Practical Applications of Dual-Energy Computed Tomography in the Acute Abdomen

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KEYWORDS

• Dual-energy CT • Abdomen • Pelvis • Trauma • Ischemia • Gangrene • Gallstone • Inflammation

KEY POINTS

- Low kiloelectron volt virtual monoenergetic image (VMI) reconstructions enable improved contrast resolution, allowing for improved assessment of organ perfusion.
- Low kiloelectron volt VMI reconstructions also allow for reduction of contrast load without sacrificing image quality.
- Dual-energy computed tomography (DECT) allows for identification of iodine, thus enabling detection of subtle hemorrhages or oral contrast extravasation.
- Virtual noncontrast images can help differentiate hematomas or calcifications from iodine without the need for further imaging.
- The ability to differentiate various materials by DECT allows for differentiation of types of renal stones and shows promise in detection of noncalcified gallstones.

INTRODUCTION

Interest in dual-energy computed tomography (DECT) has steadily increased since the introduction of the first clinical scanner in 2006. Research has particularly been focused on the role of DECT in oncological applications. Its applicability in acutely ill and injured patients was limited owing to concerns about image quality; acquisition speed; radiation dose; and, most importantly, workflow limitations requiring a large chunk of the radiologist's time. However, recent advances in DECT technologies have addressed all these issues, enabling dose-neutral (or dose-negative) scans, acquired rapidly with image quality comparable or better than conventional computed tomography (CT).[1–4] The latest software versions offered by all major CT vendors include several workflow automation options that significantly

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reduce the time needed to produce interpretable data from dual energy datasets.

The ability of DECT to characterize materials based on their chemical composition has enabled assessment of disease processes in new ways that help improve the sensitivity and specificity of CT in the acute setting. For example, by identifying iodine, contrast can be subtracted, generating virtual noncontrast (VNC) images to detect a hematoma or confirm areas of calcification. The same technique can be used to assess organ perfusion by assessing iodine distribution within the organ of interest. Contrast extravasation is also more accurately assessed by iodine-labeling techniques. Material labeling also enables stone characterization, which has a direct impact on management. New techniques are also enabling the detection of noncalcified gallstones, adding tremendous value to CT of the abdomen and pelvis because it is usually the first study for many patients with nonspecific abdominal pain and would enable detection of gallstones in suspected cholecystitis or pancreatitis.

Virtual monoenergetic images (VMIs) allow improvement of the contrast-to-noise ratio (CNR), improving detection of subtle findings such as areas of decreased enhancement or small lacerations in trauma.

This article reviews the established applications for DECT of the abdomen and pelvis in an organ system–based approach, including how it adds value in the assessment of an acutely ill or injured patient.

GASTROINTESTINAL TRACT

Bowel Obstruction and Ischemia

The causes of small bowel ischemia include arterial occlusion (60%–70%), venous occlusion (5%–10%), strangulated bowel obstruction (10%), and low-flow states (20%). Arterial occlusion is associated with abnormally thin bowel wall with decreased enhancement but it could be thickened in the reperfusion state. On the other hand, bowel wall thickening with edema or hemorrhage occurs with venous ischemia and strangulation.[5] Other findings include mesenteric fat stranding with free fluid, pneumatosis intestinalis, and portomesenteric venous gas.[6]

The most reliable sign for diagnosis of bowel ischemia is absent or diminished bowel wall enhancement, which may be subtle on conventional CT. In a study by Potretzke and colleagues,[7] the difference in attenuation between the perfused and ischemic bowels on 120 kilovolt (peak) (kV[p]) conventional CT imaging can be doubled at 51 keV VMI. Hence, an ischemic bowel segment can be more easily distinguished from a nonischemic bowel on DECT.[8] This is important, particularly in cases of acute small bowel obstruction in which conventional CT imaging has low sensitivity to identify ischemic nonviable segments, whereas low kiloelectron volt VMI increases contrast resolution. However, because of increased noise, low kiloelectron volt VMI is best used as a complementary dataset, rather than a dataset that replaces the conventional images.[9,10] Combining them with iodine overlay (IO) images can improve sensitivity and specificity of diagnosing bowel ischemia (**Figs. 1** and **2**).

Inflammatory and Infectious Conditions

Inflammatory bowel diseases include ulcerative colitis, in which the inflammation is limited to the large intestine and affects only the intestinal mucosa, and Crohn disease, which can affect any part of the gastrointestinal (GI) tract, commonly the terminal ileum, and is usually transmural in nature.[11] In the acute exacerbations of active inflammatory bowel disease, abdominopelvic CT can distinguish the location and length of the inflamed segments, as well as complications such as penetrating disease and abscess.[12]

The alteration in bowel wall enhancement is accentuated at low kiloelectron volt VMI and IO images, which have a higher sensitivity in detecting subtle areas of mural hyperenhancement compared with conventional CT images.[13,14] In Crohn disease, small bowel segments with active inflammation become clearly noticeable and distinguished from the spared bowel segments by using low kiloelectron volt VMI, demonstrating mural hyperenhancement with a corresponding increase in iodine uptake on IO images (**Fig. 3**). Similarly, the degree of enhancement and iodine density of the inflammatory stricture are expected to be higher than the chronic fibrotic stricture.[15,16] In addition, IO images can be helpful to differentiate between enteric contrast accumulation within fistulas and hyperattenuating fluid collections.[16]

Colonic diverticulitis is demonstrated as a mild increase in enhancement of the colonic wall and adjacent fat that are reflected as increased iodine density on IO images.[13] However, this increase in iodine density was found to be significantly lower than in adenocarcinoma of the colon,[17] with a cutoff value for iodine concentration of 3 mg/mL being highly suggestive of adenocarcinoma rather than diverticulitis (**Fig. 4**). Primary epiploic appendagitis results from torsion of epiploic appendages, leading to ischemic infarction, and commonly appears as oval fat-density lesion abutting the colonic wall and surrounded by inflammatory changes.[18] On IO

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