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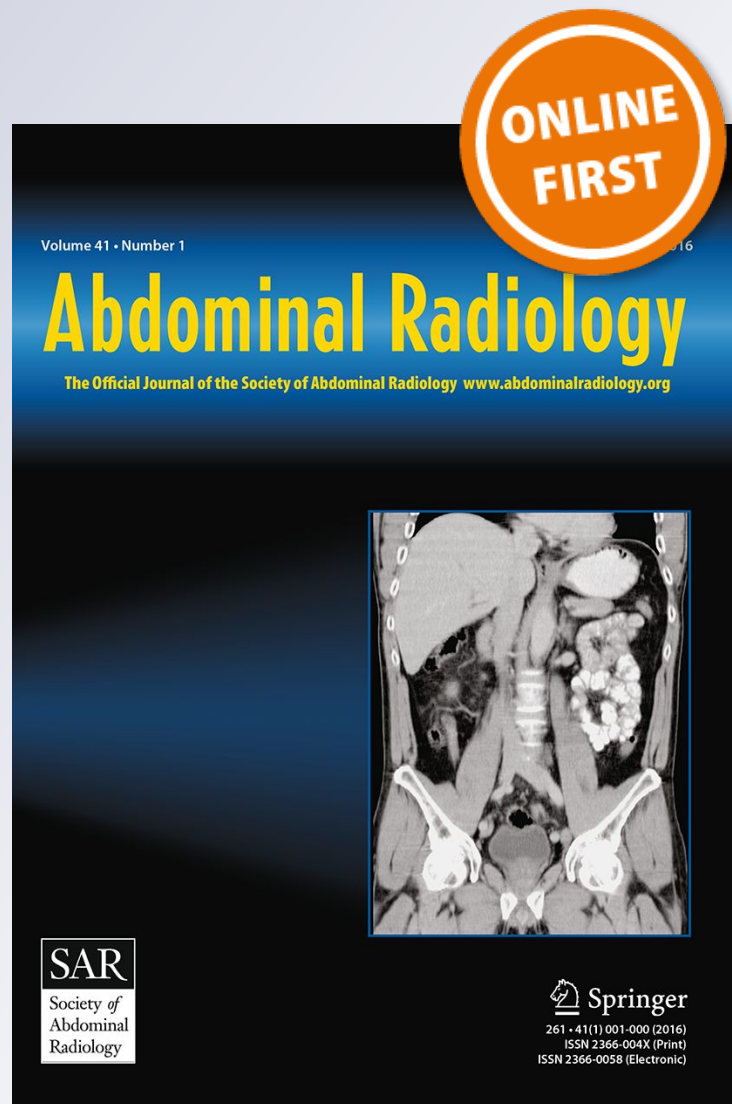
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Structured reporting and quality control in CT colonography

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Abstract

Standardized recommended techniques for performing and reporting CT colonography (CTC) examinations were developed by a consensus of experts. Published reporting guidelines, known as the CT colonography reporting and data system supplemented by recently updated comprehensive recommendations were incorporated into the American College of Radiology (ACR) practice guidelines. The application of continuous quality improvement to the practice of CT was aided by the development of an ACR national data registry (NRDR) for CTC that addressed both process and outcome quality measures. These measures can be used to benchmark an institution's CTC practice as compared to all participants. This article will discuss the best practices for reporting CTC and describe the use of NRDR to foster quality CTC performance.

Key words: Computed tomography (CT)—3-dimensional imaging—Colorectal polyps—Quality metrics

Abbreviations

ABR	American Board of Radiology
ACR	American College of Radiology
CTC	CT colonography
CTDIvol	Volume CT dose index
ECFs	Extracolonic findings
OC	Optical colonoscopy
PACS	Picture archiving and communication system
PDSA	Plan, Do, Study, Act

