

CT UPDATE

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Coronary Artery Calcification Scanning in Asymptomatic Patients: A Controversial Examination Further Complicated by Electron Beam CT versus Multislice CT Battles

Jerry Breen, MD

Our practice has been involved in the detection and quantification of coronary artery calcifications by electron beam CT (EBCT) scanning for well over a decade. We have been involved in numerous research projects initiated by many services: Radiology, Cardiology, Preventive Medicine, Hypertension, Endocrinology, and the Emergency Department. We have participated in multicenter studies, international workshops and symposia, and have tried to stay abreast of what is happening in academic and private practice settings. I presented one of the first studies correlating conventional angiography with EBCT at the 1990 RSNA meeting. We are still actively involved in several calcium projects. With that fairly extensive background, the following points sum up all what I really know about the topic of CT-detected coronary calcium:

- Having no calcium is probably a good thing.
- Having lots of calcium, especially when compared to your age group, is probably bad thing.
- Having some calcium, but not lots for your age, is probably not as good as having no calcium, but it might be years before we know what it really means.
- The public currently wants this exam.

The last point, public demand, might be the worst reason to perform this examination, but it is the only point that I am sure about. Direct marketing of this “painless, inexpensive, 10-minute exam promising to tell you if you are at risk of dying from the big one” has literally

forced traditional radiology practices into selling gift certificates for scans that you buy for your loved ones and business partners. If they don't, their competitors will. Should the people who have promoted this situation be called villains or visionaries? You will find support in the literature for either position.

Radiologists (and pathologists) have reported the use of X-rays for detecting coronary calcifications as a marker of atherosclerotic disease for more than a half century with the initial reports from autopsied hearts. One of the most often quoted studies supporting the prognostic value of coronary artery calcium detection was performed in the 1970s and utilized fluoroscopy. Despite what appeared to be a useful, simple, and painless noninvasive test to predict future coronary events, fluoroscopy for coronary disease never flourished and quietly went away. In the early 1980s, CT scanning of the chest began and it was obvious that coronary calcium deposits could be seen with greater sensitivity than fluoroscopy. But it was not until the late 1980s, with the ability to freeze cardiac motion by EBCT, that the detection of small calcific deposits could be made reliably. This also resulted in a standardized method to attempt to quantify the amount of coronary calcium present. An “Agatston Score” could be determined by multiplying the area of calcified plaque by a density-weighting factor based on the peak Hounsfield number of the calcium deposit. While standardized, the method remains controversial as to the reliability and reproducibility of Hounsfield numbers in patients of various sizes and on serial examinations. A calcium score can easily be doubled by the change in a few Hounsfield units due to the multiplying weighting factors that were initially arbitrarily assigned by Agatston et al.¹ Partial volume averaging is another variable that compounds the problem of measuring very small deposits with the standardized 3-mm slice thickness utilized by the EBCT method. Some investigators have abandoned the weighted score for what appears to be a more accurate and reproducible measurement of the area of calcium that meets a minimum CT number threshold. There are other potential pitfalls to accurate and reproducible measurements. The scan acquisition is triggered by the ECG and therefore ectopy can significantly affect accurate detection and scoring. Despite the very short acquisition 100-msec acquisition time, relatively rapid heart rates will result in blurring and smearing of calcium deposits, especially in the right coronary. The figures that accompany this article are representative of the problems we see on a daily basis. Our clinical and research practice is to routinely perform dual scans on all patients in an attempt to minimize reproducibility errors.



