Use of Dual-Energy Computed Tomography for Evaluation of Genitourinary Diseases

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KEYWORDS

• Dual-energy CT • Renal stone • Renal mass • Radiation dose

KEY POINTS

- The elemental physics basis for dual-energy computed tomography imaging is represented by application of 2 different x-ray energies.
- Renal stone mineralization can be noninvasively ascertained using dual-energy computed tomography.
- Dual-energy computed tomography has the potential for ameliorating incidental renal mass and renal cell carcinoma evaluation.
- Potential limitations and pitfalls pertain to dual-energy computed tomography and their knowledge is of utmost importance when dual-energy computed tomography is used for imaging the genitourinary system.
- Dual-energy computed tomography protocols have radiation dose values close to those of traditional computed tomography reference.

INTRODUCTION

Computed tomography (CT) is the most widely used imaging technique in the diagnosis, management, and follow-up of genitourinary diseases.[1] CT scanning can accurately detect and characterize the wide spectrum of genitourinary diseases, such as renal stone or renal parenchymal abnormalities, guiding clinician to the most appropriate treatment.[1] However, many limitations pertain to conventional CT imaging techniques in the evaluation of genitourinary disease.[1]

After its introduction for clinical applications about a decade ago, accumulating evidence has suggested that dual-energy CT scanning may overcome some of the conventional CT limitations and expands CT solution available for assessment of genitourinary system diseases.[2–4]

The aim of this article is 4-fold: to offer a practical synopsis on foundation concepts for dual-energy CT scans, to outline the clinical application of dual-energy CT scans for genitourinary diseases, to critically appraise the strengths and

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weaknesses of the technique in genitourinary imaging, and, above all, to demonstrate its impact on clinical decision making in a variety of genitourinary diseases.

BASIC PHYSICS PRINCIPLES AND TECHNOLOGY

The differentiation of various materials using conventional single-energy CT scanning is based on their x-ray attenuation expressed as CT numbers in Hounsfield units (HU). CT numbers, however, are arbitrary units of x-ray attenuation, calibrated with reference to water.[5] This inherent limitation of CT numbers results in the potential ambiguity for discriminating different materials owing to considerable overlap in material attenuation. Dual-energy CT scanning may decrease this ambiguity by interrogating the material-specific attenuation properties at different energy levels.[6] Dual-energy CT scanner designs available for clinical use include dual-source, rapid-switching, dual-layer detector, and sequential dual-energy CT scans.

The elemental physical mechanism of dual-energy CT scanning is represented by the photoelectric effect.[7] The photoelectric effect refers to the removal of an electron from the k-shell (the innermost shell) of an atom by an incident photon.[5,7] The photoelectric effect occurs when an incident photon has sufficient energy to overcome the k-shell binding energy of an electron.[5,7] This binding energy is characteristic of each elemental chemical element. The closer the energy level is to the k-edge of a substance such as iodine, the more the substance attenuates. k-edge values (ie, the maximum peak of attenuation for a given material) vary for each element, and they increase as the atomic number increases.[7–10] Indeed, chemical elements with a higher atomic number, such as calcium and iodine, can be characterized from other components of the matter that have a significantly lower k-edge and consequently a different attenuation spectrum.[7–10]

Moreover, dual-energy CT acquisition enables the generation of multiple datasets, having clear advantages in tumor detection, lesion characterization and, possibly, evaluation of treatment response. By interrogating the attenuation characteristics of different materials at different x-ray energies, virtual monochromatic images can generate tissue-specific spectral attenuation curves based on the unique k-edge characteristics of materials with different elemental composition.[10]

Dual-energy CT scanning performs as a single energy CT scan, producing conventional images (ie, blending and monoenergetic images) that can be optimized to improve iodine conspicuity and allow material-specific data analysis. Various material decomposition algorithms can be applied to reconstructed voxels, with some existing differences between dual-source and single-source platforms.[6–10] The 3-materials decomposition algorithm used by dual-source platforms allows for targeting the iodine contrast material: iodine can be either erased from the image thus producing a virtual noncontrast (VNC) image (**Fig. 1**), or selectively portrayed, resulting in a color-coded iodine series (see **Fig. 1**).[6–10] The evaluation of imaged tissues through real-time, computer-based interaction allows for quantitative extraction and measurement of iodine contrast content in milligrams per milliliter (see **Fig. 1**).[7,9] Rapid-switching and spectral detector CT systems use a 2-material decomposition approach targeting companion materials, thus enabling reconstruction of binary sets of images (eg, water-density and iodine-density images). These datasets provide separate material information and, similar to the 3-material

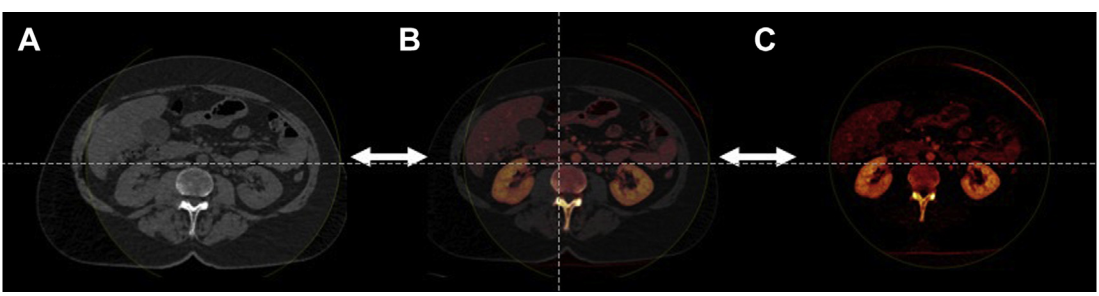

Fig. 1. Three materials decomposition algorithm allows for identifying the iodine contrast material. Iodine can be extracted from reconstructed voxels to obtain a virtual noncontrast image (*A*) or it can be selectively represented in different degrees in the same image dataset, resulting in a color-coded iodine series having varying degrees of representation of the contrast material (*B*) up to an iodine map (*C*). Based on the same principle, iodine can be quantified from a region-of-interest measurement in milligrams per milliliter.