Over the last several years, particularly after the widespread use of speech recognition, the advantages of

structured reporting in radiology became evident as a way of improving consistency of format, language, and reporting elements [1]. The use of structured reporting also allows for the processing of reports using natural language processing tools to extract key information for automated data tracking, analysis, automated communication of findings, and confirmation of appropriate follow-up. The use of a standardized format of reporting is especially important for screening examinations where comparison to benchmark data promotes consistency across readers, institutions, and geographic regions [2–4]. Furthermore, such systems promote uniformity in communication and subsequent triage of patients. With the development of CT colonography (CTC) as a colorectal cancer screening examination, there were compelling reasons to introduce structured reporting in CTC. There was a need for consensus in the terminology of colonic findings that would be consistent with the recommendations for the detection and removal of colonic polyps and masses and the interval of follow-up surveillance or screening. These recommendations needed to be clear and concise and consistent with the larger medical community. Similarly, the extracolonic findings (ECFs) in CTC compelled the radiologist to differentiate between trivial and important incidentalomas. The perceived need for structured reporting resulted in the development and publication of consensus guidelines, the “CT Colonography Reporting and Data System” known as C-RADS [5].

When CTC was a relatively new exam, it was particularly important that the high quality of exam performance found among researchers would be replicated in the general practice setting. The diagnostic accuracy of CTC was particularly sensitive to the quality of the patient preparation, the colonic distention, the CT technique used and the way the exam was viewed. Early on, there was lack of consensus on many of these issues, but as researchers eventually agreed on key elements of exam performance, it became plausible and necessary to pub-

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lish guidelines on quality control and reporting. The American College of Radiology (ACR) developed practice guidelines, the most recent update of which was published in 2014 [6].

Many organizations evolved to mandate quality in the practice of medical care to ensure a safe patient-focused national health care agenda. To meet and proactively lead that agenda as applied to radiology on a national level, the ACR developed several programs, one of which is the National Radiology Data Registry (NRDR). The goal of these registries was to take an evidence-based approach to benchmark outcomes and develop quality improvement programs. In 2008, the CT colonography registry was spearheaded by Dr. C. Daniel Johnson. Today, the CTC registry is an approved practice quality improvement (PQI) program recognized by the American Board of Radiology (ABR) in maintenance of certification program.

This paper will review the key elements of each of these programs and show their importance and potential future developments.

Structured reporting

The structured reporting elements for CTC should be comprehensive and should incorporate, but are not limited to, the features covered by both C-RADS and NRDR. The optimal structured reporting elements are described below. A sample report is shown in Fig. 1.

The *history element* should indicate if the exam was performed for screening or for diagnostic purposes. This decision should be consistent with insurance guidelines, the appropriate American Medical Association CPT® billing code and the appropriate ICD-10 code. The most common indication for CTC is screening for polyps and masses in the colon in individuals aged 50 years or greater (ICD-10 code: Z12.11 Encounter for screening for malignant neoplasm of colon). When performed for this indication, the examination is considered screening and coded as CPT® 74263. When performed in individuals with signs or symptoms of disease, the examination is usually done without IV contrast and coded as CPT® 74261 (CTC, diagnostic, including image post-processing; without contrast material). It is important for billing, reimbursement, and appropriate follow-up recommendations to carefully document the signs and symptoms of disease in the report. While the details of the use of the diagnostic CTC CPT® code are beyond the scope of this discussion, it is important to note that other factors such as family history or other risk factors for the development of colonic disease might be taken into consideration when making follow-up recommendation. It is therefore best practice to include that information in the history element (even though it ordinarily does not affect the billing code). Since many insurance carriers, including Medicare, take into consideration whether the

patient had a prior failed optical colonoscopy (OC), this information should also be included in the history. Documentation of the reason for the failed OC and the proximal extent of colon visualization on OC is frequently required to obtain insurance authorization and reimbursement. If any polyps were removed at OC, knowledge of their histology, if available, is helpful to quantify the patient's risk for CRC and might impact the recommended interval for follow-up examination.

The *comparison element* should indicate if there are no prior CTC examinations or if there are, specifying the dates of the exam. Furthermore, the *comparison element* should document the absence or presence of prior imaging of the lung bases, abdomen, and pelvis. Review and comparison to prior imaging of the lung bases, abdomen, and pelvis are important in the evaluation of extracolonic findings and in recommendations for further imaging. Frequently, the presence of a significant extracolonic finding may already be known based on prior imaging and recommendations for follow-up imaging can be avoided or modified [7].