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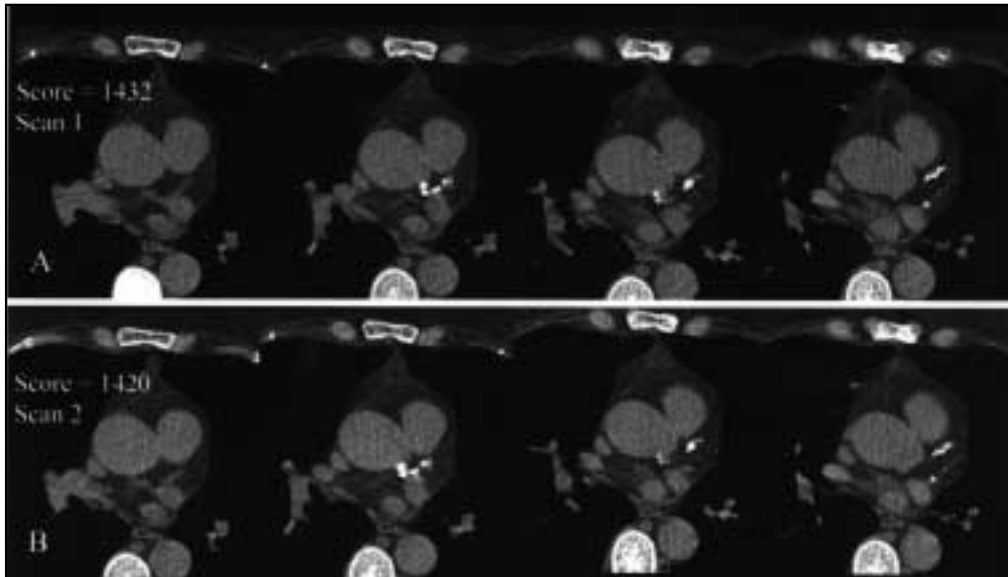


FIGURE 1. Electron beam computed tomography (EBCT) scan reproducibility—high score. (A) Four contiguous levels from the first scan run demonstrating multiple large deposits in the left coronary artery. (B) Matched levels from scan run two demonstrating the same deposits with a near identical calcium score.

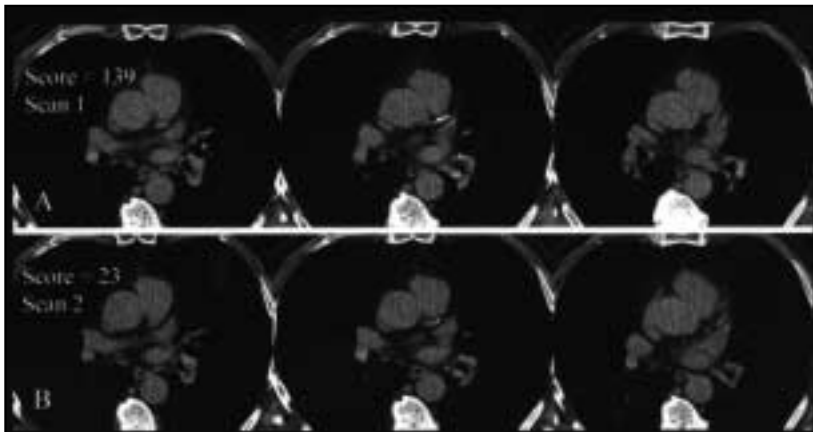


FIGURE 2. EBCT scan reproducibility—moderate score. Contiguous levels through the only calcium present on (A) scan run one and (B) run two result in significantly different scores.

Notwithstanding the known limitations, recommendations for asymptomatic patient care based on EBCT calcium scores have been published by Rumberger et al² and are often quoted not only in the literature, but also on the report forms of many imaging centers offering coronary scans. This is common practice at both EBCT and spiral CT sites. These recommendations, intended specifically for EBCT examinations, are a result of a consensus statement from an experienced group of investigators and their review of the literature available up to 1999. While there is little debate that a score of 0 indicates an extremely low likelihood of any significant obstructive disease, the remaining absolute score guidelines remains controversial. Using these guidelines, a score of 10 in a 40-year-old woman implies “very low risk,” however a score of 11 triggers a “moderate risk” for future cardiac events and a much more aggressive treatment plan. In reality, and the authors of the guidelines will also espouse, a reliable score of 10 in a 40-year-old woman places her above the 99% rank for quantity of calcium when compared with age- and gender-matched controls and probably should result in very aggressive risk-factor modification. Recent literature supports the matching of scores with their age and gender controls to provide a more accurate estimation of risk for future cardiac events.³

In my opinion, the bigger problem is the accuracy of such low scores and their reproducibility (Figures 1 through 4). Some authors (and especially vendors) have suggested that ECG-gated spiral multislice CT (MSCT), with better signal-to-noise and spatial resolution compared with EBCT, might provide a more accurate detection, and therefore measurement, of coronary calcium. In addition, MSCT can offer 4 to 16 thinner contiguous slices to be obtained per scanned heartbeat compared with the single-slice only mode of EBCT; therefore improving partial volume averaging errors. EBCT supporters will quickly point out the still significant temporal resolution advantage of EBCT (100 msec scans) over even the fastest MSCT (approximately 250 msec) in conventional ECG-triggered step-and-shoot mode. Continuous spiral mode with retrospective ECG

reconstruction can result in MSCT effective imaging times of under 100 msec, but at the cost of significantly increased radiation dose and with potential additional motion correction problems.

