



Best Practices in Computerized Tomography

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EXECUTIVE SUMMARY

- St. Mary's Regional Medical Center in Lewiston, ME, was a recipient of the Putting Patients First grant program offered by AHRA and Toshiba. This article presents an overview of the grant activities and the salient findings.
- The dual focus of the best practice initiative was to promote the physician use of the evidence-based appropriateness criteria developed by the American College of Radiology and to determine ways to improve patient safety with an eye toward incorporating any best practice reported in the literature or recommended by bona fide experts in CT.
- Some of the resulting best practices consist of: optimizing scanning protocols and scanner settings, utilizing supplemental approaches to dose reduction, and referring patients to excellent online resources.

St. Mary's Regional Medical Center (SMRMC) is a 233-bed acute care hospital located in Lewiston, ME, and provides traditional medical, surgical, behavioral, obstetrical, pediatric, and ambulatory services. The imaging services department uses a 16-slice CT scanner. Four technologists with CT certification and 3 part-time individuals who are becoming CT registry eligible staff the CT area. The Spectrum Medical Group of South Portland, ME provides contracted radiologist services. In 2008, the volume of CT exams was 7378 and it is projected to reach 8700 exams in 2009. These numbers represent 15% of the overall volume of imaging studies performed at SMRMC.

The goal of SMRMC was to develop and implement best practices in CT by using the American College of Radiology (ACR) Appropriateness Criteria coupled with the most appropriate scanning protocols. The overarching purpose was to improve patient care and safety.

This article outlines the steps being taken to achieve this goal, which consisted of conducting a literature review and data analysis, developing scanning protocols

and patient safety measures, promoting patient satisfaction and patient education, emphasizing the ACR Appropriateness Criteria, and encouraging professional development.

Literature Review

One of the concomitant activities of receiving this grant was the search for nuggets of information that could be woven together to represent best practices in CT. Myriad articles focusing on ways to reduce radiation dose and improve patient safety were reviewed. The expression "We are standing on the shoulders of giants" comes to mind after this journey. So much has been accomplished. It's now been over 10 years since the multiple detector scanner units were developed and 8 years since the 16-slice unit was unveiled.¹ Shortly after the advent of this technology, there was considerable literature about safeguards that should be implemented in CT. The beneficial incorporation of automatic exposure control (AEC) in CT scanners was embraced with gusto in the design of modern scanners. The marvelous synergy between the x-ray production, the detector

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arrays, and the computer to formulate images is so complex that it's awe-inspiring. Both medical professionals and the general public may not truly comprehend how advanced this technology is, but they do know that the use of CT has become a significant diagnostic tool. In 2006, 62 million CTs were performed in the United States. Given the predicted rate of growth of 10–15% per year, it is likely that in 2009 the figure could reach as high as 93 million.²

The popularity and accessibility of CT makes it all the more important to implement the ACR Appropriateness Criteria³ and follow the recommendations of the American Association of Physicists in Medicine (AAPM) regarding radiation dose. The patient derives substantial benefit from a CT exam that outweighs the long term stochastic risk from radiation exposure. However, when the effective dose levels of conventional radiography are compared to those given during a CT study, the gravity of the situation becomes clear. It is of paramount importance to use both the ALARA principle (meaning radiologic professionals use levels of radiation "As Low As Reasonable Achievable" to obtain a diagnostic image) in CT and make sure a CT exam is appropriate given the set of signs and symptoms. Brenner points out that patients who have repeated CT scans are exposed to levels of 5–100 millisieverts (mSv), which is the same amount the Japanese experienced at the periphery of the atomic blast in 1945.⁴ This amount of radiation exposure is in addition to the naturally occurring background radiation, which averages 3 mSv in the United States (depending on the geographic location within the United States the range is 1–10 mSv).⁵ More and more attention has been given to this topic by medical literature and the popular press. Several other studies have separately urged physicians to employ greater diligence in

making sure their decisions to order CT exams are the most appropriate for their patients because ultrasound and MRI offer radiation-free alternatives.^{4,6–8}

Mechanisms for reducing the radiation dose have been identified by numerous authors.^{9–11} Optimizing the scanning protocols is one such mechanism. Within the CT scanner, the output (mAs), the energy (kVp), the pitch, and slice thickness parameters can be adjusted to get the best images at the lowest possible radiation dose.

