Cardiac Computed Tomography in Private Practice Settings—
A Changing Landscape

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Abstract
Continued advances in computed tomography (CT) hardware and computer software and changes in reimbursement policies in the US are altering the application of this technology. For example, prospective gating, computationally sophisticated iterative reconstruction algorithms, and other refinements are drastically lowering the radiation dose to the patient. Other changes are improving image quality and reliability as well as laboratory workflow. However, the business model for providing cardiac CT services in the outpatient setting is challenging, and there are dynamic cardiologist workforce issues. Continued technical advances and clinical experience in select patient subgroups promise to lead to further changes in the use of this technology in patient care. In practice models where CT scanners can be kept very busy performing a combination of cardiac and perhaps non-cardiac CT imaging, cardiologists can offer increasingly refined and impressive diagnostic services using these technologies.

Keywords
Cardiac computed tomography (CT), coronary computed tomography angiography (CTA), prospective gating, medical reimbursement, cardiology workforce

“But doth suffer a sea-change into something rich and strange”
William Shakespeare, The Tempest

The term ‘sea-change’ is an idiom or poetic phrase meaning profound transformation, and was coined by Shakespeare in The Tempest. The term is appropriately applied to the complex transformation that the clinical practice of cardiac computed tomography (CT) continues to undergo. In the early and mid part of the first decade of the 21st century, coronary CT became established as a clinical tool following serial engineering advances, especially in CT hardware such as the number of detector rows. Very recently, continued advances in CT hardware and computer software and changes in reimbursement policies in the US have been altering the application of this technology. Continued clinical experience in select patient subgroups and issues related to the physician workforce promise to lead to further changes in the use of this technology in patient care.

Technical Advances
Each of the four major manufacturers of CT equipment has released significant advances every year for the past several years. Recent developments that have very quickly become standard of care for coronary CT angiography include new strategies for radiation dose reduction, smaller detector width, and improved gantry rotation speed. Currently, the following are considered minimal for performing consistent high-quality coronary CT angiography (CTA):1

- 64 detectors or greater;
- gantry rotation speed of 400ms or greater;
- detector width of 0.6mm or less; and
- a well-prepped and co-operative patient.

In addition, based on the rapid adoption of new technology, a cardiologist’s or radiologist’s equipment is now considered out-of-date for coronary CTA if it does not have the capacity to perform:

- electrocardiogram (ECG) radiation dose modulation;
- prospective ECG gating; and
- selective reduction in tube voltage for individual cases.

Physicians whose equipment has these capacities but who do not regularly use them have not kept up with current practice.1

Prospective Electrocardiogram Gating
Prospective ECG gating, also known as ‘step and shoot,’ is distinct from the more traditional approach for coronary CT data acquisition called spiral scanning or retrospective gating. With a spiral scanning approach, the X-ray tube is in operation as it spins around the patient and the table is continuously fed through the center bore. Images are gated in a retrospective manner. With spiral scanning, radiation dose can be lowered by timing with the ECG and reducing the tube voltage during the phases of the cardiac cycle that are not likely to need to be
reconstructed. This ECG dose modulation can lower radiation dosage substantially and is available through all manufacturers. Typically, the dose of X-rays is reduced during systole by 80–95%, and images of the coronary arteries obtained during this phase of the cardiac cycle would not be adequate for interpretation. This limitation can be important if the image quality of the diastolic phase is sub-optimal, as reconstruction of the systolic images might otherwise have allowed a poor study to be salvaged. ECG dose modulation of spiral CT scanning does reduce radiation dose compared with non-modulated scans. This reduction is in the order of 25–50%.