Nonetheless, once you have measured a volume of calcium, you can apply the same Agatston scoring method with the generation of a calcium score. With the more photon-rich image, the signal-to-noise will be improved over EBCT, but the reliance on Hounsfield numbers and density multipliers will remain a source of significant potential reproducibility errors. The potentially more accurate and reliable volume measurement of calcium might be further improved by MSCT. Whatever type of scoring you wish to report, CT vendors of spiral scanners all provide scoring software packages along with marketing aids and strategies that will get your site up and running before you competing radiology or cardiology group can promote their coronary calcium screening exam.

When trying to risk stratify an individual scanned on a spiral scanner, does it matter that the huge database that exists for trying to make sense of a calcium score is from EBCT?

This is a great question that awaits adequate validation or refutation. EBCT supporters vocally state that current claims by MSCT vendors are unsubstantiated. Peer-reviewed literature of existing comparison would suggest that MSCT and EBCT calcium score measurements are similar and both with clinical utility.⁴ We are one of numerous sites that have EBCT scanners installed feet away from MSCT scanners and are performing side-by-side comparison studies. My best guess, based on our comparison scans performed to date, is that both EBCT and MSCT will have clinical utility. Both will likely provide more than sufficient quantification data for the necessary longitudinal outcome studies that someday might enlighten us all as to the prognostic value for measuring calcium. I am not alone in being both a believer and somewhat of a skeptic. The American Heart Association states support of various clinical uses for coronary calcium scanning, but stops short of recommending widespread scanning of the asymptomatic public.⁵ It may be that knowing your calcium score or volume is more important than knowing your lipid profile, but third-party payers and the government are not yet convinced. Most likely, cash or credit cards, and not your policy number, will be needed to buy that gift certificate

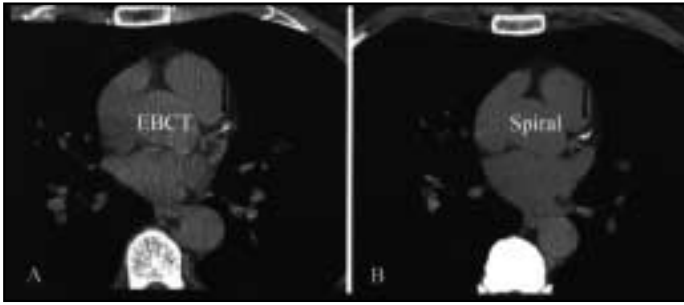


FIGURE 3 . (A) EBCT and (B) spiral multislice (MSCT) on the same patient. LAD calcium deposits (arrows) present on both scans with similar appearance. Scores were within 10%.

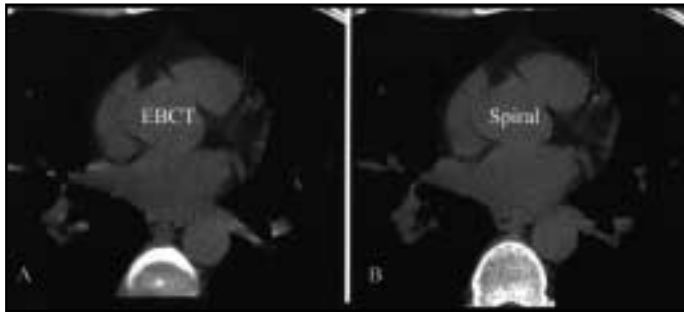


FIGURE 4. (A) EBCT and (B) spiral MSCT on the same patient. A very small calcium deposit in the LAD is more clearly defined on the spiral scan (black arrow). Our scoring program on the EBCT run did not detect the deposit.

for screening for you and your loved ones next holiday season, and possibly for many more seasons to come.

