Application of Dual-Energy CT Gemstone Spectral Imaging (DECT GSI) in the Characterization of Ground-glass nodules (GGNs)

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Abstract: Dual-Energy CT Gemstone Spectral Imaging (DECT GSI) is a new application of a fundamental physics concept that uses rapid kV switching to acquire the dual energy samples almost simultaneously to generate material density data that can be used for the separation of materials and derivation of monochromatic spectral images using a projection based reconstruction algorithm. DECT GSI of lungs allow for detection and Characterization of lung lesions including solid and ground glass nodules (GGNs)¹ ². Spectral CT plays a pivotal role in the detection, characterization, and staging of lung cancer. It acquires CT datasets at both low- and high-kVp settings that can improve diagnostic information for clinicians to quantify and separate materials – such as calcium, iodine and water – enhancing image quality, and reducing artifacts from implanted devices³. In this review article, we will outline the usefulness of dual-energy CT for the assessment of Ground-glass nodules (GGNs). In addition, we discuss the physical principles of dual-energy CT and potential future applications in patients with GGNs.

Keywords: Dual-energy CT, Gemstone Spectral Imaging, Lung Cancer, Ground-glass nodules, Characterization.

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I. Introduction

Lung cancer is one of the most common malignancies in both developing and developed countries and is also one of the leading causes of mortality worldwide⁴. Early resection and chemoradiotherapy are very important for the diagnosis of patients with lung cancer. Ground-glass nodule is one of the most common manifestations of lung cancer. GGOs are defined as having hazy increased attenuation of the lung with preservation of bronchial and vascular margins and need a standardized approach in order to avoid misdiagnosing lung cancer and delaying surgical excision whilst simultaneously avoiding unnecessary invasive procedures if the lesions prove to be benign⁵¹⁶. Recently introduced dual-energy applications of dual-energy CT plays very important role in the detection, characterization, and staging of lung cancer and other thoracic malignancies. The aim of this review is to observe the value of Dual-Energy Computed Tomography Gemstone Spectral Imaging in the diagnosis of ground-glass nodules, during the contrast-enhanced early phase and late phase.

II. Principles Of Dual-Energy CT Gemstone Spectral Imaging

Dual-Energy CT Gemstone Spectral Imaging (DECT GSI) is a new CT technique that allows the quantification of iodinated contrast material by applying different X-ray spectra and analyzing the differences in attenuation which allows differentiation of iodine from other materials due to its stronger photoelectric absorption, it is based on the varying behavior of materials when exposed to differing x-ray photon energies⁸⁹. The basic principle of the DECT is to obtain two datasets with different x-ray energy levels from the same anatomic location and material decomposition on the basis of attenuation differences at different kVp (usually 80 and 140 kVp)¹⁰. The goal of DECT is to obtain the low and high-energy attenuation characteristics of structures, which is done by analyzing the attenuation spectra at different energies but the same anatomic location. The magnitude of change in attenuation between the low- and high-energy spectra is determined by the effective atomic number of the materials that enables distinguishing materials with higher atomic number (such
as iodine), which have a greater change in attenuation, from those with lower atomic number (such as calcium and water), which have a lesser change\textsuperscript{[11]}. The main advantages of this new technique include simultaneous visualization of lower voltage tube images with improved iodine conspicuity and the performance of material specific imaging, which attempts to differentiate specific materials in the generated images and the collection of a virtual single image, which makes the image clearer after iodine deposition\textsuperscript{[12,13]}. This technique has higher sensitivity and specificity than conventional multi-slice CT, particularly in the detection, characterization, and staging of lung cancer.

2.1 Characterization of GGNs Using DECT GSI

Lung cancer is the main cause of cancer-related death in China as well as all over the world\textsuperscript{[4]}. Pulmonary nodules are the most common cause of the lung cancer. Ground-glass nodules (GGN) remain a diagnostic challenge and can be observed in both benign and malignant conditions; therefore, a more systematic approach is necessary to ensure correct diagnosis and optimal management\textsuperscript{[14, 15]}. GGNs are caused by a variety of disorders including neoplasms, infections, inflammation, and vascular and congenital abnormalities. The natural history of GGNs are generally reported to grow slowly. Approximately 20\% of pure GGNs and 40\% of part-solid GGNs gradually grow their solid component, whereas others remain unchanged for years. Therefore, it remains unclear whether all pulmonary GGNs should be surgically resected or not\textsuperscript{[16]}. However, persistent pulmonary ground-glass nodules are worth a closer look, as they have been well known to have a substantially high probability to be malignancy or benignity. The evaluation of Ground-glass nodules (GGNs) as benign or malignant remains a diagnostic challenge for thoracic imaging. GGNs have many pathological types: the malignant one is mainly lung cancer, and the benign one is mainly inflammatory nodule\textsuperscript{[23]}. For the patients with suspected lung cancer, a standard contrast-enhanced computed tomographic (CT) scan is often the first examination, followed by a number of other examinations\textsuperscript{[20]}. However, using the advent of Dual-Energy CT Gemstone Spectral Imaging (DECT GSI) we can now simultaneously obtain datasets for two different photon spectra with acceptable image quality in a single CT acquisition. DECT GSI has appeared as a potential tool for quantifying iodine concentration; studies have shown its utility in differentiating benign from malignant lesions in lung\textsuperscript{[25]}. It enables to differentiate an iodine substance from other materials by the material decomposition principle detecting all types of lung nodules, including solid, part-solid, and ground glass objects. It helps doctors and physicians to diagnose their patients more efficiently and accurately. Distinguishing benign from malignant ground glass nodules (GGNs) requires careful analysis of nodule size, morphology, and CT attenuation in the challenging medical imaging\textsuperscript{[17]}. With dual-energy CT, the attenuation of iodine is exceedingly greater at 80 kVp than at 140 kVp; thus, dual-energy CT may improve detection of GGN in comparison with conventional CT\textsuperscript{[18]}. Previous studies reported that iodine content (contrast enhancement) can successfully differentiate benign from malignant nodules and they also encouraged DECT for its applications in differentiation of benign and malignant thoracic lesions and in assessment of treatment response in patients with lung cancers\textsuperscript{[19]}. 

III. Future Applications

DECT GSI has multiple opportunities to be implemented in radiotherapy that could improve the accuracy of various parts of the workflow in the future. The development of imaging technologies that have specificity and sensitivity to enable early accurate detection of cancer and differentiating malignant GGNs from benign ones has long been a goal in medical imaging. Starting at the stage of diagnosis, the dual energy CT imaging equipment is playing a prominent role in the radiological department and will be utilized much more in the future because of the added information that is acquired compared to single energy CT imaging in a dose-neutral way\textsuperscript{[26,27]}. Radiologists believe that DECT will have further potential applications in the detection, evaluation and staging of lung cancer and thoracic lesions.

IV. Conclusion

DECT GSI provides promising quantitative approach for distinguishing malignant GGNs from benign ones by quantitatively measuring iodine enhancement on iodine maps or monochromatic imaging. And the iodine content and slope of HU curve obtained in dual energy spectral CT could be valuable parameters for the differentiation of GGNs\textsuperscript{[20, 21]}. The dual-phase DE-CT examination with a quantification of post-contrast iodine uptake is a promising method for the functional evaluation of thoracic lesions with lower radiation dose in comparison to volume perfusion CT\textsuperscript{[22]}

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