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Dual-Energy CT in Abdominal Imaging: Principles, Applications, and Limitations

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Abstract

Dual-energy computed tomography (DECT) has emerged as one of the most significant advances in abdominal imaging over the past decade. By acquiring attenuation data at two distinct energy levels simultaneously, DECT exploits the energy-dependent attenuation characteristics of materials to provide anatomic and functional information beyond conventional CT. This review introduces the principles of DECT, surveys its clinical applications in hepatic, pancreatic, renal, and gastrointestinal imaging, and critically examines the limitations that currently prevent universal adoption. While DECT offers substantial benefits-including virtual noncontrast imaging, iodine quantification, and material characterization, significant challenges persist regarding vendor-dependent variability, patient size effects, workflow complexity, and standardization. Ongoing research and technological evolution, including the emergence of photon-counting detector CT, will shape the future role of spectral imaging in abdominal radiology. The purpose of this review is to provide a concise, easy-to-comprehend review of dual energy CT for future and young radiologists.

Keywords: Dual-energy CT; Photon-counting CT; Abdominal imaging; Computed Tomography; Artificial Intelligence

Abbreviations: AI: Artificial Intelligence; CT: Computed Tomography; DECT: Dual-Energy Computed Tomography; ECV: Extracellular Volume; HCC: Hepatocellular Carcinoma; IBD: Inflammatory Bowel Disease; keV: Kiloelectronvolt; kVp: Kilovoltage Peak; PCCT: Photon-Counting Detector Computed Tomography; PDAC: Pancreatic Ductal Adenocarcinoma; QIBA: Quantitative Imaging Biomarkers Alliance; VMI: Virtual Monoenergetic Image; VNC: Virtual Non-Contrast

Introduction

Computed tomography (CT) remains the cornerstone of abdominal imaging, providing rapid, high-resolution evaluation of solid organs, bowel, and vascular structures. However, conventional single-energy CT has inherent limitations: it cannot distinguish materials with similar attenuation values, provides limited tissue characterization, and offers no functional information beyond morphology. Dual-energy CT (DECT) addresses these limitations by acquiring images at two distinct X-ray energy spectra. This approach leverages the energy-dependent attenuation of materials-particularly the K-edge effects of elements like iodine and calcium-to enable material decomposition, virtual monoenergetic imaging, and quantitative tissue characterization. Multiple technical implementations exist, including dual-source, rapid kilovoltage-switching, sequential, dual-layer, and split-beam systems, each with distinct advantages and trade-offs [1-3]. This review provides an overview of DECT principles, surveys its established and emerging applications in abdominal imaging, and critically examines the technical, workflow, and quantitative limitations that challenge its widespread clinical adoption.

Technical Principles

Physics Basis

Materials exhibit unique attenuation characteristics that vary with photon energy and atomic number. Elements such as iodine (K-edge at 33.2 keV) and calcium demonstrate significant changes in attenuation near their K-edge energies, enabling differentiation from soft tissue and fat [1,3]. DECT exploits this principle by acquiring attenuation data at two different energy spectra-typically a low-energy (80-100 kVp) and high-energy (140-150 kVp with or without tin filtration) acquisition [1-5].

Clinical Applications

Hepatic Imaging

DECT has transformed hepatic imaging through several mechanisms. Low-keV VMIs increase the conspicuity of iodinated contrast, improving detection of hypervascular lesions including hepatocellular carcinoma (HCC), neuroendocrine metastases, and renal cell carcinoma metastases. Quantitative iodine maps can estimate tissue perfusion, aiding in lesion characterization, cirrhosis evaluation, and portal hypertension assessment. This is of utmost importance in oncologic imaging. DECT-derived measurements of liver fat and iron deposition also show promise for evaluating hepatic steatosis and iron overload. Emerging evidence suggests parameters such as iodine concentration and extracellular volume fraction may serve as imaging biomarkers for fibrosis assessment and treatment response monitoring [2,5-8].

Pancreatic Imaging

Pancreatic ductal adenocarcinoma (PDAC) remains notoriously difficult to identify on conventional CT, particularly when isoattenuating. Low-energy VMIs increase iodine attenuation and improve contrast between normal pancreatic parenchyma and hypoenhancing tumors, increasing lesion conspicuity and potentially improving early detection. Iodine quantification has also shown promise in characterizing pancreatic masses, assessing acute pancreatitis, evaluating pancreatic fibrosis, and monitoring treatment response [1,7,9].

Renal Imaging

DECT offers several advantages in renal imaging. Virtual noncontrast images generated by subtracting iodine from contrast-enhanced datasets can eliminate the need for a true noncontrast phase in many instances, reducing patient radiation exposure by approximately 20-50%. VNC images also help characterize hyperattenuating renal cysts and adrenal adenomas without additional scanning phases. Additionally, DECT can determine renal stone composition by differentiating uric acid-containing stones from calcium-based calculi, guiding medical versus interventional management [1,3,4].