Coronary artery disease will remain the number one killer for the foreseeable future. Diagnosing and treating it will remain a very big

business; calcium screening is now established as part of that business. CT scanning for coronary calcium, whether by EBCT or MSCT, is probably the most practical, sensitive, noninvasive way to document the presence of the atherosclerotic process in the coronary circulation. Isn't that what a screening test should do for this often silent killer? The test is not perfect by either method and further proof of clinical efficacy will be needed to convince those controlling reimbursements. But if you would like to know if you have none, some, or lots of atherosclerotic disease in your coronary arteries compared with your peers, these tests will do just that. I know my calcium score, and I sleep better knowing that it remained 0 over a recent 5-year period. Do you know your score? Are you curious or would you rather not know, especially if you have the dreaded "some calcium, but not lots" for your age? We can hope that future investigations will answer all of our questions, but we are likely years away from any consensus. In the meantime, you can fill those years reading the volumes of literature that has already been generated. The references listed below are but a minute fraction of what is in print. See if you can sort it all out. If you do, please give me a call.

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TECHNICAL ISSUES

Pediatric Helical CT: Radiation Issues

Caroline L. Hollingsworth, MD and George S. Bisset, MD

Pediatric body CT is a well-established and increasingly utilized diagnostic tool. During the past decade, helical technology has accelerated this trend with increased options for scan technique including kilovoltage, tube current, collimation, and pitch, as well as dramatic further reduction in time necessary for acquisition of volume data sets. The fast-paced technological advances and increasing availability of multidetector CT will provide further available options for scanning. Although there are numerous articles in the current literature addressing contemporary techniques and evolving applications of adult helical CT, there is little information on the optimization of pediatric helical CT. This may be due to the fact that many more variables must be addressed including techniques for intravenous and oral contrast material administration, variable delays in onset of scanning, and consideration of the size of the child when choosing parameters that affect radiation dose. Although successful helical CT data acquisition in children is complex and often requires attention to each individual child rather than adherence to protocol, diagnostic scanning can be achieved. Recently, guidelines for size-based scanning with single-detector helical CT have been published.¹ However, CT parameters are not always adjusted for pediatric scanning. Given the complexities of helical scanning, there is potential for children to be

imaged with scan parameters that impart increased radiation dose.

Although the radiation imparted by CT has been an important consideration since its introduction more than 30 years ago, this issue has recently gained much more attention with the introduction of multislice CT (MSCT). This technology potentially delivers a higher radiation dose than conventional (helical) CT. Radiation dose due to CT can be considered a public health concern for several reasons. First, CT has become a significant source of radiation to the general population, second only to background sources, and children account for approximately 11% of all CT examinations.² Moreover, although guidelines for size-based scanning have been published, children are often scanned without adjustments in technique, exposing them to unnecessary radiation.³ This is important both because children are more radiosensitive to the same organ dose than adults, and because there is a potentially longer time in which radiation-induced malignancies could develop. We now realize that the relationship between low-level CT radiation and cancer is much closer than previously believed.⁴ Together, these facts mandate that radiation be minimized.

A number of strategies for reducing radiation dose to children have been put forth including use of other modalities that can provide sufficient diagnostic information and changing the paradigm of image quality from optimal (high dose) to acceptable. These suggestions support limiting use of multiphasic examinations, basing the scan on clinical question examinations may also be limited in their scope, for example, patients may not need pelvic CT to evaluate pancreatitis. Also, adjusting scan parameters for the region and using size-based techniques (adjusting tube current) are valuable. A weight-based protocol has been suggested by Donnelly et al.¹ Another size-based system is a color-coded format derived from the Broselow-Luten pedi-

atric color-coded system.⁵ This system assigns a color to each child based on length or weight and designates appropriate resuscitation and support equipment based on the specific color. The color zones were created based on anatomic and physiologic parameters affecting emergency support of children and, therefore, are not divided by equal weight increments. This system has been shown to decrease error rates in pediatric emergency rooms⁶ and can be applied to many other health care issues affecting children. This last point is particularly important as healthcare continually becomes more complex. By providing a single protocol scheme for many facets of children's health-care, medical errors may be avoided.

The color-coded approach to pediatric body CT scanning is used at our institution. Protocols address scan parameters affecting table speed, gantry rotation, radiation dose, and administration of contrast media. Children are classified into specific color zones, which were established in the original study,⁵ with the addition of a ninth color zone for children between 40.5 and 55 kg (children in this weight range were not included in the original Bruselow-Luten color scheme). Children who weigh more than 55 kg (approximately 120 pounds) are scanned with adult

protocols regardless of age. Importantly, recent work at our institution has shown that our technologists strongly prefer the color-coded protocols over standard weight-based protocols. In a survey, there were fewer errors and the technologists overwhelmingly favored the color-coded system to a standard weight-based protocol.