Both the ACR and the AAPM have published reference values for the CTDI_{vol} by body region so that radiologists and radiologic technologists can judge the CT scanner's performance. CTDI_{vol} is a dose matrix that is multiplied by the length (in mm's) of the scan to get the Dose Length Product (DLP). The DLP can then be used to calculate the effective dose for that particular scan. It's not a true measure of the amount that particular patient received but it's a mathematical estimate.¹

Other mechanisms involve employment of good practice such as centering the patient within the gantry. Kalra and his colleagues demonstrated reductions in radiation dose ranging from 7–29.9% for chest CT exams and 5.5–56% for abdominal CT exams when they used an automatic patient centering device.¹² Several others have each reported research results using a bismuth shield placed over the radiosensitive breast tissue.^{13–15} They have reported encouraging dose reductions ranging from 26–57%. Twenty-nine percent is the most commonly reported amount verified by different researchers. Hopper points out that a woman's lifetime risk for breast cancer increases by 13.6% for every dose of 10 mSv delivered to the breast tissue when a woman is 35 years old or younger.¹³ A typical chest CT often delivers an effective dose of 5–7 mSv. Using the bismuth shield on female children was strongly recommended.^{14,16}

Another promising approach developed by Dr. Charles M. Swaney is a breast displacement system that brings sensitive breast tissue out of the scan plane. His findings show an average dose reduction of 88% in the region around the nipple to 94% reduction in the upper-outer quadrant of the breast.¹⁷

Patient preparation is another important aspect of patient safety. ACR has long advocated the importance of having patients well hydrated before, during, and after IV contrast studies.¹⁸ Numerous studies have documented the protective effect that hydration has on the kidneys.^{19–21} Consequently, for outpatients, drinking extra fluids before and after the CT exam is emphasized. Interviewing the patient before the IV contrast is fundamental to patient safety. It provides a way to verify the patient's current condition and medications, the creatinine level, why the exam is being done, and the presence of any comorbidities that might make the use of IV contraindicated, such as the presence of sickle cell anemia, multiple myeloma, etc. All of this is consistent with the ACR recommendations as published in their Manual on Contrast Media—Version 2008.

The identification of these various mechanisms provided a baseline for a set of best practices in CT. The next challenge was to incorporate them into SMRMC's daily routine for sustained patient safety.

Data Analysis

The 2008 volume statistics for CT procedures were analyzed (7378 procedures) and, interestingly, for the first 9 months of 2009 (6646 procedures), the top 10 ranking remained the same. Nine months of protocolized scheduled CT exams consisting of over 5600 orders were analyzed. Problematic diagnoses (diagnoses that most often needed the CT order changed to a more appropriate type of CT exam) were identified (Table 1), as well as the names of the ordering physicians that could benefit from a focused in-service on the use of the ACR Appropriateness Criteria.

Significantly, the number of CT exam orders that were changed by the radiologist

■ **TABLE 1.** Problematic Diagnoses Identified through Analysis of Protocolled CT Exams

	Reason for Exam	Original CT Order	Changed by Protocolling	Comments
1.	Renal stone	abdomen without; or urogram, or CTU	stone protocol	Appears to be confusion about what to order; urogram uses IV contrast. The contrast might mask the presence of stones.
2.	Hematuria (pain not mentioned)	abdomen without	hematuria protocol	Hematuria protocol includes different sequence of images compared to stone protocol. IV contrast is used.
3.	Hematuria with pain	abdomen without	stone protocol	Stone protocol does not use IV contrast.
4.	Diverticulitis; left lower quadrant pain	abdomen with	abdomen & pelvis with	Clear teaching opportunity here. Diverticulitis is primarily found in the pelvic area.
5.	Lung nodule	chest with	chest without	Appears to be some confusion about what to order. Lung nodules do not need IV contrast.
6.	Headache; confusion; memory loss; vertigo; headache with valsalva	head with	head without	Appears to be some confusion about what to order. These symptoms could indicate a subdural hematoma which is seen best on a head CT without contrast.

during the protocolling process dropped from 52 in October 2008 to 27 in June 2009 (Figure 1). This figure shows the number of CT exam orders that were changed by the radiologists through the protocolling process for outpatient scheduled exams. Comparing October 2008 (before the grant) with June 2009 (sixth month of grant activity) shows a 52% reduction, from 52 to 27, which represents a 48% improvement in the way the CT exams are ordered.

This improvement can be attributed to the impact of multiple factors, such as promotion of ACR Appropriateness Criteria, dialogue between the radiologist and the ordering physician, easy access via links on physician computer desktops, feedback from radiologists, and feedback from the pre-authorization staff when revised orders were requested.