Gastrointestinal Imaging

Emerging applications in gastrointestinal imaging include quantitative iodine concentration correlating with inflammatory activity in Crohn disease, potentially distinguishing active from chronic inflammation. In gastrointestinal malignancies, iodine concentration and spectral attenuation curves have been associated with tumor differentiation, microvascular density, and prognostic biomarkers, suggesting future roles as noninvasive imaging biomarkers. It is also suggested that dual energy might be of value in virtual colonoscopy, allowing for better characterization of polyp [1,10,11].

Limitations and Challenges

Despite its substantial advantages, DECT faces several limitations that currently prevent universal adoption and must be recognized for appropriate clinical use.

Technical Limitations by System Type

Different DECT implementations carry distinct technical constraints. Dual-source systems have a restricted second detector field-of-view (approximately 35.5 cm), excluding peripheral structures from spectral analysis in larger patients. Sequential and rapid-switching systems may suffer from temporal or spatial mismatch between datasets, limiting their utility in regions affected by peristalsis or respiratory motion. Dual-layer and twin-beam systems can limit customizability by constraining the ability to selectively increase low-energy photon flux-a particular disadvantage for larger patients where penetration is challenging [1,3,12].

Quantitative Accuracy and Variability

Measurements of iodine concentration, effective atomic number, and other parameters vary significantly among vendors, protocols, and reconstruction algorithms. This variability complicates multi-institutional studies and longitudinal patient follow-up. Patient size, contrast timing, and lesion heterogeneity further affect quantitative accuracy. A recent study found that DECT CT numbers show significantly greater dependence on patient size compared to photon-counting CT, with mean differences ranging from -3% to 9% at higher iodine and calcium concentrations. This size-dependent variability can confound quantitative assessments and therapeutic monitoring [1,13].

Workflow and Implementation Barriers

Unlike photon-counting CT, which acquires spectral data with every scan, DECT requires prospective selection of dual-energy mode before acquisition. This adds complexity to clinical workflow and may result in missed opportunities when the mode is not activated. Additionally, DECT generates multiple post-processing datasets-VMIs, VNC, iodine maps, material decomposition-requiring sophisticated reconstruction algorithms and radiologist expertise. This intricate workflow remains a significant barrier to broader clinical adoption, particularly in high-volume community practices [4,14].

Radiation Dose Considerations

While DECT offers dose-saving potential through virtual noncontrast imaging, certain implementations are not dose-neutral compared to single-energy CT. The additional spectral acquisitions may increase radiation exposure if not carefully optimized [1,3].

Clinical Interpretation Pitfalls

Several pitfalls affect DECT interpretation:

- Virtual noncontrast images may misrepresent hemorrhagic or protein-rich contents
- Iodine quantification can be affected by patient size, beam-hardening, and reconstruction parameters

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- Low-energy VMIs amplify noise and may create false-positive enhancement patterns
- Material decomposition algorithms are subject to inaccuracies from beam-hardening and noise amplification.

The Role of Photon-Counting CT

Emerging evidence suggests photon-counting detector CT (PCCT) addresses many DECT limitations. PCCT offers full-field spectral imaging, elimination of electronic noise, improved spatial resolution (0.2-0.4 mm), "always-on" spectral capability, and reduced patient size dependence. Studies demonstrate PCCT achieves radiation dose reductions of 20-32% while maintaining or improving image quality compared to dual-source DECT. However, PCCT remains cost-prohibitive for many institutions, and prospective validation of its clinical superiority is ongoing [13,15-17].

Future Directions

We believe the future development of spectral imaging using DECT should focus on standardization across vendors and protocols, reducing dose of contrast and harnessing the benefits of artificial intelligence. Integration with photon-counting CT might be the future, yet both need more validation [13,16,18,19].

Conclusion

Dual-energy CT has significantly expanded the capabilities of abdominal imaging over the past decade. The ability to create virtual noncontrast images, quantify iodine distribution, and characterize material composition provides information far beyond conventional CT. In hepatic, pancreatic, renal, and gastrointestinal imaging, DECT has demonstrated clear benefits for lesion detection, characterization, and quantitative assessment. However, substantial limitations remain: vendor-dependent variability, patient size effects, workflow complexity, and lack of standardization all challenge universal adoption. Radiologists must recognize these pitfalls to maximize diagnostic value and avoid misinterpretation. Ongoing research, technological advances-including the emergence of photon-counting CT-and collaborative standardization efforts will help spectral imaging become increasingly central to abdominal radiology practice.