The *technique element* should indicate key information about the CT scanner, image acquisition and reconstruction, patient preparation, patient insufflations, and patient scanning positions used. Some of this information is incorporated into the NRDR exam form, such as scanner manufacturer, detector rows, detector row size, slice thickness, and interval. There is normally a "technique page" sent by the scanner to PACS that would indicate the CTDIvol and DLP for each series that can optionally be incorporated into the technique; however, since patients (and referring physicians) may not understand this metric, it is not recommended unless required by law. Since the two cans (e.g., supine and prone) cover the same body part, the sum of the CTDIvol can be used rather than the sum of the DLPs. The total CTDIvol should be the sum of all scans but exclude the scout views. Patients are traditionally scanned at least twice; supine, prone, and/ or right-side down decubitus. The technique element should specify what patient scan positions were used. The method of insufflation should be specified, i.e., mechanical insufflation of carbon dioxide or manual insufflation of room air. Description of the methodology used to prepare the patient for CTC should also be documented. The use of tagging agents is recommended unless the patient refuses or cannot comply. The type of agent(s), barium, iodine or both, should be documented to allow for subsequent review of images and determination of polyp coating which can facilitate detection of polyps, especially flat lesions. Any deviations in preparation, patient, or imaging factors that might limit diagnostic sensitivity should be described.

The *first paragraph of the findings element* should address the key quality assurance issues for CTC: colonic distension, fecal/fluid tagging, retained fecal matter, and

History: 55 year old asymptomatic woman with a positive family history of colon cancer in a brother at age 50. No prior colorectal cancer screening.

Technique: The patient was prepared with polyethylene glycol (Mirilax) and stool tagging with 50 cc oral Omnipaque. The patient was scanned supine and right side down decubitus after mechanical insufflation with carbon dioxide to tolerance on a Brand X CT scanner, Kvp =120, mAs =30, 256 channels, 0.7mm slice thickness, 1.25 mm reconstruction interval. Interpreted using 2D and 3D images on a Brand 3D workstation (ver. 2.0).

Comparison: None.

Findings: The colon was well distended and well cleansed except for the sigmoid colon which was mildly distended and distorted due to muscular hypertrophy and diverticulosis limiting sensitivity for small polyps in the sigmoid colon. There was a moderate amount of residual fluid in the right colon which was well tagged with oral contrast. There was a redundant transverse colon and a cecum inversum. The exam is of diagnostic quality.

There was a 10 mm sessile polyp on a fold located in the mid-transverse colon. No other polyps or masses were seen.

Extracolonic Findings: No significant findings. Normal abdominal aortic caliber. No evidence of hepatic steatosis.

Impression: Ten millimeter sessile polyp in the mid transverse colon. Recommend colonoscopic evaluation.

No significant extracolonic findings.

C-RADS Score: C3, E1.

Fig. 1. Sample CTC report.

the presence/absence of scanning artifacts (beam hardening, motion, etc.). As with OC and barium enema, a colon exam must evaluate the entire colon. For example, in OC the endoscopist may report that the scope was advanced to visualize the cecum, ileocecal valve, and appendiceal orifice. Similarly, CTC must evaluate the entire colon surface. Inadequate visualization due to insufficient distention, retained untagged fluid, or due to excessive retained fecal matter will compromise the diagnostic quality of the exam. Good practice would be to specify that the colon was well-distended or if sub-optimally distended specify the location and to what extent the lack of distention potentially interferes with the diagnostic quality of the exam. A guiding principle

when deciding what to include or omit from this section is that CTC reports should identify polyps ≥ 6 mm and C-RADS guidelines recommend endoscopy for polyps ≥ 10 mm. Thus, if the diagnostic quality for polyps of this size is compromised in a particular colon segment, this fact should be mentioned. A common example of this would be incomplete distention of the sigmoid colon related to muscular hypertrophy and diverticulosis. As long as the walls of the colon barely touch, a large (10 mm) polyp would likely be visible. A sample qualified statement might read: "The colon is well-distended, except for the sigmoid colon which is partially collapsed limiting sensitivity for small polyps (< 10 mm) in that region." Similarly, a statement should be made regarding

the volume and location of retained fluid and if tagging was used, whether this fluid is well tagged or not. Third, a statement should be made regarding the quality of the colon cleansing and the presence of retained stool. Whether retained stool will compromise the diagnostic quality of the exam may depend on how much stool is present, the particle size and the presence or absence of gas or tagging within the stool. For example, a report might indicate that “The colon is well-cleansed except for small particulate matter in the right colon, limiting sensitivity for diminutive polyps (< 6 mm) in that segment.” A statement regarding the presence or absence of scanning limitations should also be included. Visualization might be limited by patient motion, beam-hardening/streak artifact from orthopedic hardware or inadequate scan volume. A sample qualified statement might read: “The visibility of the lower third of the rectum is extremely limited due to artifact from bilateral total hip arthroplasty.” In addition to these factors, a subjective statement about excessively tortuous segments could be helpful in deciding on follow-up CTC vs. OC.