With a prospective gating/step-and-shoot approach, the X-ray tube emits X-rays only during a pre-specified portion of the cardiac cycle (typically diastole) and the table feeds in a step-wise fashion. This approach can lower radiation dosage substantially, and is now available on CT equipment from each of the main manufacturers. Radiation dosage reductions range from 56 to 83% compared with spiral scanning in non-randomized studies, and in all reports image quality has been judged to be equivalent or superior with the prospective gating approach. Prospective gating for coronary CTA is available and in clinical use with 64-slice, 256-slice, and dual-source CT instrumentation. One recent study described prospective gating for whole-chest CTA in an emergency room setting. Compared with spiral scanning, radiation dose was reduced from a rather high 31.8mSv to a much more reasonable 9.2mSv, and there was no difference in the number of evaluable coronary segments between the two approaches. The obvious limitation of prospective gating is that systolic images are not available. Functional CT images of the heart are sometimes needed (for example, in order to assess ventricular contraction or to image cardiac tumors), and prospective gating would not be optimal in such cases. Also, heart rate variability and arrhythmias can be problematic for prospective gating, leading to sub-optimal image quality. However, newer computer software for adaptive ECG gating allows CT scanners to adjust to unanticipated arrhythmias, making this problem less of an issue than it has been with previous CT equipment.

Several other maneuvers to lower radiation dosage have been applied very recently. Each of the manufacturers has proprietary software (for example for contouring) and filtering to lessen the dose to the patient. Also, in many patients undergoing coronary CTA, a lower tube voltage (for example 100kVp rather than 120kVp) results in very adequate image quality with a substantially lower radiation dose. In the recent Prospective Multicenter Study on Radiation Dose Estimates Of Cardiac CT Angiography I (PROTECTION I) study, Bischoff et al. assessed the impact on image quality and radiation dose of reduced 100kV tube voltage in 321 non-randomized, non-obese registry patients. This study found that, compared with the 120kV approach, there was no significant difference in image quality but a substantial reduction in radiation dosage (mean dose 14mSv with 120kV versus 6mSv with 100kV; p<0.05). Radiation dosage from medical diagnostic studies has received much attention in the medical and lay press recently. One of the primary tenets of radiation safety is keeping the radiation dose as low as reasonably achievable (ALARA). Thus, prospective ECG gating should be used when possible. Also, ECG-modulated dose reduction should be applied with retrospective gating when feasible, and lower tube voltage and other radiation-sparing techniques should be utilized whenever reasonable to do so.

Other Technical Advances
While coronary CTA can often produce coronary angiographic images of superb diagnostic quality with a very high negative predictive accuracy, there are significant limitations in some patients. For example, confines of spatial resolution make it difficult to discern stenosis severity in intermediate lesions and to deal with the blooming effects of coronary calcium. Also, issues of temporal resolution can limit the number of evaluable coronary segments because of motion artifact. Some of the important advances brought forth by the vendors of CT scanners that are part of the changing landscape of cardiac CT are discussed below.

Wide Field of View Coverage
The Toshiba Aquilion ONE (320 slices x 0.5mm width = 16cm coverage) is combined with novel cone beam reconstruction and scatter correction. This system allows for full volume coverage and dynamic scanning (see below). The Philips iCT scanner (128 slice x 0.625cm width = 8cm coverage) includes a novel air-bearing gantry with a rapid (270ms) rotation speed and a new tube with new 2-flying focal spot and 2D scatter grid. This system allows for a superb compromise of resolution, speed, and coverage. The Siemens Definition Flash AS+ scanner (64 x 0.6mm = 3.8cm coverage) utilizes dual-source CT, a new tube with 2-flying focal spot, and improved gantry rotation speed to provide superb temporal resolution (85ms). This scanner also has broader coverage than prior generations of Siemens scanners. These wider coverage systems allow for imaging the heart with fewer beats of the cardiac cycle (or even only one beat of the cardiac cycle), resulting in minimization or elimination of slice misregistration artifacts. They also expand the potential for CT perfusion imaging, now under development.

High Definition
GE’s new garnet-based detector material and design (CT7750 HD) results in improved spatial resolution compared with other CT scanners. The spatial resolution at 2mm scan length is 230µm, compared with about 300µm for other 64-slice CT scanners. This improvement results in less calcium blooming and better in-stent visualization, and should lead to improved stenosis detection.