Conclusion

Helical CT scanning has become an invaluable tool for imaging children. Although scanning children often presents unique challenges, diagnostic scanning can be achieved. Attention to the individual child and diagnostic question to be addressed, and the use of appropriate scan techniques can provide excellent results while minimizing risks, even in the most complex circumstances. The implementation of a color-coded system for pediatric helical body CT allows a reproducible format for CT protocols and reduction of radiation dose while helping to minimize errors in scan technique. Reduction in radiation dose can be achieved while preserving acceptable scan quality and standardized imaging. This system has potential applications across a wide array of care issues in the pediatric population.

PRACTICAL ISSUES

Practical Approach to Adult Renal Masses: Emphasis on CT

Brian J. Jellison, MD and Fred T. Lee Jr., MD

Historically, the role of the radiologist in the work-up of potentially malignant renal neoplasms has been limited to detection and preoperative staging. If the patient was a surgical candidate, the majority of these masses were removed via radical nephrectomy. Recently however, nephron-sparing surgery, laparoscopic nephrectomy, and less-invasive percutaneous ablative techniques (most notably cryotherapy and radio-frequency ablation) have become more standard therapy for small renal masses. These treatment options require a thorough investigation of the anatomy of the kidney, renal vessels, and surrounding tissue. Therefore, multislice CT, sometimes combined with CT angiography, now plays a dominant role in the pretreatment evaluation of renal masses.

Malignant solid renal masses include renal cell carcinoma (RCC), transitional cell carcinoma, lymphoma, and metastases. Any renal mass with solid components should be viewed as malignant until proven otherwise. Renal cell carcinoma is characterized at CT by a solid or mixed solid and cystic (heterogenous) enhancing mass that is less dense than enhancing renal parenchyma. Hemorrhage and necrosis are common. In up to 10% of cases, central calcifications are identified. Staging of RCC depends on accurate evaluation of local spread, including invasion through the renal capsule, fascia, lymph nodes, and into vascular structures, such as the renal vein and inferior vena cava (Figure 1).

Benign solid masses include oncocytoma, adenoma, angiomyolipoma, and xanthogranulomatous pyelonephritis. No imaging features reliably distinguish oncocytomas and adenomas from RCC, therefore, they are treated as malignant neoplasms. Cystic renal masses include simple and complex cysts, abscesses, cystic RCC, and multilocular cystic nephromas. Because of the overlap in appearance of cystic RCC and complex renal cysts, the Bosniak classification was introduced in 1986 in an attempt to separate cystic renal masses into two groups: surgical (high risk of malignancy), and non-surgical (low risk of malignancy).¹ More recently, this classification has expanded to include the use of ultrasound and MRI.

The exact CT protocol for evaluating potential renal masses will

depend to a degree on the type of CT scanner, but several fundamental principles are important. There are two reasons why noncontrast scans are performed prior to contrast-enhanced scans: 1) enhancement of a renal mass by >10 HU is a worrisome sign of malignancy, and 2) non-contrast scans allow the radiologist to evaluate calcifications without mistaking them for excreted contrast material. Therefore, the kidney should be scanned without IV contrast (preferably by ≤ 5 mm increments), followed by scanning after the administration of contrast. The timing of the scan through the kidneys after IV contrast is controversial, but numerous studies have demonstrated improved detection of small renal masses during the later nephrographic phase (approximately 2 minutes after injection) versus the earlier corticomedullary phase (approximately 40 to 90 seconds after injection).² At The University of Wisconsin, we perform noncontrast, corticomedullary phase, and nephrographic phase sequences (Table 1). For CTA, three-dimensional postprocessing of the CT datasets, including volume rendering and maximum intensity projections, are obtained with the Advantage Windows Workstation 4.0 Software (GE Medical Systems, Waukesha, WI) with volume-rendering techniques.

