Dual-Energy and Dual-Source CT: Is There a Role in the Abdomen and Pelvis?

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KEYWORDS

• Radiation dose • CT applications • Abdominal CT
• Dual-energy CT • Dual-source CT

Dual-energy CT refers to the use of CT data representing two different energy spectra to display anatomy and pathology in addition to differentiating and classifying tissue composition. Dual-energy CT data can be obtained and viewed using various hardware and software applications capable of material-specific classification and image display.

Dual-source CT refers to the use of two x-ray sources and two detectors mounted on a single x-ray gantry. A dual-source CT system can be used in a dual-energy mode (with each x-ray tube operating using a different polychromatic x-ray spectrum), in a cardiac mode (with both tubes operating at the same tube energy to improve temporal resolution), or in an "obese" dual-source mode (to permit a wider range of tube currents at low or high tube energies).[1,2] Throughout this article we refer to this obese mode (using the same tube energy in both tubes) as dual-source CT.

One principal advantage of both dual-energy and dual-source abdominal CT is the ability to perform lower-kV scanning in a larger number of patients. The CT numbers displayed in CT images are related to the linear attenuation coefficient of a substance, which is a function of its material composition, the photon energies generated by the x-ray tube, and the mass density of the material. This relationship explains why two different materials (such as iodine and calcium) can have the same CT number (**Fig. 1**). Both dual-energy and dual-source CT techniques can consequently use lower x-ray tube potentials (ie, photon energies) to highlight pathologies that become more conspicuous with the use of intravenous iodinated contrast, because the signal of iodine at 80 kV is approximately twice that at 140 kV. The difficulty with the routine use of low-kV CT is increased image noise, which can be minimized using both techniques. With dual-energy CT, the noise of the low-kV data is offset by the decreased noise of the higher-kV data. At dual-source CT, the use of both x-ray tubes extends the dynamic range of tube currents available beyond the system limits of single-source CT systems. The separation of materials can be achieved using only dual-energy CT, wherein CT numbers at each voxel can be compared between two different tube energies. Although the polychromatic spectra of commercial x-ray tubes overlap, the mean energy at different tube energies is unique. By analyzing our

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Fig. 1. Using single-source CT two different materials can have the same CT number because they possess different mass densities, a point illustrated by this image from a CT angiogram, in which the CT numbers of the calcium-containing bone overlap with the CT numbers of the aorta, which contains intravenous iodinated contrast.

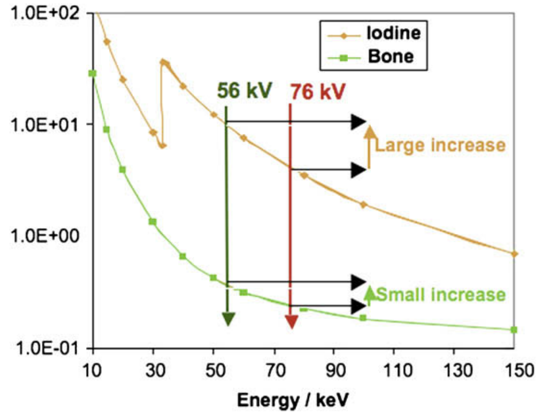

Fig. 2. The separation of materials of different composition can be achieved using dual-energy CT, wherein the CT numbers at each voxel can be compared between two different tube energies. This graph shows the linear attenuation coefficients of iodine (*orange line*) and calcium (*green line*) at 56 kV (the mean photon energy generated from a commercial x-ray tube operating at 80 kV) and 76 kV (the mean photon energy generated from a commercial x-ray tube operating at 140 kV). In this example, there is a large difference in the linear attenuation coefficients of iodine between the two energies, but a much smaller difference in the linear attenuation coefficients for calcium. These unique absorption properties of the two materials permit their material classification at dual-energy CT.

knowledge of the absorption or properties of different materials at different x-ray energies, materials can be separated. For example, there is a large difference in the linear attenuation coefficients at two energies for iodine but a smaller difference in the linear attenuation coefficients for calcium (**Fig. 2**). Dual-energy CT, therefore, provides an opportunity to separate materials with different effective atomic numbers.

IMPLEMENTATION AND APPROACHES

Dual-Energy Hardware Approaches

There are three primary hardware approaches to dual-energy CT technology: two x-ray sources (in dual-source CT scanner), rapid kV switching (using single-source CT), and a "sandwich" detector. When using a dual-source scanner, each x-ray tube operates at a different energy. With current hardware the x-ray tube operating at a lower kV has a diminished field of view (FOV, 26 cm) compared with the tube operating at the higher energy, which has a 50-cm FOV, because the detector size is limited by the gantry. The advantage of this approach is ample preliminary experience (because dual-source CT technology has been in existence for approximately 2 years) and routine image reconstruction, because images are acquired simultaneously by the two detectors separated by 90° phase. The current weakness of this approach is that the dual-energy processing is performed after image reconstruction (ie, in image space), rather than on projection data before image reconstruction (ie, in projection space), because most data are acquired in helical mode with the two detectors 90° apart. Additionally, there is some slight blurring of mixed-kV image displays when combining the output of the two x-ray tubes.

Another approach is rapid kV switching. In the rapid kV switching paradigm, the x-ray tube is capable of rapid kV and mA modulation, switching from low to high energy at adjacent projections. This switching necessitates doubling the number of projections per rotation to maintain image quality, thereby requiring refinements at the tube and detector levels. The principle advantage of this technique is that it offers the potential to perform dual-energy processing using projection data acquired in both axial and helical modes, theoretically permitting accurate material decomposition and monochromatic CT image display, which should substantially decrease image artifacts. The disadvantage of this technique is that the low- and high-energy scans are limited to the same filtration and hence the spectra separation of the two energies is suboptimal. Another potential disadvantage of this technique is that it may be difficult to change the tube current fast enough during each kV switching, thus yielding mismatched noise level in the two data sets.