Iterative Reconstruction
Iterative reconstruction protocols have been utilized in other imaging modalities, such as nuclear cardiology, for a number of years. These computationally intensive approaches improve image quality and/or allow the use of lower radiation dose compared with traditional reconstruction with filtered back projection. GE released its adaptive statistical iterative reconstruction (ASIR) technique on the CT7750 HD scanner in 2008. The approach reduces radiation dose by 30–50% and will be available on other CT scanners in the near future. GE is also working on another generation of ASIR called model-based iterative reconstruction (MBIR) that will require additional computing capacity for scanners to use it, but is expected to achieve additional dose reduction. Siemens has recently released a new iterative reconstruction technique called iterative reconstruction in image space (IRIS), which offers a 60% reduction in dose. The company reports that ISIR used with the
Imaging

Table 1: American Medical Association Current Procedural Terminology Codes for Cardiac Computed Tomography Angiography, 2010

| 2010 CPT Code | Description |
|--------------|-------------|
| 75571        | Computed tomography, heart, without contrast material, with quantitative evaluation of coronary calcium |
| 75572        | Computed tomography, heart, with contrast material for evaluation of cardiac structure and morphology (including 3D image post-processing, assessment of cardiac function, and evaluation of venous structures, if performed) |
| 75573        | Computed tomography, heart, with contrast material for evaluation of cardiac structure and morphology in the setting of congenital heart disease (including 3D post-processing, assessment of LV cardiac function, RV structure and function, and evaluation of venous structures, if performed) |
| 75574        | Computed tomographic angiography, heart, coronary arteries and bypass grafts (when present), with contrast material, including 3D image post-processing (including evaluation of cardiac structure and morphology, assessment of cardiac function, and evaluation of venous structures, if performed) |

Table 2: 2010 Medicare Allowables, Midwest Region

| Global | Professional | Technical |
|--------|--------------|-----------|
| 75571  | 64.19        | 21.47     | 42.73     |
| 75572  | 198.16       | 65.83     | 132.33    |
| 75573  | 281.68       | 94.35     | 187.33    |
| 75574  | 344.20       | 89.80     | 254.40    |

Source: Wisconsin Physician Services.

Table 3: Estimated Shortage of General Cardiologists in the US

| Year | Number |
|------|--------|
| 2008 | 1,685  |
| 2020 | 7,000–14,000 |

Somatom Flash CT scanner can conduct coronary CTA images at radiation doses of 0.85mSv. Toshiba’s iterative reconstruction offering is called adaptive iterative dose reconstruction (AIDR). It is expected to be released in the near future and the company says it can reduce dose by 76% for body imaging and 58% for head imaging on the Aquilion ONE scanner. Philips has recently unveiled iDose, its version of iterative reconstruction algorithms. The company indicates that with iDose, the radiation dose of coronary CTA studies can be reduced to 0.25–1mSv, as much as 80% lower than conventional filtered back projection reconstruction, with no loss of image quality.

Dual Energy/Spectral Energy

For several years Siemens has investigated the use of its dual-source CT scanner in a dual-energy mode. This approach uses a different kV from each source to produce different signals from basic materials in target organs, such as calcium, iodine, and water. The differences in the signals are exploited in order to improve image quality in software programs and to remove confounding calcium. Physicians have hoped that this dual-energy approach can be used to characterization atherosclerotic plaques. To date, Siemens has released 12 applications for dual-source imaging. Some sites use it routinely in clinical practice for non-cardiovascular applications. GE has recently rolled out its Gemstone spectral imaging. This approach utilizes one detector and what is called fast kVp switching. The kVp levels are switched with every other view and the benefits should be similar to dual-energy imaging with two detectors. Toshiba’s coming application of dual-energy imaging uses kVp and mA switching techniques. Calcium is obviously a frequent confounder for coronary and peripheral vascular CT angiograms. In the future, dual energy/spectral energy imaging techniques may provide insights into malignant versus benign tissue characterization and provide characterization of atherosclerotic plaques. In the near term, dual-energy calcium removal techniques appear promising.