The *second paragraph of the findings element* should indicate the location, size (at minimum the single longest dimension or if preferred bi-dimensional measurements) and the morphology (e.g., sessile, pedunculated, or flat) of polyps greater or equal to 6 mm found following C-RADS guidelines detailed below. The reporting of diminutive polyps (< 6 mm) is not uniformly recommended but may be reported if multiple, confidence is high or if larger polyps are detected and reporting of the diminutive polyps might alert the endoscopist to areas of the colon warranting additional attention. A statement documenting the presence or absence of complications (perforation) should also be included.

The *extracolonic findings (ECFs) element* should include a statement that the exam is not sensitive for findings outside of the colon due to the low radiation dose and the lack of intravenous contrast. This can be part of the reporting template. If there is a recent contrast-enhanced CT, the ECFs can be omitted and just refer to that study date. Good practice is to mention only important ECFs that might affect management as per C-RADS and ACR guidelines [8]. However, since CTC can substitute for sonography when screening for abdominal aortic aneurysms, good practice is to specifically mention that there is no evidence of aortic aneurysm or state the size of the aorta taken from the appropriate plane which is perpendicular to the aortic lumen. Medicare reimburses for sonography for aortic aneurysm screening for individuals at risk, e.g., with a family history or patient aged 65–75 with a strong smoking history. Given the increasing prevalence of steatohepatitis, unequivocal hepatic fatty infiltration (e.g., under 40 HU) should be mentioned as well.

The *impression element* should not only state the polyp findings, but also based on the history make a

recommendation for follow-up [9]. Although placing the overall C-RADS score may be helpful for data reporting and review, most physicians receiving the report will be unfamiliar with the meaning of the score. The follow-up statement corresponding to the score should be included in the impression. Knowledge of the full history, risk factors, and sometimes in complex cases a discussion with the referring physician may be helpful in deciding on the best follow-up interval or type of exam. For example, in pre-cardiac transplant patients, the clinical consensus is often to just observe and follow patients with a 6- to 9-mm polyp and even 10-mm polyps because of the high risk of bleeding and anesthesia associated with colonoscopy and polypectomy. Only significant extracolonic findings should be included in the impression. Care should be taken to review prior pertinent radiology images and reports to avoid recommending follow-up for known pathology or previously evaluated findings.

C-RADS guidelines

After the successful implementation of standardized reporting for mammography using Bi-RADS [10], a CTC reporting scheme was developed in a similar fashion and formalized by consensus. A polyp is defined as a soft tissue attenuation lesion and polyps are stratified based on size, diminutive (< 6 mm), 6 mm or greater, or 10 mm or greater. Clear definitions were given for the method of polyp measurement (single longest dimension usually based on the 3D view), polyp morphology (sessile, pedunculated, flat—defined by being 3 mm or less in height, or a frank mass) and for polyp location based on six well-defined colon segments (cecum, ascending colon, transverse, descending, sigmoid, and rectum).

The metric for sensitivity was based on the largest polyp per patient. The size threshold for reporting polyps agreed upon by consensus (including joint guidelines agreed upon by the American Cancer Society is 6 mm) [11, 12]. The low rate of concerning histologies in polyps smaller than 6 mm is supported from data in large cohorts [11, 13] and studies of the complications and cost of polypectomy [14]. Surveillance for growth of 6–9 mm polyps is recommended at 1–3 years but this is tempered by referring physician and patient preferences.

