Dual-Energy Computed Tomography in Genitourinary Imaging

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KEYWORDS

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

KEY POINTS

- Dual-energy computed tomography (CT) imaging relies on the near-simultaneous collection of information at 2 energy spectra.
- Dual-energy CT enables in vivo determination of renal stone composition.
- Dual-energy CT can improve the noninvasive characterization of renal masses.
- Radiation dose values achieved with dual-energy and single-energy CT techniques have become nearly comparable.

INTRODUCTION

Contemporary imaging assessment of urogenital disease is entrusted to cross-sectional modalities, often computed tomography (CT) imaging.[1] In many clinical circumstances, CT yields confident depiction of the variety of etiologic agents underlying urogenital disorders, such as renal stone, renal parenchymal, or urothelial abnormalities.[1] Nonetheless, conventional CT imaging techniques have inherent limitations in their ability to precisely typify genitourinary disease, including the composition of kidney stones or the nature of a renal mass.[1]

Revitalized by modern breakthroughs in hardware and computer architecture, dual-energy CT compellingly returned to the clinical imaging stage.[2–9] This powerful imaging technology enriches the assets in CT solution available to the practicing radiologist for diagnosing genitourinary diseases.[3,6,8] This state-of-the-art review article offers a practical synopsis on foundation concepts for dual-energy CT and its clinical applications in genitourinary imaging.

FOUNDATION FOR DUAL-ENERGY COMPUTED TOMOGRAPHY IMAGING

The foundation principle for dual-energy CT imaging is represented by the near-simultaneous application of 2 different x-ray energies to the matter.[2–4] Although dual-energy CT imaging can be achieved by both tube-based (ie, dual-source CT, single-source CT with rapid switching in tube voltage, or single-source CT with consecutive scans or beam-splitting) and detector-based (ie, multilayer spectral CT and energy-resolved photon-counting CT) hardware solutions aimed to attain 2 diverse photon spectra (**Fig. 1**), its elemental physical mechanism—the common denominator among all viable implementations—is represented by the photoelectric effect.[5,6] This physical interaction occurs when an incident photon leads to ejection of an electron from the innermost orbital (so-called

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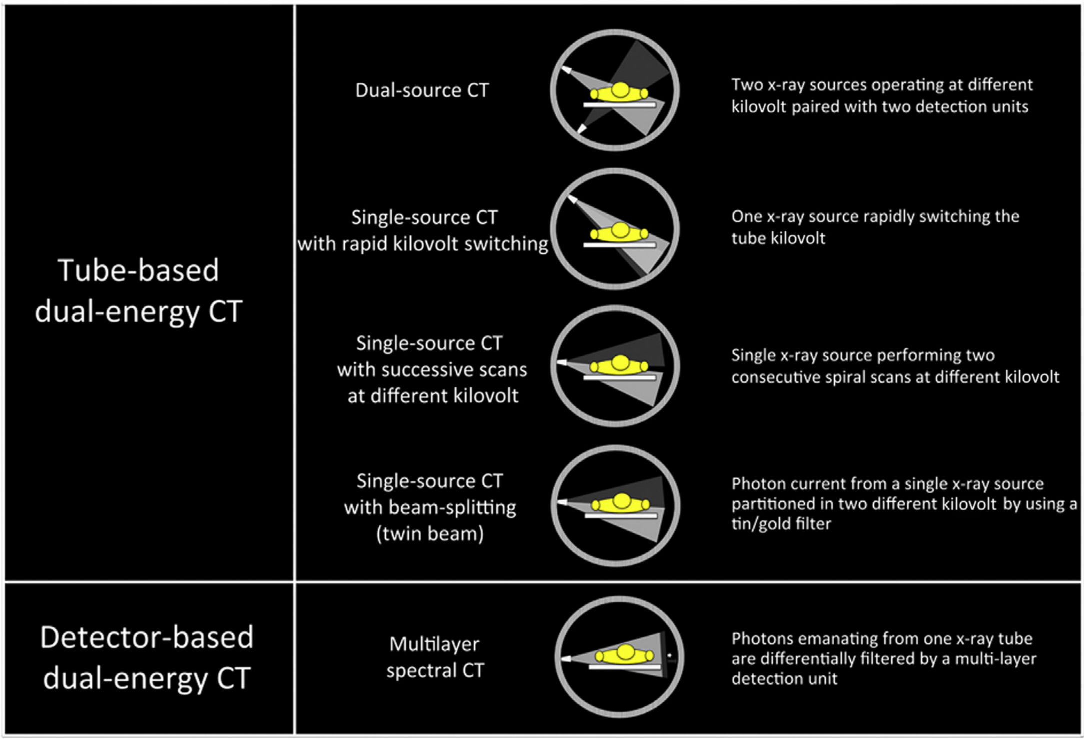

Fig. 1. Hardware-based scanning approaches to achieve dual-energy CT. Note that energy-resolving photon-counting technology is not represented under the category detector-based dual-energy CT because it is not currently widely available for clinical use.

k-shell) of the atomic structure; the electron-binding energy is directly related to the likelihood of the photoelectric effect to happen and is referred to as k-shell's binding energy.[5–9] This binding energy is characteristic of each elemental chemical element. The probability of physical photoelectric interactions is closely linked to the atomic number of a given material.[5–9] As such, it is possible to obtain data from materials or tissue under investigation.[5–9]

Translating these concepts into human imaging, when tissue components having varying atomic number and k-shell energy characteristics are illuminated with 2 different x-ray spectra, they can be identified, extracted, selectively displayed, and quantified based on photon absorption peculiarity.[5–9] Image datasets achieved with dual-energy CT can be depicted as material-specific display series (eg, virtual unenhanced series, iodine maps) or single-energy-equivalent datasets (ie, blended series and virtual monochromatic datasets).[6,9,10] The latter allow for seamless integration of dual-energy imaging into routine radiology practice for diagnostic interpretation on a picture archiving communication system (PACS).[6,9,10]

DETERMINATION OF RENAL STONE COMPOSITION

The in vivo, noninvasive ascertaining of renal stone mineral composition has long represented an ideal goal for imaging.[11–13] The chemical composition of a renal stone can guide the appropriate management (ie, urine alkalization in case of urate stones vs the need of extensive metabolic workup and more aggressive surgical therapies for nonuric acid stones) and, potentially, predict the likelihood of stone recurrence.[11–13] Although an array of different approaches based on a single-energy CT acquisition (eg, use of thresholds based single-energy CT numbers) have been investigated for differentiating among diverse types of renal stones, clinical results were not optimal.[5,11–14]

By leveraging spectral information analysis, dual-energy CT–based material decomposition postprocessing algorithms are able to separate the major chemical components of renal stones, which include water (ie, urine), calcium, and uric acid.[5,11–14] This information is displayed by means of a color-coded map that magnifies all voxels exhibiting dual-energy spectral behavior in a