Dual Energy Computed Tomography Scans of the Bowel

Benefits, Pitfalls, and Future Directions

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KEYWORDS

• Dual energy CT • Multi-energy CT • Bowel • Computed tomography

KEY POINTS

- The evaluation of bowel may be dramatically improved by simple dual energy computed tomography image reconstructions, with attention to a few caveats.
- Iodine and water maps, viewed together, allow for the differentiation of iodinated contrast material, such as in gastrointestinal bleeding, from high attenuation pills.
- Owing to gas–tissue interface artifacts, iodine maps must always be viewed with virtual monoenergetic images to confirm the presence or absence of bowel wall enhancement abnormalities.
- Iodine maps may be used to minimize the severity of bowel peristalsis artifact on the bowel wall and adjacent structures.
- Future dual energy computed tomography contrast agents may increase the confidence in diagnosis of a range of disease involving the bowel and adjacent structures.

INTRODUCTION

The diagnostic evaluation of the gastrointestinal tract is one of the most challenging tasks in medicine. Direct endoscopic visualization is difficult owing to the long length of the intestines and the need for sedation. Cross-sectional imaging may be confounded by artifacts created by gas, particularly when MR imaging or ultrasound examination are used, and by the large physical size of the bowel. Furthermore, peristalsis continuously changes the location and distension of individual bowel segments, as well as bowel contents, creating additional pitfalls in all imaging modalities.

Dual energy computed tomography (DECT) of the bowel has not been as extensively studied as for solid abdominal organs. Nevertheless, many of the benefits of DECT are uniquely beneficial to imaging of the gastrointestinal tract. DECT provides the ability to distinguish between different materials that cause high density in and around the bowel, and to highlight areas of mural hypoenhancement or hyperenhancement. Furthermore, the decrease in beam hardening artifacts, for

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example, from hip arthroplasty, spinal hardware, and abdominal surgical implants, is beneficial for the evaluation of the intestines. Relatively unexplored aspects of DECT include material decomposition and the impact of potential additional artifacts that may be introduced by DECT. This review describes the basic technical aspects of DECT image reconstruction and its benefits and potential pitfalls for the evaluation of several individual clinical scenarios involving the bowel.

BASIC CONCEPTS OF DUAL ENERGY COMPUTED TOMOGRAPHY IMAGING

Although an in-depth review of DECT physics is beyond the scope of our article, we provide an overview of concepts that are relevant to bowel imaging. DECT is based on the knowledge that (1) any given material will attenuate low versus high-energy spectra x-rays to a predictable material-specific degree, and (2) different materials will attenuate low versus high-energy spectra x-rays in distinctly different and predictable degrees. In this way, DECT images can be used to distinguish different materials, even if they have the same Hounsfield unit (HU) value at conventional CT, which employs a single polychromatic X-ray beam and detector array to generate images.

Five different DECT platforms are available, each with its own theoretic advantages and limitations. A brief description of these options is given below.

The dual-source DECT scanner uses 2 orthogonally mounted x-ray source/detector arrays that operate at different tube potentials, one at a low and the other at a high kVp. A drawback of this configuration is that one of the tubes is located closer to the patient, and, therefore, has a slightly smaller field of view. A benefit of this arrangement is the ability to filter the high kVp x-ray source with tin to improve the x-ray spectral separation between the 2 sources (**Fig. 1**).

The rapid kV-switching DECT scanner uses a single x-ray source that switches between a high and a low kVp hundreds of times per gantry rotation. This arrangement grants full field-of-view imaging and near perfect co-registration of the low- and high-energy projection data, which allows for projection-based, rather than image-based, material decomposition, which reduces noise.

The split filter DECT scanner uses a single x-ray source and gold and tin filters that block high and low keV photons of one-half of the x-ray beam, respectively, thereby creating 2 different photon energy spectra in the z-axis. This arrangement

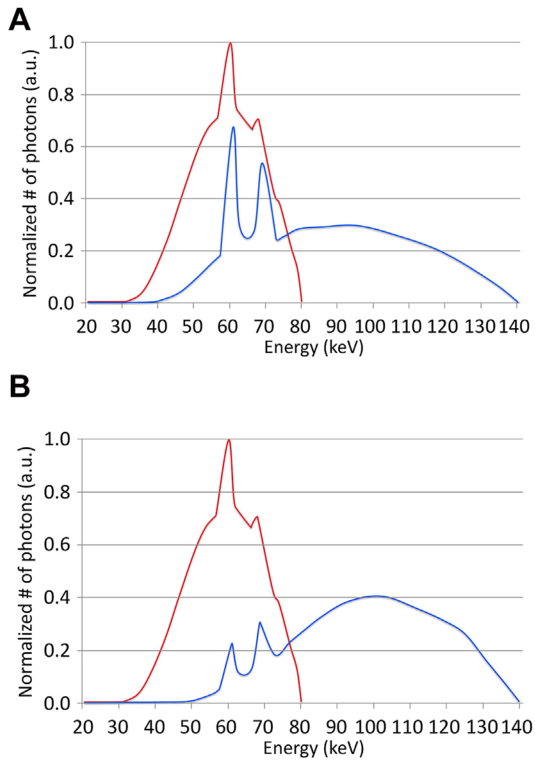

Fig. 1. X-ray energy spectra at low and high kVp. (*A*) X-ray energy spectra produced by a commercial CT scanner at 80 kVp (*red*) and 140 kVp (*blue*). The difference in x-ray spectra, and the fact that individual materials show different and predictable characteristic attenuation x-rays of different energies, allows imaged materials to be differentiated on dual energy computed tomography (DECT). (*B*) Tin filtration of the 140 kVp x-ray beam results in reduced overall flux of x-rays, and a harder x-ray beam with a higher mean x-ray energy. The resultant greater difference in x-ray spectra between the 80-kVp and the tin-filtered 140-kVp beams allows for better material separation at DECT.

provides full field of view imaging, but generally requires a slow table speed and gives less robust spectral separation than other dual energy implementations.

The sandwich detector DECT scanner (spectral detector or dual/double layer DECT scanner) achieves spectral separation of the x-ray beam at the detector level. The thin top layer of the detector, which is closer to the patient, detects the low-energy photons and the thicker deeper layer of the detector detects the remainder of the photons, which are largely higher in energy. As with the rapid kV-switching system, this arrangement provides full field-of-view imaging and outstanding co-registration of the low- and high-energy data, allowing for projection-based, rather