The “colon” or “C” scores in C-RADS (Table 1) are as follows: C0: inadequate study; C1: normal colon or benign (e.g. lipomatous) lesion: routine screening to be continued; C2: indeterminate polyp: surveillance or colonoscopy based on a size of 6–9 mm in diameter when there are only one or two polyps; C3: possibly advanced adenoma: follow-up colonoscopy based on either a size of ≥ 10 mm in diameter or three or more 6- to 9-mm polyps. Finally, C4 is a designation for an obvious colonic mass, likely malignant requiring urgent surgical referral based on its size, luminal narrowing, and extra-

Table 1. CT colonography reporting and data systems (C-RADS) colorectal and extracolonic classification scores *Source* Reproduced with permission from [5, 15]

C0	Inadequate study/awaiting prior comparisons Inadequate prep: cannot exclude lesions ≥ 10 mm because of presence of fluid/feces Inadequate insufflation: one or more colonic segments collapsed on both views Awaiting prior colon studies for comparison
C1	Normal colon or benign lesion; continue routine screening ^a No visible abnormalities of the colon No polyp ≥ 6 mm Lipoma or inverted diverticulum Non-neoplastic findings (e.g., colonic diverticula)
C2	Intermediate polyp or indeterminate finding: surveillance colonoscopy recommended ^b Intermediate polyp(s) 6–9 mm, one or two in number Indeterminate findings, cannot exclude polyp ≥ 6 mm in technically adequate scan
C3	Polyp, possibly advanced adenoma: follow-up colonoscopy recommended Polyp ≥ 10 mm ≥ 3 polyps, each 6–9 mm
C4	Colonic mass, likely malignant: surgical consultation recommended ^c Lesion compromises bowel lumen, demonstrates extracolonic invasion

^aEvery 5–10 years

^bEvidence suggests that surveillance can be at a 1- to 3-year interval, subject to individual patient circumstance

^cCommunicate to referring physician as per accepted guidelines for communication, such as the ACR practice guideline for communication: diagnostic radiology. Subject to local practice, endoscopic biopsy may be indicated

colonic extension. The ECF or “E” designations are discussed in detail elsewhere in this issue. A few points that might clarify the application of C-RADS scores are worthy of mention. The C-RADS score applies to the patient as a whole, not to the individual lesions. A patient is scored based on the most worrisome or largest lesion present. Causes of C0 score are poor bowel preparation, poor insufflation, or need to wait for comparison to prior studies. This event should be rare. Unlike mammography where “waiting for comparison studies” is common, in CTC there should be excellent communication of the preparation requirements to the patient and inadequate studies due to poor patient preparation can be minimized. By prescreening patients by telephone, patients who continue to have formed stool can be told to continue laxatives and diet until adequately prepped. Also, by having the technologist’s question toward the patient and review of the scout images, one can avoid scanning patients with inadequate stool cleansing. A C0 score is also minimized by good technologist training and physician oversight to ensure good colonic distension before the rectal tube is removed and the patient is discharged. Rarely, a repeat series or an extra decubitus view is needed to ensure distention of all colonic segments. In a cohort of Medicare patient published by Brooks et al., only 3.3% of patients had a C0 score [16].

For a C1 score, a definitively “benign” lesion refers to a submucosal lipoma which can be diagnosed on CT by its fat density. Patients with tagged retained fecal material, appendiceal stumps, inverted diverticula, and other normal or benign findings are also classified as C1. In

cases of clearly benign strictures or muscular hypertrophy, a C1 score is the most appropriate. The management recommendations for a patient with a C1 score is routine surveillance in 5 years. Patients with a C3 or C4 should be referred for optical colonoscopy. In patients with a C2 score, only one or two lesions 6–9 mm should be present. These patients may undergo imaging surveillance at 1–3 years. If there are three or more lesions, polypectomy is recommended primarily because of the risk that the polyps are adenomas. Additionally, there are limited data suggesting that hyperplastic polyps might be associated with a small increased CRC risk. (This might, in part, be related to the fact that polyp currently categorized as serrated adenomas may have been previously categorized as hyperplastic.) For that reason, patients with three or more 6- to 9-mm lesions are placed in the C3 category. Patients with lesions equal to or greater than 10 mm are also placed in the C3 category in which colonoscopy and polypectomy would normally be recommended unless comorbid conditions or other factors are present. Last, the designation of C4 should be used only if a mass is so certain that if the lesion could not be confirmed by OC, that the patient would nevertheless be referred for surgical evaluation. These lesions are usually large, show features of obvious malignancy such as spread into the surrounding fat/organs and associated malignant lymphadenopathy. Structured reporting for ECFs is equally important. As in the “C” score, C-RADS incorporates an “E” score, the purpose of which is to guide management and prevent unnecessary workup. The intricacies of the “E” score is discussed elsewhere in this issue.

