Note—Data are no. (%) of subjects.

dergo routine screening in 5 years. In our program, C0 was used exclusively to denote nondiagnostic examinations. The C-RADS criteria for classification of extracolonic findings are summarized in Table 1. It is important to note that, although categories E3 and E4 denote potentially significant extracolonic findings, further workup may or may not be indicated for a given patient and is dependent on a number of factors, including clinical scenario, previous diagnosis, and prior workup history [15].

Experience of Radiologists

CTC examinations were interpreted by one of 11 board-certified radiologists during the study interval (mean, 615 examinations; range, 37–2122 examinations). All radiologists were board certified with an average of 9 years in practice by the conclusion of the study (range, 2–31 years). Nine of the 11 radiologists had completed a fellowship in abdominal radiology, and six of those had dedicated instruction in CTC. Six of the 11 radiologists work solely in the subspecialty area of abdominal imaging, whereas five have a more general radiology practice.

Statistical Analysis

The Fisher exact test was used to test for differences in categoric variables. The Student *t* test and analysis of variance were used, where appropriate, to test for differences in continuous variables. Two-tailed $p < 0.05$ was used as the criterion for statistical significance.

Results

The mean (± SD) age of the population (n = 6769) was 56.7 ± 6.1 years, with a male-to-female ratio of 3110 (45.9%) to 3659 (54.1%). The overall positive rate at CTC in this first-time screening cohort was 14.3% (969/6769), with a negative rate of 85.0% (5751/6769) and a nondiagnostic rate of 0.7% (49/6769). The overall distribution of C-RADS scores was 0.7% C0 (49/6769), 85.0% C1 (5751/6769), 8.6% C2 (579/6769), 5.2% C3 (351/6769), and 0.6% C4 (39/6769) (Table 2). This led to an overall colonoscopy referral rate of 8.7% (587/6769), reflecting the fact that many patients in the C2 category opt for CTC surveillance. Of the 579 patients with C2 findings, 66.0% (382/579) initially chose CTC surveillance and the remain-

TABLE 3: Polyp Characteristics by Size

Characteristic	All Polyps (*n* = 1473)	Small (6–9 mm) (*n* = 1035)	Large (≥ 10 mm) (*n* = 438)
Polyp morphologic features			
Sessile	946 (64.2)	799 (77.2)	147 (33.6)
Pedunculated	244 (16.6)	91 (8.8)	153 (34.9)
Flat	227 (15.4)	145 (14.0)	82 (18.7)
Mass (all)	47 (3.2)	0 (0.0)	47 (10.7)
Mass (bulky or carpet)	40 (2.7)	0 (0.0)	40 (9.1)
Mass (benign stricture)	7 (0.5)	0 (0.0)	7 (1.6)
Submucosal or extrinsic	9 (0.6)	0 (0.0)	9 (2.1)
Polyp location			
Cecum	166 (11.3)	96 (9.3)	70 (16.0)
Ascending colon	291 (19.8)	190 (18.4)	101 (23.1)
Transverse colon	212 (14.4)	161 (15.6)	51 (11.6)
Descending colon	119 (8.1)	88 (8.5)	31 (7.1)
Sigmoid colon	453 (30.8)	334 (32.3)	119 (27.2)
Rectum	232 (15.8)	166 (16.0)	66 (15.1)
Diagnostic confidence			
3 (most)	1165 (79.1)	800 (77.3)	365 (83.3)
2 (somewhat)	272 (18.5)	211 (20.4)	61 (13.9)
1 (least)	36 (2.4)	24 (2.3)	12 (2.7)

Note—Data are no. (%) of polyps.

der (34.0% [197/579]) opted for immediate optical colonoscopy. Twelve patients (10 C3 and two C4) refused optical colonoscopy and were followed by CTC polyp surveillance. Of patients who proceeded to colonoscopy for polypectomy, 75.7% (435/575) of procedures occurred on the same day, without repeat bowel preparation.

