Spectral Computed Tomography

Technique and Applications for Head and Neck Cancer

Almudena Pérez-Lara, MD, PhD[a], Reza Forghani, MD, PhD[b,*]

KEYWORDS

• Dual-energy CT • Virtual monochromatic images • Spectral Hounsfield unit attenuation curves • Iodine map • Squamous cell carcinoma • Cartilage invasion • Artifact reduction • Workflow

KEY POINTS

- There are increasing applications of spectral or dual-energy CT (DECT) for the evaluation of the neck, particularly head and neck squamous cell carcinoma (HNSCC).
- Low-energy DECT virtual monochromatic images can improve tumor visibility and soft tissue boundary delineation.
- High-energy DECT virtual monochromatic images and iodine maps can improve diagnostic evaluation of thyroid cartilage invasion; high-energy reconstructions can also be used to reduce dental artifact.
- Several other applications under investigation are likely to further increase the use and impact of DECT for diagnostic evaluation of the neck in the future.

INTRODUCTION

There is increasing use of spectral or dual-energy CT (DECT) in routine clinical practice. In the neck, multiple innovative applications of this technique have been shown to improve detection, characterization, and delineation of the extent of head and neck cancer, improving overall diagnostic evaluation.[1–4] This article provides an overview of the DECT technique and its applications in the neck, focusing on head and neck oncology. The review begins with an overview of the basic underlying principles and approaches for DECT scan acquisition and material characterization, which form the basis for different clinical applications of DECT and its optimal use. This is followed by a discussion of basic and essential information for the use of this technology in the clinical setting. The common types of DECT reconstructions that are generated are reviewed, followed by a brief overview of practical issues pertaining to DECT implementation, including those related to radiation dose and workflow impact of DECT. A detailed discussion of oncologic applications of DECT,

Disclosures: R. Forghani has acted as a consultant for GE Healthcare and has served as a speaker at lunch and learn sessions titled "Dual-Energy CT Applications in Neuroradiology and Head and Neck Imaging" sponsored by GE Healthcare at the 27th and 28th Annual Meetings of the Eastern Neuroradiological Society in 2015 and 2016 (no personal compensation or travel support for these sessions). A. Pérez-Lara declares no relevant conflict of interest.
[a] Department of Radiology, Jewish General Hospital, McGill University, Room C-212.1, 3755 Cote Ste-Catherine Road, Montreal, Quebec H3T 1E2, Canada; [b] Department of Radiology, Segal Cancer Centre and Lady Davis Institute for Medical Research, Jewish General Hospital, McGill University, Room C-212.1, 3755 Cote Ste-Catherine Road, Montreal, Quebec H3T 1E2, Canada
* Corresponding author.
E-mail address: rforghani@jgh.mcgill.ca

Magn Reson Imaging Clin N Am 26 (2018) 1–17
http://dx.doi.org/10.1016/j.mric.2017.08.001

mri.theclinics.com

focusing on head and neck squamous cell carcinoma (HNSCC), then follows. This includes a discussion of the use of specialized DECT reconstructions for improving tumor visualization and soft tissue boundary delineation, evaluation of thyroid cartilage invasion, and reduction of dental artifact for improving assessment of oral cavity and the oropharynx. A multiparametric approach using different DECT reconstructions is discussed, summarizing key reconstructions and their application. The article concludes with a brief discussion of applications under investigations and other exciting emerging applications of this technology in the head and neck.

OVERVIEW OF DUAL-ENERGY COMPUTED TOMOGRAPHY TECHNIQUE

A detailed discussion of the physics underlying DECT and different DECT systems is beyond the scope of this article and is found elsewhere.[5–9] However, familiarity with the basic principles underlying DECT scan acquisition, image processing, and analysis is essential for successful implementation and optimal use of this technique and is reviewed here. DECT consists of obtaining projecting data at two different peak energies. The raw data obtained from each of the two acquisitions are then processed and blended to generate different types of image reconstructions or to perform advanced quantitative analysis, such as generation of spectral Hounsfield unit attenuations curves (SHUACs) demonstrating the energy-dependent attenuation changes of a tissue of interest, as discussed in the subsequent sections. Although the terms DECT and spectral CT are sometimes used interchangeably, spectral CT could also encompass more advanced CT systems capable of discrimination between more than two spectra, such as the photon counting scanners currently under development experimentally.

The two different energy acquisitions in DECT are commonly at 80 to 100 kVp (lower energy acquisition) and 140 to 150 kVp (higher energy acquisition).[5,8] The reason behind this is that at energy peaks significantly lower than 80 kVp, a high proportion of the photons are absorbed by the tissues with little clinically useful information generated. At energy peaks significantly higher than 140/150 kVp, the dose may become prohibitively high and there is little soft tissue contrast, limiting usefulness in most clinical scenarios. These settings can vary depending on the scanner type, generation/model, other factors (eg, use of filters with dual source scanners), and for highly specialized applications. The basic requirements for DECT scan acquisition are summarized in **Box 1**.

Box 1
Essentials of DECT scan acquisition

- Emission of X-rays at two different energy levels, with as little overlap as possible (except for purely detector based systems).
- Acquisition of the different energy spectra simultaneously or near-simultaneously for optimal spatial registration and to minimize delay between the high- and low-energy measurements (temporal skew), enabling robust material decomposition.
- Differentiation of data from the low- and high-energy acquisitions through innovations at the source and/or detector arrays.

DUAL-ENERGY COMPUTED TOMOGRAPHY SCANNING SYSTEMS: A REVIEW OF CURRENT AND EMERGING TECHNOLOGY

Since the first DECT scanner was approved for clinical use in 2006 (dual source DECT, Siemens AG, Forchheim, Germany),[10,11] the technology has significantly evolved and there are multiple scanning systems currently available for use in clinical practice.[7,8] Some DECT systems have been refined over time (and continue to be refined) to address important challenges including optimizing radiation dose, image quality, improving material decomposition and other postprocessing tasks, reducing postprocessing times, and addressing ease of use and a more workflow friendly implementation. The different DECT approaches and scanner types are reviewed next. A more detailed discussion of different DECT systems can also be found in other recently published reviews on this topic.[7–9]

Dual-Source Dual-Energy Computed Tomography

Dual-source DECT scanners consist of two source X-ray tubes combined with separate detector arrays (Siemens AG) (**Fig. 1**).[5,7,8,12] The tubes and detector layers are aligned at a perpendicular or near-perpendicular angle, so that the same volume is scanned with the high and low energy X-ray beams simultaneously. The main advantage of this system is the use of separate imaging chains for the acquisition of the low- and high-energy spectra, enabling independent adjustment of the tube voltage and current for each chain and facilitating balancing of the quanta emitted from the two tubes. This can help improve separation of the low- and high-energy spectra. Depending on the model, filters may also be applied at the source, further optimizing quality and decreasing