Scanning Protocols

The scanning protocol guidebook was revised through collaboration between the lead CT radiologic technologists from Maine Medical Center and SMRMS. Each protocol was revised to show the recommended settings for the 16-slice scanner. The guidebook had originally been created for a 64-slice CT scanner. (See sample protocol page in Box 1.)

The parameters within the scanner were carefully revised, resulting in substantial decreases in radiation dose by adjusting the pitch, speed, tube current (mA), and beam penetration (kV): eg, 50% dose

reduction for extremities and lumbar spines, 66% dose reduction for cervical spines, and 75% dose reduction for brain/heads.

Patient Safety

Significant reductions in radiation dose have been achieved by adjusting the scanner protocols as previously stated and by reminding the technologists about the importance of centering the patient within the gantry.

Before each IV contrast study, the patient is interviewed to gather specific details about the reason for having the

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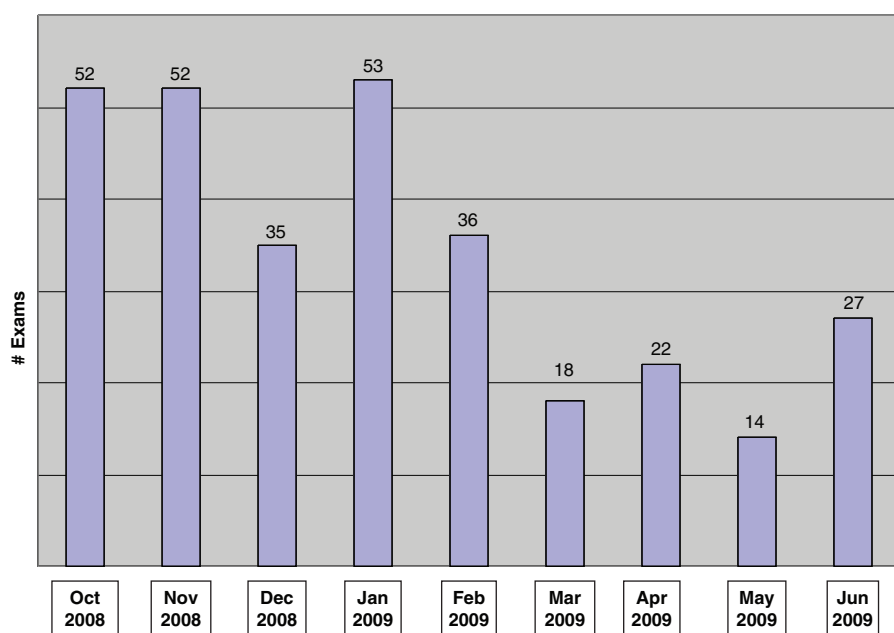


Figure 1 • Number of CT Exams Changed by Radiologist October 2008–June 2009

CT exam. A customized questionnaire is used which highlights those conditions that are contraindicated for IV contrast. A paper version was replaced with an electronic version that is archived within the order entry software program. Both the patient's history and current list of medications are recorded. On subsequent visits, the previous questionnaire pops up to be updated. The method shortens the interview time and increases patient satisfaction because they don't have to list their medications again.

For those patients with a history of hypertension or renal disease and those who are 70 years old or older, a serum creatinine lab test is required within 30 days of the CT exam if the patient is having IV contrast. The software program customized a pop-up feature that shows the creatinine results when a CT exam is selected for ordering. In addition, the creatinine results are printed on the requisition. A creatinine level below 1.5 indicates that the kidneys are functioning within normal limits and can handle the excretion of the IV contrast.

To assist Type II diabetic patients, the technologists use a list of the 10 metformin formulas with the brand and generic names to help identify the particular prescription

the patient is using. If the patient is given IV contrast, then they are given written instructions about abstaining from taking their diabetes medicine for the next 48 hours. Electronic documentation that the written instructions were given is recommended. A trial mechanism was developed for notifying the physician who is managing the diabetes treatment for that patient. The idea was to let the physician know that their patient had an IV contrast study and been advised to stop their metformin for 48 hours.

Patient Satisfaction and Patient Education

The brand of oral contrast was changed from a bitter tasting product given in 2 doses (1 dose in the evening prior to the CT and another in the morning just before the CT scan) to a neutral tasting one given in 1 dose 1 hour before the CT scan. The previously used contrast often caused diarrhea and compliance was

questionable given the very unpleasant initial taste and lasting aftertaste. Patient compliance and satisfaction has increased according to anecdotal feedback we received. The image quality is comparable and eliminating 1 dose reduced costs.