References

1. Garcia-Figueiras R, S Baleato-Gonzalez, O Busquets-Carrera, C Fraga-Pineiro, A Luna (2026) Quantitative Dual-Energy CT in Abdominal Imaging: Technical Considerations and Emerging Clinical Applications. Radiographics 46(3): e250074.
2. Heye T, RC Nelson, LM Ho, D Marin, DT Boll (2012) Dual-energy CT applications in the abdomen. AJR Am J Roentgenol 199(5 Suppl): S64-S70.
3. McCollough, CH, S Leng, L Yu, JG Fletcher (2015) Dual- and Multi-Energy CT: Principles, Technical Approaches, and Clinical Applications. Radiology 276(3): 637-653.
4. Marin D, DT Boll, A Mileto, RC Nelson (2014) State of the art: dual-energy CT of the abdomen. Radiology 271(2): p. 327-342.
5. Masakatsu Tsurusaki, Keitaro Sofue, Masatoshi Hori, Kosuke Sasaki, Kazunari Ishii (2021) Dual-Energy Computed Tomography of the Liver: Uses in Clinical Practices and Applications. Diagnostics (Basel) 11(2): 161.
6. Kramer H, PJ Pickhardt, MA Kliewer, D Hernando, GH Chen, et al. (2017) Accuracy of Liver Fat Quantification with Advanced CT, MRI, and Ultrasound Techniques: Prospective Comparison with MR Spectroscopy. AJR Am J Roentgenol 208(1): 92-100.
7. Keitaro Sofue, Eisuke Ueshima, Yoshiko Ueno, Takeru Yamaguchi, Masatoshi Hori, et al. (2026) Improved Image Quality of Virtual Monochromatic Images with Deep Learning Image Reconstruction Algorithm on Dual-Energy CT in Patients with Pancreatic Ductal Adenocarcinoma. J Imaging Inform Med 39(1): 815-826.
8. Brooks J, OAE Mohamed, JH Miao, H Megahed, A Hamimi (2026) When Cancer Clots: An Extensive Radiologic Analysis of Cancer-Associated Thromboembolism. Cancers (Basel) 18(11): 1732.
9. Mahmoudi S, Simon Martin, Vitali Koch, Leon David Gruenewald, Simon Bernatz, et al. (2022) Value of Dual-Energy CT Perfusion Analysis in Patients with Acute Pancreatitis: Correlation and Discriminative Diagnostic Accuracy with Varying Disease Severity. Diagnostics (Basel) 12(11): 2601.
10. Zhou HF, W Chen, JQ Li, GJ Bai, LL Guo (2024) Prediction of pathological activity in Crohn's disease based on dual-energy CT enterography. Abdom Radiol (NY) 49(6): 1829-1838.
11. Ahmed Hamimi, Hazem Masoud, Moataz Montasser, Bora Kalaycioglu (2025) CT Virtual Colonoscopy: A Contemporary Review of Benefits and Limitations. Nov Appro in Can Study 8(3): NACS.000690.
12. Parakh A, S Lennartz, Chansik An, Prabhakar Rajiah, Benjamin M Yeh, et al. (2021) Dual-Energy CT Images: Pearls and Pitfalls. Radiographics 41(1): 98-119.
13. Sartoretti T, JE Wildberger, T Flohr, H Alkadhi (2023) Photon-counting detector CT: early clinical experience review. Br J Radiol 96(1147): 20220544.
14. Parakh A, C An, S Lennartz, P Rajiah, BM Yeh, et al. (2021) Recognizing and Minimizing Artifacts at Dual-Energy CT. Radiographics 41(2): 509-523.
15. Esquivel A, A Ferrero, A Mileto, F Baffour, K Horst, et al. (2022) Photon-Counting Detector CT: Key Points Radiologists Should Know. Korean J Radiol 23(9): 854-865.
16. Sofue K, K Nishiuchi, K Ishikawa, Y Ueno, N Negi, et al. (2026) Intraindividual comparison of photon-counting detector CT and third-generation dual-source energy-integrating detector CT in multiphasic contrast-enhanced abdominal CT. Sci Rep 16(1).
17. Wu Y, Z Ye, J Chen, L Deng, B Song (2023) Photon Counting CT: Technical Principles, Clinical Applications, and Future Prospects. Acad Radiol 30(10): 2362-2382.
18. Moataz Montasser, Hazem Masoud, Ahmed Hamimi (2025) Beyond the Algorithm: Quick review of Real-World Hurdles for Radiology AI. Cancer Therapy and Oncology International Journal 30(3): 1-3.
19. Aljabal A, L Ananthakrishnan, N Yadu, A Goel, E Zeikus, et al. (2026) Image quality and radiation dose comparison for abdominopelvic CT studies performed using photon-counting CT and dual-energy CT: a clinical study. BJR Open 8(1): tzag012.

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