ADVANCES IN FUNCTIONAL AND DUAL ENERGY CT

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First experiments with dual energy CT date back to the late 1970s. However, the spatial resolution of early computed tomography, the unstable density values with additional systematic errors and the scan durations at that time hampered the success and general application of the technique.

Another major problem was that tube technology did not provide sufficient tube currents at low tube voltages to achieve an equal and sufficient output of quanta relative to the higher voltage tube, and this adaptation is impossible with a two detector technique. Thus, bone densitometry in projection radiography has remained the only broad application of dual energy techniques today, and some other applications such as dual energy projection radiography or CT for the detection of calcifications in pulmonary nodules or for the quantification of abdominal fat tissue never found widespread application.

The differentiation of material in computed tomography is based on their radiolucency or radiodensity as quantified in Hounsfield Units and displayed in shades of grey at different window levels in normal CT scans. However, radiodensity is a description for the attenuation caused by absorption and scattering of radiation by the material under investigation. The two main mechanisms responsible for these effects in the photon energy range used in CT are the Compton scatter and the photo effect. The contribution of these two processes to the radiodensity of different materials varies and also depends on the energy of the x-ray photons.

Thus, materials can be differentiated further than by radiodensity alone by applying different x-ray spectra and analyzing the differences in attenuation. This works especially well in materials with large atomic numbers due to the photo effect. One of these materials is iodine, which is generally used in CT as contrast material and of which it is generally known that the enhancement is stronger in low tube voltage settings. This effect makes it attractive to use the spectral information to differentiate iodine from other materials that do not show this behavior. One purpose of this differentiation in imaging can be the display of contrast-enhanced vessels without any calcium containing structures to assess the carotid and vertebral arteries in the skull base and the cervical spine. Another potential application is to differentiate contrast enhanced structures from otherwise dense material in parenchymatous organs, for example to differentiate initial metastases from focal fat sparing in the liver or to differentiate complicated cysts from neoplastic tissue in the kidney.

With the recently introduced dual source CT scanner, a main drawback of contrast material applications with dual energy differentiation has been resolved. With single source scanners, the spiral datasets at both energy levels have to be acquired separately so that the contrast enhancement will change between the scans. With the two tubes and detectors mounted orthogonally in dual source CT, both spiral acquisitions run simultaneously, which excludes changes in contrast enhancement or patient movement between the acquisitions.

Our initial patient studies have confirmed that the technique makes clinically relevant applications of dual energy CT feasible without additional patient dose. Of course, a lower image noise would be desirable for most of these applications, but a higher patient dose could not be justified at the current state of knowledge. The differentiation of iodine in tissue can be of diagnostic value, as shown in the liver and kidney lesions. Of course, the reliability of correct classification will have to be determined in more specific studies with external validation. The ‘virtual unenhanced’ image may make it possible to discard the additional acquisition of a pre-contrast scan. Although the noise is higher and the resolution of the image is lower in this reconstruction, it may be sufficient to assess contrast enhancement in parenchymatous organs with the advantage that a misregistration is impossible. Another potential application of dual energy CT of the liver would be the quantitative assessment of steatosis or of iron overload in hemochromatosis patients. However, it has been recognized in earlier studies that these only work reliably in the absence of each other. Another interesting approach in this field may be the differentiation of copper for the detection of Wilson’s disease.

The application of bone removal may help to assess supra-aortic vessels without overlay of calcified plaques and bones at the skull base and in the cervical spine around the vertebral arteries. Of course, the performance of these algorithms will have to be evaluated and will also depend on the further technical development. The depiction of pulmonary perfusion may offer new insights comparable to perfusion scintigraphy, and the additional application of single-breath xenon acquisitions to assess lung ventilation without previous unenhanced acquisitions may give a new functional aspect to pulmonary imaging in CT.

Regarding the differentiation of collagen, image noise has proved to remain a problem. However, the technique may be of interest to assess the continuity of tendons and ligaments or to assess residual articular cartilage in arthrosis for the consideration of joint replacement in trauma patients.

All these applications await further investigation to determine their reliability and clinical diagnostic value. This will be facilitated by the fact that Dual Energy CT can be performed without additional radiation exposure and with the simultaneous reconstruction of fully diagnostic images with a spectrum very close to 120 kV and the same low image noise as in a routine exam.

SUGGESTED READING

1. *Flohr et al.*
   First performance evaluation of a dual-source CT (DSCT) system.
   European Radiology (2006) vol. 16 (2) pp. 256-68

2. *Petersilka et al.*
   Technical principles of dual source CT.
   European Journal of Radiology (2008)

3. *Godoy et al.*
   Basic principles and post processing techniques of dual-energy CT: illustrated by selected congenital abnormalities of the thorax.
   Journal of thoracic imaging (2009) vol. 24 (2) pp. 152-9

4. *Graser et al.*
   Dual-energy CT in patients suspected of having renal masses: can virtual nonenhanced images replace true nonenhanced images?
   Radiology (2009) vol. 252 (2) pp. 433-40