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Applications of dual energy computed tomography in abdominal imaging

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Abstract Dual energy computed tomography (CT) is an imaging technique based on data acquisition at two different energy settings. Recent advances in CT have allowed data acquisition and almost simultaneously analysis of two spectra of X-rays at different energy levels resulting in novel developments in the field of abdominal imaging. This technique is widely used in cardiovascular imaging, especially for pulmonary embolism work-up but is now also increasingly developed in the field of abdominal imaging. With dual-energy CT it is possible to obtain virtual unenhanced images from monochromatic reconstructions as well as attenuation maps of different elements, thereby improving detection and characterization of a variety of renal, adrenal, hepatic and pancreatic abnormalities. Also, dual-energy CT can provide information regarding urinary calculi composition. This article reviews and illustrates the different applications of dual-energy CT in routine abdominal imaging.

Introduction

Dual energy computed tomography (DECT) is based on CT data acquisition at two different energy settings. X-ray photons interact differently with matter at different energy settings resulting in different attenuation values. At two different energy settings, information about the composition of a given tissue may be obtained by analyzing how it interacts with

Abbreviations: CT, computed tomography; DECT, dual-energy computed tomography; HU, Hounsfield unit; HCC, hepatocellular carcinoma; GIST, gastrointestinal stromal tumor; NET, neuroendocrine tumor.

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the photons [1,2]. DECT has been known for many years. Studies published in the 1970s have shown that this technique was useful for tissue characterization, but applications remained limited because of technical difficulties, especially prolonged data acquisition at different energy settings thereby decreasing spatial and temporal resolution [3]. Recent advances in computed tomography (CT) technology allow now acquisition and almost simultaneously analysis of two X-ray spectra at different energy settings. For these reasons, a new interest in DECT has emerged. In cardiovascular imaging, DECT is used in patients with suspected pulmonary embolism, because iodine is better visualized in distal, small pulmonary arteries and perfusion imaging offers excellent correlation with scintigraphy [4,5]. In musculoskeletal imaging, DECT helps characterize monosodium urate deposits in patients with gout and can also improve the assessment of metallic implants by reducing metal artifacts [6,7]. Abdominal applications of DECT are less well-known and still under development. With DECT it is possible to obtain virtual unenhanced images from monochromatic reconstructions as well as attenuation maps of different elements, thereby improving detection and characterization of a variety of renal, adrenal, hepatic and pancreatic abnormalities. Finally, using DECT is possible to determine urinary calculus composition.

This article reviews and illustrates the different applications of DECT in abdominal imaging.

Physical and technical considerations

General principles

With CT, attenuation is directly related to the interaction between X-rays and matter. A matter's attenuation coefficient depends on the matter's composition and on the energy of the incident X-ray photons [8]. At the energy levels used in diagnostic imaging, X-ray photons interact with matter either by a photoelectric effect or by Compton scattering. At lower kilovoltage, the photoelectric effect prevails. Here, attenuation, which is tissue-density dependent (i.e., atomic number), is high. This results in high contrast and noise. On the other hand, at higher kilovoltage, the attenuation is primarily driven by the Compton scattering mechanism. Here, attenuation is lower, resulting in lower image noise and contrast.

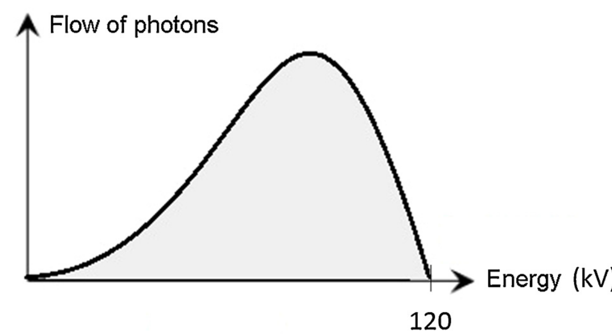

Figure 1. Example of energy level distribution (simplified) of a beam of X-ray photons in conventional single source CT at 120 kVp. Note the asymmetry of the curve. At low energy setting, X photons are partially filtered at the exit of the tube (beam hardening).

With CT, tissue contrast depends on tube voltage (in kVp), which is an adjustable parameter. This parameter determines the upper limit of the energy spectrum of the X-rays produced by the tube. With conventional single-source CT using polychromatic X-rays, images are usually acquired at an energy setting between 80 and 120 kVp, to optimize the balance between contrast and noise (Fig. 1). DECT is based on the simultaneous acquisition at low (80 kVp) and high (140 kVp) energy levels (Fig. 2).

Depending on the manufacturer, several technical approaches are available to acquire double datasets. Dual-source CT consists of two tubes and two detectors, simultaneously rotating around the patient, with an angle of 90° between both measuring systems with different fields of view (FOV) (Fig. 3). The single-source system consists of

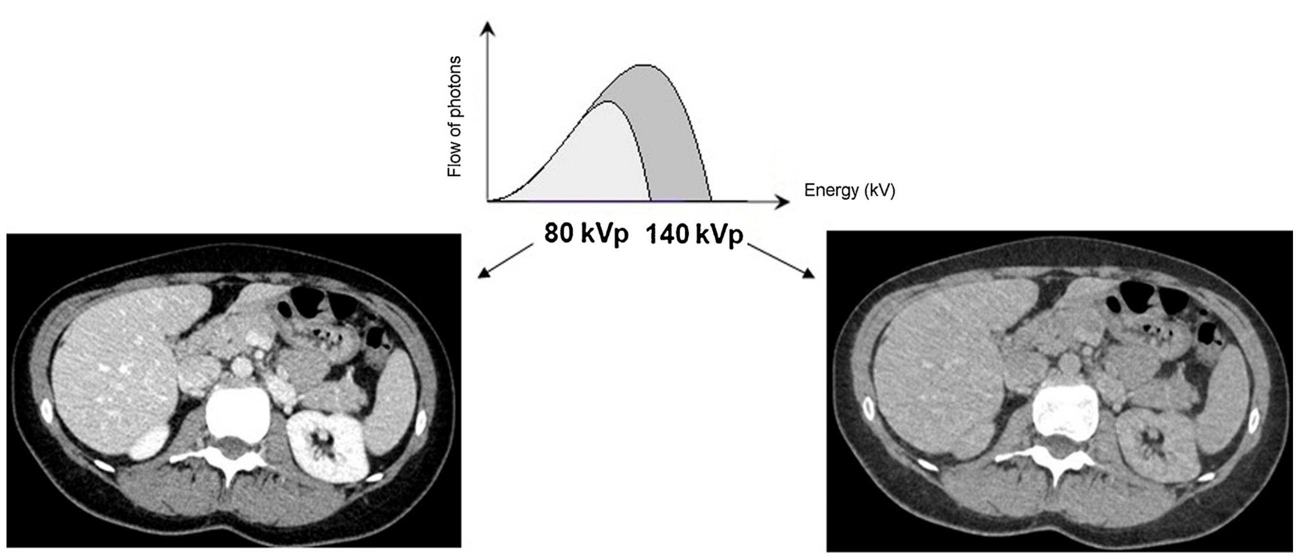

Figure 2. Example of energy level distribution (simplified) of a beam of X-ray photons in dual energy computed tomography (DECT) at 80 and 140 keV.