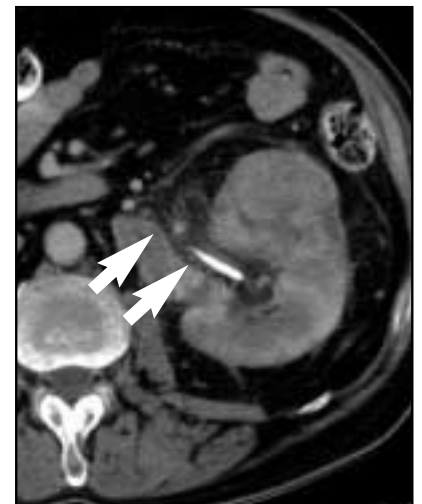


Figure 1. Large renal cell carcinoma with extension into the renal vein (arrows). Tumor thrombus usually causes an enlarged, heterogeneous appearance to the renal vein.

Table 1. University of Wisconsin Multislice CT Protocol for Evaluation of Renal Masses

	Phase		
	Non-contrast	Corticomedullary	Medullary
Slice thickness	5 mm	1.25 mm	5 mm
Pitch	3:1	6:1	3:1
Milliamperes (mA)	170	400	210
Reconstruction interval	N/A	0.5 mm	N/A

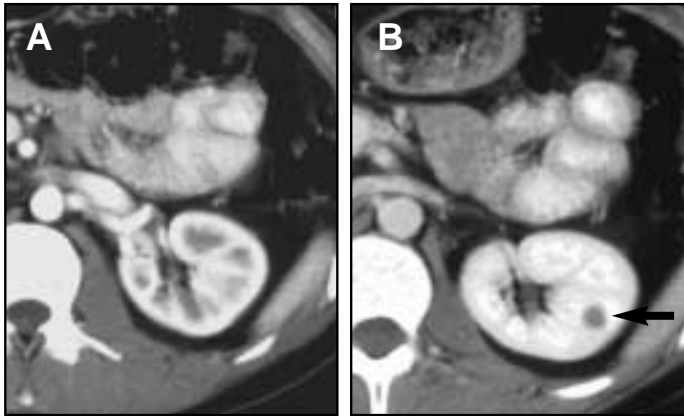


Figure 2. (A) Detection of small renal masses can be difficult during the corticomedullary phase due to lack of contrast opacification of the renal medulla. (B) Later scans during the nephrographic phase increase the detection of central renal masses (arrow).

Detection of small renal masses can be difficult during the corticomedullary phase due to lack of contrast opacification of the renal medulla (Figure 2). Many centers now perform multiphase CT, including noncontrast, corticomedullary, nephrographic, and delayed images when evaluating renal masses. Multiphase CT has also been assessed in the initial evaluation of microscopic hematuria.³ Although the nephrographic phase remains important in the detection of small renal masses, the corticomedullary phase is essential for detection of renal vein extension and parenchymal organ involvement by metastases. The pattern of contrast enhancement of renal masses could also prove helpful, with one recent study describing characteristic enhancement patterns of papillary subtypes of RCC.⁴

Contrast-enhanced CT remains the study of choice in the evaluation and staging of renal masses, with staging accuracy reportedly as high as 91%.^{5,6} However, two indications for MRI include: the patient with renal insufficiency and/or with a history of contrast allergy who is unable to receive IV contrast material; and to evaluate the renal veins and inferior vena cava (IVC) for tumor thrombus prior to nephrectomy. MRI has the advantage of multiplanar capability, thus the renal veins and IVC can be imaged in an oblique coronal format. MRA sequences for the renal veins and IVC can also be useful to characterize tumor thrombus. Compared with CT, MRI most likely has increased sensitivity for the diagnosis of renal vein and IVC tumor invasion, although this has not been studied recently. MRI protocols vary depending on the particular sequence, but generally T1 pre- and post-gadolinium injection (especially with fat suppression), T2, and gradient-echo sequences with IV contrast are recommended.⁷⁻⁹ As with



Figure 3. Volume-rendered image of a central renal cell carcinoma. This examination was performed prior to potential partial laparoscopic nephrectomy. Because of the central location of the renal cell carcinoma (arrows), particularly the close relationship to the right renal artery, a complete laparoscopic nephrectomy was performed.

CT, enhancement of a renal mass is highly suspicious for RCC.

Three-dimensional postprocessing of CT datasets provides a more complete evaluation of renal masses than axial images alone, including the relationship to renal vessels and the collecting system (Figure 3). The use of advanced processing techniques and optimal protocols is likely to increase in importance as newer, less-invasive treatment options become more widespread.

