<u>Dual-source Computed Tomography:</u>

<u>A Resolution Revolution</u>

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Abstract

Current single-source computed tomography (SSCT) scanners can image the coronary arteries, but SSCT's temporal resolution is undesirably low. Dual-source computed tomography (DSCT) is a new scanner technology using two x-ray tubes instead of the ordinary one, thereby cutting the standard temporal resolution in half. This breakthrough has many advantages over SSCT by not requiring multisegment image reconstruction, low scanner pitch, high radiation dose, or beta blocker use; and DSCT's dual energy has many exciting applications.

Introduction

Ever since computed tomography (CT) was introduced by Godfrey Hounsfield in the 1970s,[1,2] this imaging technology has expanded by leaps and bounds. First-generation scanners used a single detector and required almost 5 minutes per image slice. Currently, CT technology has progressed to the present-day scanners which use thousands of detectors and are able to take multiple images in less than a second.[1] Still, even with the latest generation SSCT scanners, due to imaging speed, some areas of CT imaging have remained elusive, such as imaging the coronary arteries on a fast-beating heart.[3] Yet, just when it seemed that CT was reaching its maximum potential in terms of gantry rotation times, a new scanner has been developed that promises to revolutionize CT imaging.[4-7] This scanner is twice as fast at imaging structures as an ordinary CT machine, but it only requires half the radiation dose.[2,7] What is this exciting, new scanner? Enter the SOMATOM Definition by Siemens Medical Solutions.[4] Introduced in 2005, this new scanner uses two x-ray sources instead of the ordinary one and is known as dual-source CT (DSCT).[3,4] It has opened up a whole myriad of potential applications for CT imaging, ranging from coronary angiography, to better imaging of pediatric, obese, and agitated patients. DSCT even offers new methods of tissue characterization and subtraction imaging.[4]

Discussion

In order to understand DSCT's ground-breaking status for CT, ordinary SSCT must be understood. A present-day CT machine consists essentially of a gantry controlled by an operating console which sets imaging parameters and has a computer for data analysis and storage.[1] The gantry comprises a circular housing containing a high-voltage generator, a rotating x-ray tube and its track, a concentric array of x-ray detectors, and a patient table that moves through the aperture of the housing during image acquisition. As the x-ray tube rotates around the patient lying within the bore of the CT scanner, the x-rays being produced are differentially attenuated (absorbed) by the various body tissues as the x-rays pass through them at different angles. Detectors located around the patient's body receive these x-rays, then quantify and process them using the computer into cross-sectional images. State-of-the-art CT scanners use a fanshaped x-ray beam and commonly have 64 concentric rows of detectors, allowing 64 images or cross-sectional slices to be imaged at one time.[1]

With 64-slice SSCT scanners, scans such as coronary angiography have become more achievable than ever before, yet problems still remain.[7] Essentially, SSCT's temporal resolution, or time of image capture,[8] is too low to do every patient that presents for a heart scan.[3] These ordinary CT scanners are simply not fast enough to adequately image areas of high motion, such as the coronary arteries of the heart, without a number of undesirable modifications, both to the patient's heart rate and to the CT scanner.[3,4,7] A different quality of scanner is needed. In the words of Cardiologist Dr. Gilbert Raff, "Better coronary imaging at this level is going to revolutionize the treatment of coronary disease."[7] This innovation is necessary for healthcare, because according to Dr. Raff, "coronary disease is the most common serious health problem in the developed world."[7] DSCT is that revolution for CT imaging, especially coronary angiography, because it can capture images twice as fast as SSCT scanners.[3-7]

The reason SSCT scanners cannot increase their temporal resolution is that the maximum rotational mechanical limit, which is the determinant of scan speed, is being reached.[4-6] SSCT scanners are capable of a gantry rotation time of 330 milliseconds (msec).[4] The mechanical force on the gantry associated with this rotational speed is approximately 28 times the force of gravity.[4,5] In imaging of the coronary arteries, the desired temporal resolution requires a gantry rotation time of less than 200 msec (temporal resolution of 100 msec) which generates mechanical stresses greater than 75 times the force of gravity.[4,5] These mechanical stresses are too high for today's technology.[4,6]

Because a minimum of 180 degrees (half) of the 330 msec long gantry rotation is required to create one image slice, SSCT is only capable of producing 165 msec true temporal resolution.[3-6] The solution to increase imaging speed is to take a 64-slice SSCT scanner and add another x-ray tube at 90 degrees to the first, as well as another array of detectors.[3,4,6-8] The result is a DSCT scanner. This scanner only requires 90 degrees of the gantry rotation to create one image slice, giving a temporal resolution of 83 msec,[3,4,7] as seen in Figure 1.