The prep instructions for CT abdomen and CT abdomen/pelvis exams were revised for the new oral and distributed electronically through a software program used by the majority of physician's offices sending patients to SMRMC. The wording has been revised twice to incorporate patient suggestions for better clarity.

The prep instructions were placed on the SMRMC Web site and patients are encouraged to visit RadiologyInfo™ online. RadiologyInfo™ is a patient education Web site developed and maintained through the collaboration of the ACR and the Radiologic Society of North America (RSNA) for patients to learn more about CT or any other type of diagnostic imaging study.

A dedicated patient education computer was installed in the main radiology waiting area. It is locked onto RadiologyInfo™ so that patients can learn about their exams while they are waiting. Often, family members use this computer to become better informed about the exam their loved one is having.

A blanket warmer was added to the CT scanner room for easy access. The small cabinet used to be a contrast media warmer. Patients consistently express gratitude for the comforting warmth of the heated blanket.

Breathing instructions have been recorded on the scanner to help patients who understand French or Somali better than English. (SMRMC's service area includes a significant number of French Canadians and Somalians.) Through SMRMC's Somali interpreter, we are able to give Somali patients written information about the CT scans via the Ohio based

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■ **BOX 1. Sample Page from Scanning Protocol Guidebook (Abdomen & Pelvis)**

ABDOMEN & PELVIS PROTOCOL

Indications—Lymphoma, colon CA, mass, diverticulitis, abscess, pain , appendix

Series 1: Localizer—AP & Lateral abdomen and pelvis

Series 2: Scan—from above the diaphragm to the symphysis pubis

Scan Type	Thickness	Interval	Pitch	SFOV	kV	Min mA	Max mA	Noise	DFOV	Algorithm
Helical 0.6	1.25mm	1.25mm	1.375:1	Large Body	120	100	440	15.63	36 or per patient size	Standard

Recon 2: Turn on 5mm axial images auto sent to PACS

coronal and sagittal reformats and send to PACS

Contrast			
Oral	IV Contrast		
50 ml of Omnipaque 240 Oral in 950 ml of water one hr prior to start of scan *** diverticulitis 2 hr prep	Volume— See IV Contrast Chart Average amount 100–120 ml	Rate 3 ml/sec	Prep Delay 70 seconds

Reviewed and approved:

Sharon Siegel, MD

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ACR Appropriateness Criteria

On the SMRMC Web site, physicians are encouraged to click on the link connecting them to the ACR Web site. Once there,

physicians can search by procedure or by diagnosis to locate a list of recommended imaging studies that are appropriate. In addition, the Spectrum Medical Group that provides the contracted radiologist

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services at SMRMC obtained permission to print the full collection of criteria. Selected pages from this collection have been assembled for distribution to specialty physician practices based on the CT exam ordering patterns identified from the data analysis.

The first of a series of visits were conducted in April. The visits included an informal lunch and learn session in which the medical director of imaging services presented the Appropriateness Criteria to the medical staff and office personnel who place the CT orders. The presentation included a tailored discussion on problematic diagnoses flagged by the analysis of protocol schedule sheets.

Professional Development

The lead CT technologist from Maine Medical Center agreed to serve as one of the key consultants to this grant. She spent a full day on site assessing exam protocols, scanner settings, and workflow. She produced a list of recommendations that were implemented quickly. She continues to be accessible whenever a question arises.

On April 30, 3 radiologic technologists spent the day observing the workflow at 2 locations in Portland, ME upon the recommendations of the lead technologist. One was an outpatient imaging department and the other was the CT department at Maine Medical Center. The technologists gained valuable insight from their experiences.

Fifty-five continuing education (CE) credits were purchased from the Philips Online Learning Center on a special departmental account. An intriguing array of CT courses comprises the offerings through the Learning Center. Five technologists earned CE credits through this arrangement. Of special note, a technologist used these

courses plus other textbooks and study guides to successfully pass the comprehensive Registry Exam for Computerized Tomography.

On May 8, a 1 hour presentation was delivered at the spring meeting of the Maine Society of Radiologic Technologists. And in August, a poster highlighting the grant's accomplishments was on display at AHRA's 37th Annual Meeting in Las Vegas, NV. The poster was one of a number of entries on performance improvement initiatives showing measurable results. Conference attendees were encouraged to vote on the merits of the posters and SMRMC's entry obtained the fourth highest number of votes overall. On October 17, this same poster along with pertinent handouts was also part of the annual Octoberquest conference at Maine Medical Center in Portland, ME.