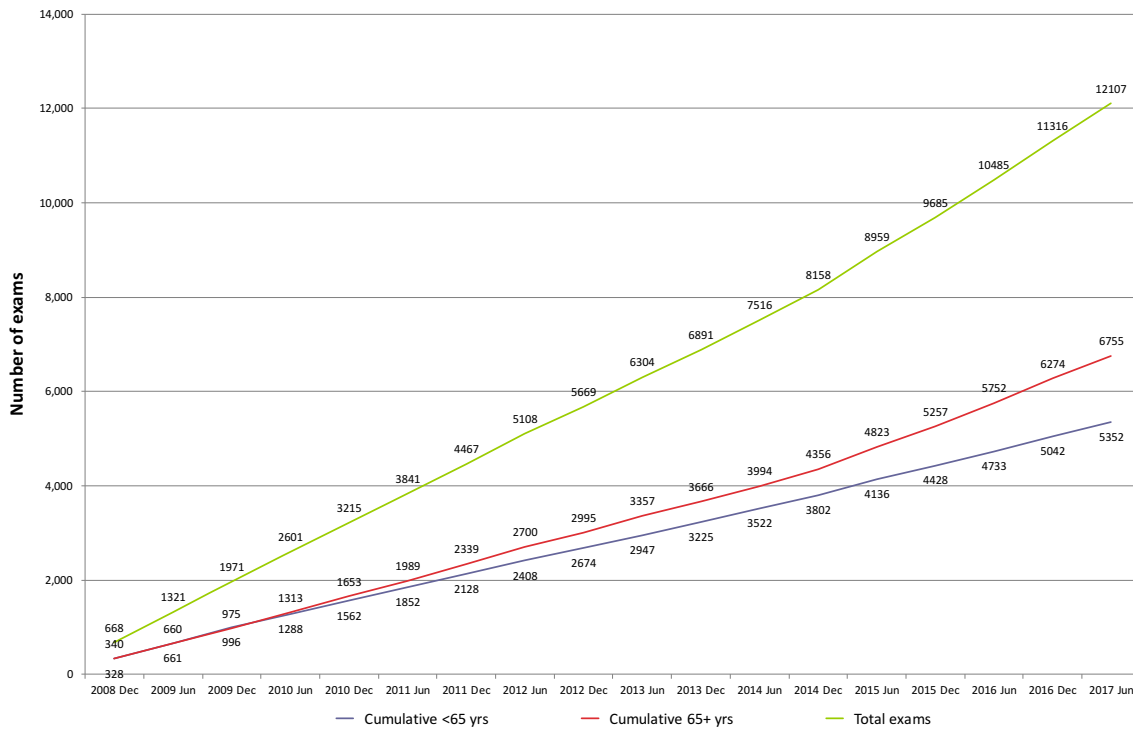


Fig. 2. Cumulative recruitment of CTC exams into CTC NRDR registry through June 2017.

CTC Registry
New Facility Registration
Forms and Data Dictionary
Entire Form Package
Case Registration Form
Case Registration Form
Exam Form
Polyp Form
Data Dictionary
FAQ
CTC Measures
CTC User Guide
CTC Sample Facility Report
CTC Sample Physician Report
CTC ABR PQI Project
CTC Brochure
NRDR

Fig. 3. ACR NDRD CTC registry pull-down menu for reporting and related resources.

ACR NDRD database

Since initiation of the testing phase in 2008 and implantation shortly thereafter, the number of cases entered into the NRDR CTC data base continues to grow (Fig. 2). The NDRD CTC report forms are designed to balance simplicity with the collection of meaningful data. The pull-down menu for registration and forms is shown

in Fig 3. There are three forms: a case registration form, an exam form, and a polyp form. A non-radiologist can enter most of these data. At The University of Chicago Medical Center, a member of the scheduling team fills out the case registration form when a CTC is scheduled and a radiologist fills out the exam and polyp forms.