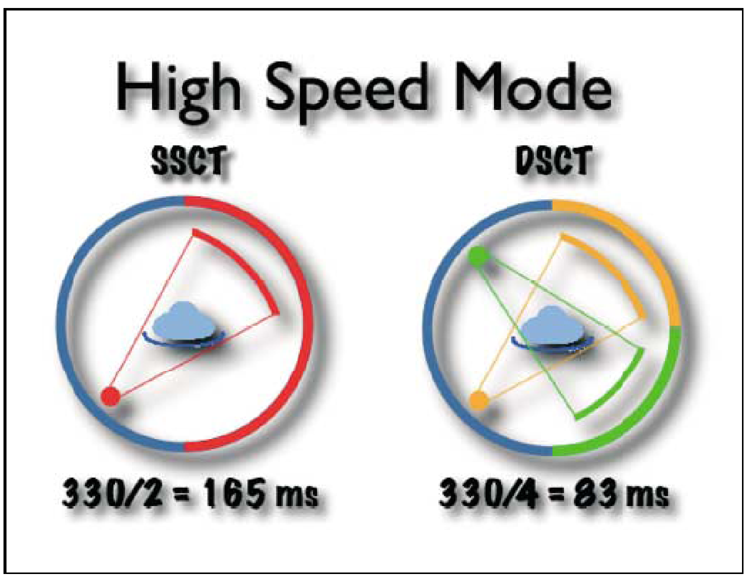

Figure 1. Temporal resolution of single-source CT versus dual-source CT[9]

To prevent motion artifacts, SSCT often requires beta blocker medications to be administered to the patients to lower their heart rates.[4-7] The target heart rates required for SSCT are approximately 65 beats per minute (BPM) or less, to prevent motion.[3] Radiologist Richard White says that with SSCT's comparatively low temporal resolution, doctors are "dependent upon picking the right patients. With future CT technology improvements, we need to be able to do an examination on any patient."[7] The problems with beta blockers are that the patients require medical surveillance,[7] and many patients are unable to take the medications due to their medical conditions.[3] According to Dr. Raff, "We could save a lot of time, work, and cost, if we didn't need to give patients these beta blockers."[7] Beta blockers are not required for DSCT because of its high temporal resolution.[3,7]

Another benefit of the DSCT scanners is that they do not need to use the multisegment reconstruction techniques that the SSCT scanners use in order to increase temporal resolution.[4,6] Multisegment reconstruction is gathering information from one scan and combining it with a previous scan to increase temporal resolution.[7] Unfortunately, unless the heart beats at a perfectly consistent rate and rhythm, then the image will be blurred.[5,7] In addition, only a few very specific heart rates are useful for multisegment reconstruction with SSCT.[4] Because of its high temporal resolution, DSCT does not need to use multisegment reconstruction.[3-5,7] It may obtain all of its information for an image slice in one heart beat, eliminating the problems with high and irregular heart rates that SSCT faces.[3-5,7]

Because DSCT does not require multisegment reconstruction for imaging the coronary arteries, with increasing heart rates, pitch may also increase.[3-7] Pitch is a ratio showing how far the table moves each time the x-ray tube rotates around the patient.[1] SSCT requires a low pitch or table speed, using a pitch of about 0.2 to 0.3, on average.[3] DSCT, on the other hand, allows an increase of pitch with increased heart rates.[3-7] For instance, a heart rate of less than 50 BPM may be scanned at a pitch of 0.2, but a heart rate greater than 100 BPM may be scanned at a pitch of 0.5, typically.[3] If pitch is doubled, the area imaged with each scan is also doubled,[1] and radiation dose is reduced.[3] In one study with DSCT,[5] as heart rate increased from less than 55 BPM to greater than 90 BPM, table speed increased from 11.6 to 26.8 millimeters per second. This rate is over twice the table speed, thus half the radiation time.[5]

This radiation dose reduction highlights one of DSCT's chief advantages over existing scanners in that it cuts a patient's radiation dose in half.[5,7] According medical physicist Dr. Cynthia McCollough, "minimizing radiation exposure is very important."[7] Because DSCT has two x-ray tubes, the logical expectation is that it doubles the radiation dose compared to that of a SSCT scanner, but this assumption is negated by the fact that DSCT images at twice the speed of SSCT.[3-5,7] Yet, DSCT does not merely provide the same dose in half the time, it provides as little as half the dose in half the time![5-7]