In total, there were 1473 polyps detected in the 6769 patients (Table 3). Small polyps (6–9 mm in diameter) accounted for 70.3% (1035/1473) and large polyps (≥ 10 mm in diameter) accounted for 29.7% (438/1473). The breakdown of polyp morphologic features was 64.2% sessile (946/1473), 16.6% pedunculated (244/1473), 15.4% flat (227/1473), 2.7% bulky or carpet mass (40/1473), 0.5% benign-appearing mass or likely stricture (7/1473), and 0.6% submucosal or extrinsic mass (9/1473). The breakdown of polyp location by segment was 11.3% cecum (166/1473), 19.8% ascending colon (291/1473), 14.4% transverse colon (212/1473), 8.1% descending colon (119/1473), 30.8% sigmoid colon (453/1473), and 15.8% rectum (232/1473). Polyps were called with a diagnostic confidence of 3 (most confident) 79.1% (1165/1473) of the time, a diagnostic confidence of 2 (somewhat confident) 18.5% (272/1473) of the time, and a diagnostic confidence of 1 (least confident) 2.4% (36/1473) of the time.

A total of 95.8% (551/575) of patients initially referred for polypectomy ultimately underwent polypectomy and 4.2% (24/575) deferred. Of patients who opted for CTC polyp surveillance, 97.0% (382/394) had a C-RADS score of C2; as mentioned already, there were 10 patients with scores of C3 and two patients with scores of C4 who refused polypectomy and thus were followed with CTC polyp surveillance. Of C2 patients who initially chose CTC polyp surveillance, 24.1% (92/382) ultimately underwent polypectomy, typically after discussing results with their primary care provider.

Overall, the men in this cohort were slightly older than the women (mean age, 56.9 ± 6.3 vs 56.5 ± 6.0 years; $p = 0.0076$). The positive rate (C2–C4) among men was 17.5% (545/3110) and was significantly higher than the 11.6% (424/3659) seen for women ($p < 0.0001$). The rate of nondiagnostic examinations (C0) was similar between men (0.7% [22/3110]) and women (0.7% [27/3659]; $p = 0.8868$). Positive rates increase dramatically as patients age (Table 2), with rates of 13.4% (811/6043) for patients 50–64 years old and 21.8% (158/726) for patients 65–79 years old ($p < 0.0001$).

Overall, 0.7% (49/6769) patients had a technically inadequate study (C-RADS classification C0). Of these studies, the reason for this was poor luminal distention in 49% (24/49), poor bowel preparation in 31% (15/49), and both poor distention and preparation in 16% (8/49) of cases. In addition, two patients could not be evaluated because of technical issues with the 3D reconstruction software. Clinical management of this heterogeneous group was handled on a case-by-case basis in terms of follow-up strategies.

The distribution of extracolonic classification scores was 0.0% E0 (0/6769), 35.7% E1 (2416/6769), 50.9% E2 (3445/6769), 11.3% E3 (764/6769), and 2.1% E4 (144/6769) (Table 2). Overall, 13.4% (908/6769) of patients had indeterminate or potentially significant extracolonic findings (E3 or E4). Rates of E3 or E4 extracolonic findings increased with age from 12.8% (774/6043) for patients 50–64 years old to 18.5% (134/726) for patients 65–79 years old ($p < 0.0001$). Women were also significantly more likely than men to have an E3 or E4 finding, with rates of 14.7% (538/3659) and 11.9% (370/3110), respectively ($p = 0.008$).

Discussion

C-RADS represents an important structured reporting construct [4]. As with BI-RADS in mammography, it standardizes terminology and classification of examination output as well as management options for colorectal cancer screening by CTC. Ultimately, it allows valid comparisons among different institutions for both clinical and research purposes. There are few data detailing the usage of C-RADS in the clinical screening setting since it was proposed in 2005. Only recently have such programmatic measures been reported in smaller single-institution series [16]. This study represents the results of a 7-year clinical CTC screening experience where C-RADS was prospectively applied to over 7000 patients. If clinical use of CTC for colorectal cancer screening increases, we offer our data—including distribution of C-RADS colorectal and extracolonic scores, colonoscopy referral percentage, and polyp output and characteristics—for use as benchmark values to guide other clinical screening programs and assist with quality improvement.

Our study shows that in an average-risk healthy screening population, the majority of CTC examinations (> 85%) are negative using the 6-mm threshold for positivity. At our center, the positive fraction (C2–C4 findings) ultimately led to a reasonable colonoscopy referral rate of less than 10%, with the option of imaging surveillance for one or two isolated small polyps (C2 findings) available and the threshold for examination positivity set at 6 mm. The fraction of patients with C2 findings opting for CTC surveillance over immediate polypectomy may vary considerably among programs and will also be influenced by evolving data on the natural history of small polyps [17, 18]. Although about two thirds of our patients with one or two small polyps found at CTC screening (i.e., C-RADS C2) will initially opt for CTC surveillance, nearly one quarter will later switch to colonoscopy for polypectomy. In our experience, this follow-up decision is typically related to input from the patient's primary care provider, who are often not aware of all the relative risks and benefits involved with this decision [19, 20]. Regardless, this is a complex decision that can be influenced by many factors, including patient preference, understanding of relative risks, insurance coverage, demographic and risk factors, and whether the counseling is coming from radiology, gastroenterology, or primary care.