The case registration form includes fields for the patient name, birthdate, race, and exam date. The exam form has fields that define the type of study (e.g. screening, surveillance, or symptomatic) and whether the patient is being referred from an incomplete OC. Other features of the case report forms were recently simplified allowing a site to assert that C-RADS minimum technique criteria were met rather than entering the scan parameters for each exam. The source form addressed all the CT technique features mentioned above (e.g., detector rows, detector row size, CTDIvol, slice thickness, etc.). The case form logs post-examination findings including the presence or absence of one polyp ≥ 10 mm, whether the entire colon and rectum were in the scan field of view, and whether one or more colon segment was non-diagnostic. If the answer to the latter question is 'yes', then the cause is categorized as due to excess fluid, fecal material, segmental collapse, or other.

Reports with tables, color bar graphs, and plots are generated quarterly and are available to the user on the web site. Figure 4 represents hypothetical facility and hypothetical overall NRDR data. There are six key metrics: (1) adequacy of bowel cleansing and distention,

	Facility						All		
	Sample facility			Other					
	Num ¹	Den ²	%	Num ¹	Den ²	%	Num ¹	Den ²	%
Adequate Bowel Cleansing and Distention	337	400	84.3	10643	11800	90.2	10980	12200	90.0
Adequacy of Screening CTC Exam	250	300	83.3	8305	8850	93.8	8555	9150	93.5
Adequacy of Diagnostic CTC Exam	87	100	87.0	2734	2950	92.7	2821	3050	92.5
Colonic Perforations	1	400	0.25	1	11800	0.0085	2	12200	0.016
True Positives	60	80	75.0	1505	1750	86.0	1565	1830	85.5
Clinically Significant Extracolonic Findings	33	400	8.25	638	11800	5.41	671	12200	5.5

Fig. 4. Sample hypothetical facility report. The six key facility metrics can be benchmarked against all participants.

(2) adequacy of screening CTC exam, (3) adequacy of diagnostic CTC exam, (4) colonic perforations, (5) true positives, and (6) clinically significant extracolonic findings. The reports can be generated by facility and by individual physician.

Quality improvement cycle

The classic four-step iterative management continuous improvement cycle known as the Deming or PDSA cycle involves (1) identifying a process to improve, (2) defining performance metrics and collecting baseline data, (3) developing and implementing an action plan, (4) reviewing the results of the plan's intervention, and (5) repeating the cycle with an alternate intervention if needed. The process and outcome metrics in the CTC NDRD database can be used to implement such a cycle or merely show a high quality compared to other participating sites.

Various strategies can be implemented when a quality metric is found to be suboptimal. If adequacy of the exam (either screening or diagnostic) is poor, then a site can conduct an investigation to more precisely define the problem. Are the exams inadequate due to poor distention? If so, then an in-service for the technologists on optimizing insufflation can be done. If the problem is poor patient preparation, then a review of colon cleansing instructions, identifying patients with constipation who might need more rigorous cleansing, can be done by working with the staff that schedule patients and take a brief intake history. If the problem is poor tagging of fluid or stool, then a review of the tagging method can be done and an alternate option should be tested. Colon perforations are such rare events but have known predisposing etiologies such as insufflation in the presence of an obstructing hernia or mass. In some cases, use of an older rigid rectal catheter or over inflation of the rectal

retention cuff has been surmised to be a cause. The exact circumstances of the case should be investigated to determine if there is lesson for the future. We have taught our technologists to perform a scout view if a patient has extreme pain despite the use of a small volume of gas. In one case, this led to the detection of sigmoid colon located in an incisional hernia which caused a retrograde obstruction to the flow of gas. This was confirmed with a limited pelvic CT scan and a perforation was averted. A low true positive rate can have many causes. First, it can be due to either missing lesions completely or mistaking a polyp candidate for stool or other non-polyp etiology. A systematic review of the false negative cases can help reveal the dominant cause for the facility. Sometimes additional reader training or mentoring will help optimize exam sensitivity and specificity.

Judicious use of the quality improvement cycle and standardized reporting not only provides an excellent method of communicating results, but also documents the elements that are needed to retrospectively analyze CTC performance. Issues related to patient preparation, scan technique, or complication rate for example can be analyzed and improved. The use of structured reporting as suggested also incorporates sufficient detail for retrospective analysis of these factors.

Summary

In summary, there are many advantages to the use of structured reporting in CTC. NRDR case registration is encouraged. The registry qualifies as a practice quality improvement (PQI) program recognized by the American Board of Radiology (ABR) maintenance of certification program.

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Compliance with ethical standards

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Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval and informed consent Not applicable

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