Reimbursement Picture

As of January 1, 2010, the American Medical Association’s (AMA’s) current procedural terminology (CPT) 2010 includes new, permanent CPT codes for coronary CTA. The previous category III codes have been replaced with new category I codes to be used in billing. This development is an important step toward practitioners obtaining reliable and appropriate reimbursement for coronary CTA. Table 1 includes a detailed description of the four CPT codes that apply to coronary CTA, and Table 2 lists the global and technical/professional fee schedule for Wisconsin Physician Services (WPS), a Medicare contractor for one of the Midwestern regions. These rates apply only to this carrier in this location—there is no national Centers for Medicare and Medicaid Services (CMS) payment policy for these codes. Many other insurers reimburse more reasonably. However, at present, most locations in the US find that coronary CTA is reimbursed poorly, and numerous private insurance carriers decline to pay for these procedures. These policies leave many patients in a position of having to pay for the test themselves or deciding to decline to undergo the test. The reimbursement picture is also influenced by the 2010 CMS rule, which changes assumptions regarding the use of imaging equipment that costs more that $1 million. CMS has increased the assumption of the amount of time the equipment is in use from 50 to 90% of the time a practice is open for business. This change, of course, results in lower reimbursement for the technical component of the test. Other changes have been proposed in the US Congress and it does not appear that reimbursement for coronary CTA will be increasing in the US in the near future.

The relatively low reimbursement makes for a challenging business model for cardiac CT in the private setting. These CT machines do have enormous throughput capacity, but few centers have the number of referrals necessary to keep them adequately busy with cardiac studies alone. The higher-end (and more expensive) CT machines are really only needed for contrast coronary imaging, but many practices use them for coronary calcium scoring, which is usually paid for directly by the patient rather than a third party, to allow the business model to be successful. Also, peripheral vascular CTA is uniformly reimbursed and is a part of the CT business model for many cardiology practices. Hybrid positron-emission tomography (PET) and single-photon-emission CT (SPECT) are becoming more widespread in the cardiology private practice setting. The CT scanners in these instruments provide attenuation correction for the PET or SPECT myocardial image, but can be used for other purposes such as concomitant calcium scoring. Many
of these instruments have full-function CT scanners that can be used for coronary and vascular CTA. Some practices find that these hybrid scanners are a useful solution to the challenging business model of providing these services. For example, in setting where the number of coronary CTA and PET myocardial perfusion imaging case referrals are relatively low, a single machine can be used to provide multiple cardiac imaging services—an approach that uses space and personnel more efficiently.3

**Physician Work Pool Issues**

In the mid-1990s there was a commonly held belief that the US was training too many specialists, including cardiologists. The belief was furthered by the growth of for-profit managed care, which limited access to specialty services with its gatekeeper model. As a result of these beliefs, the number of cardiology training positions was reduced, and fellowship positions are today still less numerous than they were in 1994.10 However, managed care did not gain as much traction as expected and the projected surplus of medical specialists did not develop. In addition, several factors have led to an increase in demand for cardiology services: the aging of the baby boomer generation, the epidemic of obesity, dysmetabolic syndrome, and diabetes, and the clear finding that patients obtained better outcome if at least some of their care was from cardiologists. There is now a shortage of cardiologists in the US that the American College of Cardiology (ACC) task force estimates to be approximately 4,000 for all categories of cardiologists.10 The shortfall of general cardiologists is expected to more than quadruple by 2025, as patient demand continues to increase and a large portion of the cardiology work force approaches retirement age (see Table 3). These workforce dynamics will have a continued impact on the landscape of cardiac CT. It is not entirely clear what the results of that impact will be, but cardiology imaging specialists should experience less competition among themselves and the need for expertise in choosing and administering optimal cardiac diagnostic testing strategies should continue to grow.