For practical purposes, C-RADS places screened patients with C1 findings with potential isolated diminutive polyps (≤ 5 mm) into a 5-year follow-up interval (i.e., routine screen interval for negative examinations) [21]. The selective polypectomy approach advanced by C-RADS achieves what we think is the primary target of colorectal screening—that is, early detection of advanced neoplastic lesions—but also realizes a marked decrease in polypectomies and associated complications compared with universal polypectomy strategies observed in colonoscopic programs [5]. The difference in polypectomy rates between CTC and colonoscopy screening, which can be over fourfold in magnitude, is almost entirely due to the different handling of diminutive lesions from setting the positivity threshold at 6 mm for CTC. In our series, the majority of the CTC-detected polyps (nearly 98%) were classified with moderate or high diagnostic confidence. Programs that include radiologists with appropriate (CTC-specific) training should expect similar numbers. Using this systematic approach, we have shown that the variation in lesion detection rates among radiologists in our program is quite narrow [22], especially compared with the wide variation in performance typically seen at colonoscopy [23].

Our study shows that demographic considerations become important, particularly

when referencing these data as programmatic benchmarks. The effects of age and sex are significant because both have also been shown to be strongly associated with colorectal neoplasia risk [24]. As expected, positive examinations in this study increased dramatically with age, with the rate seen in patients 65–79 years old approximately double that of patients 50–64 years old. Also as expected, the rate increased substantially among men compared with women. Thus, the cohort composition of these two factors should be taken into consideration as programs compare output with these values. Our reported results also reinforce likely explanations regarding the differences in positive and advanced neoplasia rates reported in the literature [18]. For example, Lieberman et al. [25] reported an advanced adenoma rate of 10.5% in an older male cohort of Veterans Administration patients, whereas such rates have been much lower in other screening series with younger female-dominated populations [5, 18, 26].

Interestingly, although men had a significantly higher rate of C2 and C3 findings, there was no difference observed between the sexes with regard to C4 findings (defined as colorectal mass, likely malignant). At face value, this result appears somewhat surprising. Besides higher rates of adenomatous polyps, it is well established that men have higher overall rates of adenocarcinoma than women [27]. However, the lack of a sex difference in the C4 rates may be related to the imaging-based nature of the classification. Although most C4 lesions prove to be malignant, benign causes such as focal diverticular strictures are included in this group because there is currently no other way to categorize them. Taken together, the group of focal concentric masses of various causes led to similar rates between men and women in this study. Future iterations of the C-RADS construct should take these likely benign masses into consideration.

The nondiagnostic study rate was less than 1% for this screening cohort. This points to the robust reproducible nature of CTC and compares favorably against incomplete colonoscopy rates, which are reported to be as high as 13% [28]. Furthermore, there is generally much more diagnostic information contained within a C0 CTC examination compared with an incomplete optical colonoscopy, because the entire colon is always visualized to some degree in the former but is completely nonvisualized proximal to the point of scope passage in the latter. The nondiagnostic rate at CTC is another important quality metric against which other programs can measure. In our experience, approximately one third of nondiagnostic examinations were related to the bowel preparation, one half to distention, and the remainder to a combination of the two factors. If substantially higher rates are seen in other programs, this metric should prompt programmatic review for potentially correctable causes such as an insufficient bowel preparation or setting the threshold for distention adequacy too high. The C0 rate will also be influenced by the experience and comfort level of the interpreting radiologist when dealing with a suboptimal CTC examination.

The results of this study are particularly important with regard to extracolonic findings. The cross-sectional nature of CTC allows diagnoses outside of the colorectum [15, 29]. It is imperative to minimize unnecessary workup while maintaining the ability to uncover important diagnoses, such as extracolonic cancers and vascular aneurysms. The percentages seen here should help in establishing baseline values for the E categories of C-RADS to allow comparison with other screening programs with comparable demographics. Once set, programmatic and individual radiologist percentages can be compared for the identification of outliers. Such quality measures would be helpful to help optimize the evaluation of incidental findings. It is particularly important to prevent radiologist practices that artificially upstage E2 findings (benign findings that do not require additional workup) because of "defensive medicine" approaches. Going forward, E4 (potentially important) findings should be emphasized because most E3 (likely unimportant) findings will ultimately prove to be of little or no clinical relevance.