DSCT achieves this feat in a number of ways. First of all, DSCT takes advantage of the previously mentioned increase in pitch.[3-6] Without a need for multisegment reconstruction, scan slices need not overlap. In other words, the same area does not have to be scanned multiple times as with SSCT. The increased pitch allows increased table feed through the CT scanner with increasing heart rate, meaning that increased heart rate is actually an advantage with DSCT. Another method of reducing patient radiation dose that is not as effective with SSCT as with DSCT, is through electrocardiogram (ECG) gating.[3-6] ECG gating limits radiation exposure by monitoring the patient's heart rate and only allowing exposure during its optimal imagable phase.[3,5,8]

To fully understand the importance of DSCT's ability to reduce radiation exposure, one must understand how much the radiation is reduced and the corresponding benefit to the patient. The greatest risk from radiation exposure is cancer.[2] The Food and Drug Administration estimates the radiation risk of 10 millisieverts (mSv) of radiation as causing a 1/2000 risk of fatal cancer, while other estimates place the risk at 1/1000.[2] The question, then, is how much radiation does DSCT, or CT in general give?

Coronary CT angiography gives an effective radiation dose of about 14.8 mSv with ECG gating and 9.4 mSv without it, using a SSCT scanner.[3,10] Using ECG gating with a DSCT scanner, the effective dose is 7.8 to 8.8 mSv.[3,10] In contrast, heart catheterization, the alternate and conventional method of coronary artery imaging, itself gives 2-6 mSv of effective dose,[8] but carries with it a multitude of other risks.[3,7] For reference, annual background radiation, or the radiation received during normal life for the average United States resident, is 3.6 mSv.[5]

Just how good is DSCT at imaging patients, especially those with high heart rates? Flohr et al.[4] did a study of eight patients that were not given beta blockers or other heart-control medications, and whose heart rates were between 65 and 90 BPM. Despite the high and often irregular heart rates, they found that there were minimal motion artifacts on the images because of DSCT's high temporal resolution.[4]

Just because DSCT excels at coronary angiography, does not mean it is its only application. If just one tube is energized, the DSCT scanner functions essentially the same as an ordinary single-source 64 slice CT scanner.[4,5]
In addition, the two x-ray tubes may be operated at independent kilovolt and milliampere techniques[4,11] and together have 160 kilowatts of power for x-ray production.[4-6] The extra power is helpful for very rapid scans, allowing all the x-ray production in a very short amount of time.[4]

DSCT is also helpful for imaging pediatric patients, because it reduces radiation and its high temporal resolution eliminates the motion problems that SSCT faces.[6,7,12] Finally, DSCT's high temporal resolution is beneficial for agitated or traumatized patients, because like pediatrics, they are often unable to remain still for a scan.[7]

Another benefit of the DSCT scanner is its previously mentioned 160 kilowatts of power for creating x-rays. The extra power from the second tube is extremely useful for imaging obese patients.[3,4,7] Their large amounts of soft tissue absorb much of the x-rays, and the inadequate x-ray dose with ordinary scanners results in high image noise.[7] According to one expert, "In obese patients, the deterioration of image quality can be so substantial with conventional CT scanners that many of these patients have undiagnosable lesions."[7]

Of great usefulness is DSCT's ability to distinguish between tissue types and subtract unwanted material, using its two x-ray sources, one tube operating at 80 kilovolts and the other at 140 kilovolts.[3,4,7,11] This ability is based on the fact that different tissues attenuate x-rays differently at different x-ray energy (kilovolt) levels.[1,4,7] This feature is extremely useful for subtracting bone during angiographic studies.[4,7,11] Other dual-energy uses of DSCT include measurement of the amount of blood perfusion following a stroke, measurement of the amount of elements such as iron in the body or calcium in a stone, and tissue characterization such as tumors versus healthy tissue.[4,11]

Conclusion

DSCT is a technological breakthrough that is far more than just a researcher's toy. Nor is DSCT just for specialty clinics either. DSCT has clearly surpassed ordinary CT in many areas, ranging from its higher temporal resolution, and lower radiation dose, to its immense usefulness with cardiac, pediatric, or obese patients, and its ability to differentiate tissues. If patients understand the clinical advantages of DSCT over SSCT, given the option and cost not prohibiting, they would probably choose the DSCT scanner. It would seem the clear choice to use this technology to remain competitive in healthcare, but more importantly to provide the best possible patient care, getting pictures with the most information and least radiation dose. Dual-source CT is CT on a whole new level. This development is radiology at its best.[7]

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Best regards
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