Other Interventions

Two purchases were made to embrace the recommendations of The Joint Commission. A digital thermometer that records the high and low temperatures as well as the current temperature within the contrast warmer was installed to replace the glass column thermometer. A set of seamless positioning sponges replaced the more traditional sponges with seams so that surface contaminants could more effectively be cleaned off, thus increasing patient safety.

Since June 2009, over 100 email addresses have been collected from patients who had imaging studies at SMRMC. Patient's names were entered into a monthly drawing for a \$25 gift card for gas or groceries if they were willing to contribute their email addresses. Once the database reaches 250 entries, a patient satisfaction survey using a customized survey instrument will be conducted.

Conclusions

In 2008, there were 1742 orders for the combo abdomen/pelvis with contrast exam. Year to date (January–September) statistics for 2009 show 1550 orders for this same combo. This is the most frequently ordered CT exam with contrast. In the original grant proposal, we mentioned developing a 3 page protocol for the top 10 types of CT exams with contrast. We discovered that the 3 page protocol idea was not workable. However, we used a different approach. We grouped abdominal and pelvic symptoms together and created a list of “Tips for the Technologist” that focused on 10 symptoms that would often prompt the physician to order such an exam (Box 2). The technologist would then refer to the previously mentioned Scanning Protocol Guidebook.

The development of best practices is a “work in progress” throughout radiology and the health professions. Some of the best practices for CT consist of: optimizing scanning protocols and scanner settings, utilizing supplemental approaches to dose reduction, and referring patients to excellent online resources. The partnership of radiologists and technologists can promote patient safety by using these multiple approaches. Reductions in radiation dose are best achieved by ensuring patients receive the most appropriate imaging study for their situations. Helping the ordering physicians fine tune their choice of diagnostic exams through the dissemination and promotion of the ACR Appropriateness Criteria will yield lasting benefits. ☸

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■ **BOX 2. Abdomen/Pelvis with Contrast: Tips for the Radiologic Technologist**

1. Symptom of left lower quadrant pain
Both abdomen and pelvis scanned
Both IV and oral contrast used
2. Symptom of blunt trauma to abdomen
Make sure floor of pelvis is included in scan to detect any pooling of blood
3. Symptom of pancreatitis
Water used for oral contrast: 2–3 glasses (8–24 ozs)
Scan upper abdomen without IV contrast
Inject IV contrast using Smart Prep (20–30 sec)—scan pancreas to include duodenum
After an additional 30 seconds, scan from liver dome to iliac crest
4. Symptom—Suspicion of Pancreatic Tumor
Water used for oral contrast: 2–3 glasses (8–24 ozs)
Scan without IV contrast
Smart Prep used as configured for GE 16-slice Lightspeed scanner
Inject IV contrast, scan pancreas to include duodenum (arterial phase)
After 50 seconds, scan liver dome to iliac crest
5. Symptom of renal stone (acute renal colic without & with hematuria—no IV contrast)
Scan from diaphragm down below the symphysis pubis to include the end of urethra.
6. Symptom of pain and hematuria with only one kidney present
Reduce amount of IV contrast to 90 ml instead of 140 ml
7. Symptom of hematuria (gross and micro) and atypical pain syndrome.
Do abdomen pelvis without contrast; below diaphragm to end of urethra
Inject 50 ml wait 7 minutes then inject additional 90 ml
Scan after 90 seconds include entire abdomen pelvis
8. Symptom—suspicion of renal mass
Limits scan to kidneys—without contrast
Inject 100 ml, scan after 20 second delay—kidneys only
Scan after 50 second delay—dome of liver to symphysis
Order exam as Combo abd w/wo and pelvis with
9. Symptom—suspicion of liver dysfunction—hepatocellular carcinoma (3 Phase);
hemangioma (4 Phase)
Phase I abdomen without—water for oral contrast
Phase II–IV contrast injection—Smart Prep used
Phase III 70 second delay, scan from diaphragm to bifurcation
Phase IV 5–10 minute delay—limit scan to hemangioma
Reformats done; goal arterial and venous phases of portal circulation
10. Symptom—abdominal obstruction
Both IV and oral contrast given
Abdomen and pelvis scanned to localize region of obstruction
11. Body Habitus Considerations
If patient has short, swarthy build, then oral contrast might take longer
to move to sigmoid section of colon. 90 minutes instead of 60 minutes
12. Poor Veins
Reduce power injector rate to “2” (normal flow rate is “3”)
13. Hydration
Pre exam hydration enhances the ease of the venipuncture, the quality of the images,
and affords protection to the kidneys (8–12 hrs before exam).
Post exam hydration facilitates flushing of the contrast out of the body.

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