The E3 and E4 cohort represents the pool of incidental extracolonic findings that may generate additional imaging. For patients with E4 findings, additional workup of some sort is typically mandatory, whereas it may or may not be indicated in patients with E3 findings, depending on the specific clinical situation. By definition, no workup is recommended for an incidental E2 finding or for a negative E1 examination. In our study, this rate for potential additional evaluation was 13%. It is important to recognize that this represents the upper limit of possible workup. A previous analysis of a portion of this population (n = 2195) showed that the actual workup rate was only 6.1% [30]. This mirrors other such studies where the actual workup rate was substantially smaller than the overall E3 and E4 rate. Zalis et al. [28] reported an actual workup rate of 5.5% from the E3 and E4 cohort in a large prospective multicenter laxative-free CTC trial (n = 605). Possible explanations for this observation include redemonstration of previously known findings or intentional deferral of further investigation because of the specific situation of the patient.

Conducting this study has allowed us to identify several issues with C-RADS that may require revision in the future. On the colorectal side, modification to separate out likely submucosal, extrinsic, or nonneoplastic lesions would be helpful because they often do not fit neatly in the positive categories of C2–C4. Likely benign masslike lesions (e.g., diverticular strictures) have already been discussed. On the extracolonic side, the current integration of clinical significance and need for further workup creates difficulties in interpreting the E categories. Because of this combination, it is difficult to determine the true rate of recommended workup related to extracolonic findings because additional workup is not appropriate for all E3 findings even though they may still be considered significant. Separation of finding significance and management recommendation in the lexicon would be helpful.

We have identified limitations to this study. Our data were collected in the setting of a single academic center in the midwestern United States, and our screening patient population is relatively young and healthy with a higher percentage of women than many other colorectal cancer screening experiences. Therefore, there may be issues when generalizing our results to other locales and patient populations. There exists the possibility of selection bias in our sample because we are dependent on primary physician referral for our patient volume, but this is likely to be the case in many clinical screening programs. In addition, all radiologists at our institution use 3D reconstructions for primary polyp detection with 2D cross-sectional series for primary confirmation and secondary detection; consequently, our results may not generalize to centers where a combined approach is not used [11].

In conclusion, we report the results of our 7-year experience with a clinical CTC screening program. The majority of examinations are negative for polyps at a 6-mm threshold with a reasonable referral rate to colonoscopy. Extracolonic findings potentially requiring additional evaluations constitute a low

percentage. Our single-center results categorized by C-RADS may serve as initial benchmark values for comparison by other clinical screening programs and for the generation of quality improvement measures.

