Dual Energy Computed Tomography: How Does It Work and What Can It Do?
Michael R. Bruesewitz, R.T.(R)1, Cynthia H. McCollough, Ph.D.1, Natalie N. Braun, B.S.1, Andrew N. Primak, Ph.D.1, Joel G. Fletcher, M.D.1, Bernhard Schmidt, Ph.D.2, Thomas Thohe, Ph.D.2
1CT Clinical Innovation Center, Department of Radiology, Mayo Clinic, Rochester, MN; 2Siemens Medical Solutions, Forchheim, Germany

What is Dual Energy CT
In CT imaging, materials having different chemical compositions can be differentiated by the use of two or more tube potentials for electronic excitation and a subsequent decomposition and quantification of different types of sources (scatter, primary, material composition) as well as their corresponding virtual non-contrast images. Scattered radiation results from the low kV beams that are preferentially absorbed by highly attenuating materials. The low kV dataset therefore becomes the virtual non-contrast image (VNC). The high kV beam, on the other hand, would pass through these materials with better penetrating power and would have a relative increase in the amount of scatter. The high kV dataset then becomes a mixed image, with both scattered and high-energy beams contributing to the final image. The VNC and mixed images can be used to construct an effective atomic number map and consequently, a component image for each material of interest. As a result, any two materials can be distinguished from each other regardless of their respective densities. Although medical x-ray attenuation is determined by the mass attenuation coefficient and the material density, which is a function of the material composition, the effective atomic number and the electron density, the electron density is also a function of the material composition. Therefore, the virtual non-contrast image is a function of both the density and the material composition.

New Approaches for Dual Energy CT Using Dual Source CT Systems
Dual source CT is a CT system that has two x-ray sources that can be operated simultaneously with different tube potentials. The low kV beam is used to principally excite the material composition. The high kV beam is used to principally excite the electron density. At Siemens Medical Solutions, the virtual non-contrast and mixed images of the different dual source CT platforms are reconstructed using the same algorithm. Although the dual energy software tools (SyngoDE) for the Siemens Definition became commercially available in March 2007, with an initial focus on the following three clinical tasks:

Iodine Imaging
Virtual-Non-Contrast (VNC) Images
Automated Bone Removal in CT Angiography

Clinical Applications of Image-Based, Dual-Source, Dual-Energy CT
Iodine Imaging
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Image-Based Dual Energy CT Techniques
The principle of dual energy CT is to simultaneously acquire images at low (e.g., 80, 85, 90 kV) and high (e.g., 100, 120, 140 kV) tube potentials. As a result, two sets of data are acquired at different kV characteristics. The effective atomic number can be calculated from the dual energy data using the following relationships:

\[ Z_{eff} = \frac{Z_1 + \frac{Z_2}{2}}{1 + \frac{Z_2}{2}} \]

where \( Z_1 \) and \( Z_2 \) are the electron densities of the low and high kV data, respectively. The resulting effective atomic number can then be used to calculate the mass attenuation coefficient and subsequently, the mass density of a material. By calculating the mass density of a material, the material composition can be determined.

Projection-Based Dual Energy Image Decomposition
Projective methods for dual energy image decomposition were first reported by Schmücker and Maier-Hein in 2005. They demonstrated that even with polychromatic x-ray beams, one can still differentiate materials on polychromatic CT images into their fundamental components from the monoenergetic effect and the angular factor.

Material Characterization
Several clinical applications exist where neither bone nor iodine are of interest. Dual energy CT may be used to characterize materials present in the body. By calculating the mass density of a material, the material composition can be determined.

Stone Characterization
Dual energy CT may be employed to detect and characterize renal stones. Although the use of dual energy CT can improve stone characterization, it is not a substitute for conventional intravenous urography (IVU) or ultrasound (US) imaging. In many cases, a combination of dual energy CT and standard imaging modalities (IVU or US) is required to achieve a complete characterization.

Conclusion
Dual energy CT is a powerful tool that can be used to improve the accuracy and efficiency of CT imaging. Although the use of dual energy CT can improve stone characterization, it is not a substitute for conventional imaging modalities. In many cases, a combination of dual energy CT and standard imaging modalities is required to achieve a complete characterization.

References