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MEDICAL ECONOMICS

eHealth Act of 2002: Grants for Provider Groups

Jeff Hagmeier

Payers and larger healthcare entities are successfully adopting new technologies for transaction processing and patient data management at astounding rates. They do this in the face of smaller operating margins and regulatory requirements, such as HIPAA and CMS. This shift promises to follow in the footsteps of the financial services industry by creating efficiencies through standardized transaction processing and improvements.

Heavy Burden

The transition is creating substantial financial and patient management burdens for provider groups and smaller acute care clinics. Groups of all sizes face broad-based changes in requirements for reimbursement processing and patient information storage and security. Even small provider groups now face a confusing array of different and seemingly incompatible systems and requirements. On average, more than a half-dozen software applications are used to gain a current "snapshot" of a single patient's overall status, diagnosis, treatment, and reimbursement. While a comprehensive electronic medical record software package may solve many of these issues, provider groups often find implementation costs and decision-making prohibitive. The net result is providers struggle with disparate and legacy systems that require significant increases in manual processing by already overwhelmed administrative staff who manage patient information across multiple applications routinely. Experts estimate

an additional \$17.6 billion must be spent over the next several years for more efficient and secure record processing.¹

Help for Providers

Help in moving to a consistent secured standard for software and Internet transactions and data retrieval may be on the way for some provider groups. Unlike other recent regulatory bills such as HIPAA, The Efficiency in Health Care Act, S. 2638, also known as the "eHealth Act of 2002," if passed, requires payers and providers to increase their use of information technology (IT) and it authorizes at least \$350 million in grants to assist providers.

Introduced by Senator Edward Kennedy (D-MA), the Bill is intended to "encourage health care facilities, group health plans, and health insurers to reduce administrative costs, and to improve access, convenience, quality, and safety, and for other purposes."² Kennedy echoes government and business analysts in his belief that widespread use of IT in the healthcare industry will save lives and dollars each year "Reducing administrative costs to the level of other industries would save enough to finance universal health care several times over."³

The Bill requires "each group health plan and insurer...to have in effect an automated, integrated system that allows for efficient and effective adjudication of claims and the detection of fraud and abuse."⁴ These systems must be capable of accepting and accurately processing claims with 99% accuracy.

The proposed legislation requires the "installation and use of a computerized physician order entry by all healthcare facilities"⁵ to reduce medication errors. The Bill specifies that the Secretary of Health, acting through the Agency for Healthcare Research and Quality and with assistance from an advisory group, would establish standards for computerized order entry.

To assist providers, the Bill authorizes \$250 million for fiscal year 2003 "and such sums as may be necessary for each of fiscal years 2004 through 2007."⁶ The proposed legislation provides grant preference for providers operating in rural areas and those treating large numbers of uninsured patients or those "in determination of the Secretary have

special needs for awards."⁶ Additionally, the Bill authorizes matching grants for fiscal year 2003, "and such sums as may be necessary for each fiscal year thereafter," to assist not-for-profit healthcare facilities with implementing physician order-entry systems.

Counterpoint

Critics focus on this lack of clarity in light of the healthcare industry's frustration with continually changing guidelines for HIPAA compliance. The Health Information and Management Systems Society of Chicago expect that "Provider and payer organizations likely will argue the true cost of the Bill would be billions of dollars higher." The Bill's failure to provide grants to insurers, healthcare facilities, and providers could substantially undermine legislative approval and compliance.

The eHealth Act of 2002 compliance deadlines of 5 to 10 years before withholding Federal plan payments is inconsistent with the pace of technology. More than 70% of Information Technology executives responding to an informal survey conducted by Health Data Management said they expect the Bill will fall short of positively impacting the healthcare focused software and information technology industry.⁷ While the Bill's goals are consistent with the healthcare industry's substantial need for cost containment and quality improvement, the eHealth Act of 2002 seems an unlikely vehicle for dramatic change in healthcare information management.

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LEARNING OBJECTIVES

After completing this program, the reader will:

- Be aware of the role of coronary artery screening within the context of full-body screening and its potential benefits.
- Recognize the value of the role of MSCT in identifying and characterizing adult renal masses.
- Appreciate the medical economic impacts of new radiologic technology.

- Recognize the value of MSCT and how it can be adapted to the pediatric population to provide optimal image quality but minimize the radiation dose.

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