In addition to this projected cardiology workforce shortage, economic forces are leading to a large shift in the practice arrangement of many cardiologists in the US. Declining outpatient reimbursement over the past few years, especially in cardiac imaging, has led to a large number of practices selling to non-profit hospitals.11 This phenomenon accelerated after CMS released its 2010 final rule—a rule that cut reimbursement for outpatient nuclear cardiology services by more than 35% in one year. Thousands of cardiologists who were recently in private practice are now, or will soon be, employed by healthcare systems. For these cardiologists, there may be a return of some of the credentialing quarrels with hospital radiologists that were common in the 1990s. However, for physicians who are able to work across specialties, the change in practice will allow a number of opportunities. For example, the business model for high-end cardiac CT equipment is much more likely to be successful if the CT scanner can be used broadly. Some of the newer advanced CT instruments have applications that are useful for both cardiac and non-cardiac purposes. For example, wide field of view scanners can be used for the heart as well as for whole brain perfusion imaging. Also, dual-source CT/spectral CT can be used for bone and calcium removal for both cardiovascular and non-cardiovascular imaging applications. Practice models in which cardiologists collaborate with other physicians may make it much easier for them to provide advanced cardiovascular CT imaging services to their patients. Given the realities of reimbursement and the physician work pool, many centers will likely put a premium on work flow and scanner efficiency in their CT purchase decisions.

**Conclusion**

The landscape of cardiovascular CT is in great transition. There continue to be important advances in CT instrumentation, especially in methods of reducing radiation dosage and in improving image quality and work flow. However, the business model for providing cardiac CT services in the outpatient setting is challenging and there are dynamic reimbursement and cardiologist workforce issues. In practice models where CT scanners can be kept very busy performing a combination of cardiac and perhaps non-cardiac CT imaging, cardiologists can offer increasingly refined and impressive diagnostic services using these technologies. 

1. DeFrance T, Opinion expressed at the Scientific Sessions of the Society of Cardiovascular Computed Tomography, July 20, 2009.
2. Earls JP, Berman EL, Urban BA, et al., Prospective gated transverse coronary CT angiography versus retrospectively gated helical technique: improved image quality and reduced radiation dose, Radiology, 2008;246:742–3.
3. Shuman WP, Branch KR, May JM, et al., Prospective versus retrospective ECG gating for 64-detector CT of the coronary arteries: comparison of image quality and patient radiation dose, Radiology, 2008;248:431–7.
4. Husmann L, Valenta I, Gaemperli O, et al., Feasibility of low-dose coronary CT angiography: first experience with prospective ECG-gating, Eur Heart J. 2008;29:191–7.
5. Efstathopoulos EP, Kelekis NL, Pantos I, et al., Reduction of the estimated radiation dose and associated patient risk with prospective ECG-gated 256-slice CT coronary angiography, Phys Med Biol, 2009;54:5209–22.
6. Xu L, Yang L, Zhang Z, et al., Low-dose adaptive sequential scan for dual-source CT coronary angiography in patients with high heart rate: comparison with retrospective ECG gating, Eur Radiol, 2009;19:1111–18.
7. Shuman WP, Branch KR, May JM, et al., Whole-chest 64-MDCT of emergency department patients with non-specific chest pain: radiation dose and coronary artery image quality with prospective ECG triggering versus retrospective ECG gating, Am J Roentgenol, 2009;192:1662–7.
8. Bischoff H, Hein F, Meyer T, et al., Impact of reduced tube voltage on CT angiography and radiation dose, JACC Cardiovasc Imaging, 2009;2:947–9.
9. Bateman TM, Business aspects of cardiovascular computed tomography: tackling the challenges, ACC Cardiovasc Imaging, 2008;1:111–18.
10. Rodgers GP, Conti JA, Feinstein JA, et al., ACC 2009 Survey results and recommendations: addressing the cardiology workforce crisis, J Am Coll Cardiol, 2009;54:1195–1208.
11. Wann S, Nonprofit hospitals buying up cardiology practices, Cardiology Today, December 1, 2008. Available at: www.cardiologisttoday.com/view.aspx?Id=33249References (accessed January 23, 2010).