References

1. Wilson JM, Jungner YG. Principles and practice of screening for disease (in Spanish). *Bol Oficina Sanit Panam* 1968; 65:281–393
2. D'Orsi CJ, Getty DJ, Swets JA, Pickett RM, Seltzer SE, McNeil BJ. Reading and decision aids for improved accuracy and standardization of mammographic diagnosis. *Radiology* 1992; 184:619–622
3. Berg WA, D'Orsi CJ, Jackson VP, et al. Does training in the breast imaging reporting and data system (BI-RADS) improve biopsy recommendations or feature analysis agreement with experienced breast imagers at mammography? *Radiology* 2002; 224:871–880
4. Zalis ME, Barish MA, Choi JR, et al. CT colonography reporting and data system: a consensus proposal. *Radiology* 2005; 236:3–9
5. Kim DH, Pickhardt PJ, Taylor AJ, et al. CT colonography versus colonoscopy for the detection of advanced neoplasia. *N Engl J Med* 2007; 357:1403–1412
6. Pickhardt PJ. Screening CT colonography: how I do it. *AJR* 2007; 189:290–298
7. Pickhardt PJ, Choi JR, Hwang I, et al. Computed tomographic virtual colonoscopy to screen for colorectal neoplasia in asymptomatic adults. *N Engl J Med* 2003; 349:2191–2200
8. Pickhardt PJ, Taylor AJ, Kim DH, Reichelderfer M, Gopal DV, Pfau PR. Screening for colorectal neoplasia with CT colonography: initial experience from the 1st year of coverage by third-party payers. *Radiology* 2006; 241:417–425
9. Shinners TJ, Pickhardt PJ, Taylor AJ, Jones DA, Olsen CH. Patient-controlled room air insufflation versus automated carbon dioxide delivery for CT colonography. *AJR* 2006; 186:1491–1496
10. Buchach CM, Kim DH, Pickhardt PJ. Performing an additional decubitus series at CT colonography. *Abdom Imaging* 2011; 36:538–544
11. Pickhardt PJ, Lee AD, Taylor AJ, et al. Primary 2D versus primary 3D polyp detection at screening CT colonography. *AJR* 2007; 189:1451–1456
12. Pickhardt PJ, Lee AD, McFarland EG, Taylor AJ. Linear polyp measurement at CT colonography: in vitro and in vivo comparison of two-dimensional and three-dimensional displays. *Radiology* 2005; 236:872–878
13. Pickhardt PJ, Choi JR, Nugent PA, Schindler WR. The effect of diagnostic confidence on the probability of optical colonoscopic confirmation of potential polyps detected on CT colonography: prospective assessment in 1,339 asymptomatic adults. *AJR* 2004; 183:1661–1665
14. Pickhardt PJ, Wise SM, Kim DH. Positive predictive value for polyps detected at screening CT colonography. *Eur Radiol* 2010; 20:1651–1656
15. Pickhardt PJ, Hanson ME, Vanness DJ, et al. Unsuspected extracolonic findings at screening CT colonography: clinical and economic impact. *Radiology* 2008; 249:151–159
16. Moore H, Dodd N. Computed tomographic colonography: colonic and extracolonic findings in an Auckland population. *N Z Med J* 2012; 125:68–74
17. Pickhardt PJ, Kim DH, Pooler BD, et al. Assessment of volumetric growth rates of small colorectal polyps with CT colonography: a longitudinal study of natural history. *Lancet Oncol* 2013; 14:711–720
18. Pickhardt PJ, Kim DH. Colorectal cancer screening with CT colonography: key concepts regarding polyp prevalence, size, histology, morphology, and natural history. *AJR* 2009; 193:40–46
19. Pickhardt PJ, Hassan C, Laghi A, et al. Small and diminutive polyps detected at screening CT colonography: a decision analysis for referral to colonoscopy. *AJR* 2008; 190:136–144
20. Pickhardt PJ, Hassan C, Laghi A, et al. Clinical management of small (6- to 9-mm) polyps detected at screening CT colonography: a cost-effectiveness analysis. *AJR* 2008; 191:1509–1516
21. Kim DH, Pooler BD, Weiss JM, Pickhardt PJ. Five year colorectal cancer outcomes in a large negative CT colonography screening cohort. *Eur Radiol* 2012; 22:1488–1494
22. Pooler BD, Kim DH, Hassan C, Rinaldi A, Burnside ES, Pickhardt PJ. Variation in diagnostic performance among radiologists at screening CT colonography. *Radiology* 2013; 268:127–134
23. Barclay RL, Vicari JJ, Doughty AS, Johanson JF, Greenlaw RL. Colonoscopic withdrawal times and adenoma detection during screening colonoscopy. *N Engl J Med* 2006; 355:2533–2541
24. Kolligs FT, Crispin A, Munte A, Wagner A, Mansmann U, Goke B. Risk of advanced colorectal neoplasia according to age and gender. *PLoS ONE* 2011; 6:e20076
25. Lieberman DA, Weiss DG, Bond JH, et al. Use of colonoscopy to screen asymptomatic adults for colorectal cancer. *N Engl J Med* 2000; 343:162–168
26. Kim DH, Pickhardt PJ, Taylor AJ. Characteristics of advanced adenomas detected at CT colonographic screening: implications for appropriate polyp size thresholds for polypectomy versus surveillance. *AJR* 2007; 188:940–944
27. Ries LAG, Wingo PA, Miller DS, et al. The annual report to the nation on the status of cancer, 1973-1997, with a special section on colorectal cancer. *Cancer* 2000; 88:2398–2424
28. Zalis ME, Blake MA, Cai WL, et al. Diagnostic accuracy of laxative-free computed tomographic colonography for detection of adenomatous polyps in asymptomatic adults a prospective evaluation. *Ann Intern Med* 2012; 156:692–702
29. Pickhardt PJ, Taylor AJ. Extracolonic findings identified in asymptomatic adults at screening CT colonography. *AJR* 2006; 186:718–728
30. Shah HA, Paszat LF, Saskin R, Stukel TA, Rabeneck L. Factors associated with incomplete colonoscopy: a population-based study. *Gastroenterology* 2007; 132:2297–2303