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Myocardial perfusion imaging with dual energy CT

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ABSTRACT

Dual-energy CT (DECT) enables simultaneous use of two different tube voltages, thus different x-ray absorption characteristics are acquired in the same anatomic location with two different X-ray spectra. The various DECT techniques allow material decomposition and mapping of the iodine distribution within the myocardium. Static dual-energy myocardial perfusion imaging (sCTMPI) using pharmacological stress agents demonstrate myocardial ischemia by single snapshot images of myocardial iodine distribution. sCTMPI gives incremental values to coronary artery stenosis detected on coronary CT angiography (CCTA) by showing consequent reversible or fixed myocardial perfusion defects. The comprehensive acquisition of CCTA and sCTMPI offers extensive morphological and functional evaluation of coronary artery disease. Recent studies have revealed that dual-energy sCTMPI shows promising diagnostic accuracy for the detection of hemodynamically significant coronary artery disease compared to single-photon emission computed tomography, invasive coronary angiography, and cardiac MRI. The aim of this review is to present currently available DECT techniques for static myocardial perfusion imaging and recent clinical applications and ongoing investigations.

1. Introduction

Coronary CT angiography (CCTA) has developed into a widely used, non-invasive imaging tool to detect coronary luminal narrowing with high diagnostic accuracy [1–3]. Although CCTA remains an excellent morphological technique for evaluating the degree of stenosis, it requires additional information in order to determine the hemodynamic relevance of the coronary stenosis [4]. Myocardial imaging plays a pivotal role in assessing the physiological severity of coronary stenosis, selecting an appropriate treatment plan, as well as predicting the results of the treatment [5]. In single-photon emission computed tomography (SPECT), which is commonly used for myocardial imaging, intrinsic poor spatial resolution and soft tissue attenuation artifacts hamper its diagnostic accuracy [6]. However, thanks to recent technological advances, new CT techniques are emerging that hold promise for achieving a comprehensive appraisal of both anatomical and functional aspects of coronary heart disease using a single modality [7,8]. Thus, the multifaceted capabilities of CCTA have the potential to greatly limit the use of invasive angiography or revascularization.

Techniques for the direct assessment of myocardial ischemia can be divided into static CT myocardial perfusion imaging (sCTMPI) and dynamic myocardial perfusion imaging (dCTMPI). Static CT myocardial perfusion imaging is a single snapshot of myocardial attenuation during early arterial phase, and thus does not represent true perfusion, but it can provide an accurate assessment of iodine distribution within the myocardium. In the early days, sCTMPI feasibility was demonstrated using single energy techniques; however, since it was only based on Hounsfield attenuation, it was less accurate in determining the iodine myocardial distribution [9]. Dual energy acquisition, on the other hand, provides a direct quantitative assessment of the iodine within the myocardium [10]. Recent technological developments in dual energy CT (DECT) allows for accurate material decomposition by different x-ray energy levels, which has been used to evaluate the

Abbreviations: CCTA, coronary CT angiography; CMR, cardiac magnetic resonance; CCTA, coronary CT angiography; CTMPI, CT myocardial perfusion imaging; dCTMPI, dynamic myocardial perfusion imaging; DECT, dual-energy CT; DSCT, dual source CT; ICA, invasive coronary angiography; sCTMPI, static CT myocardial perfusion imaging; SPECT, single photon emission computed tomography.

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myocardial blood supply by mapping iodine distribution within the myocardium [11,12]. The purpose of this article is to present current applications of DECT in static myocardial perfusion imaging by reviewing recent literature.

2. Dual-energy CT static MPI

2.1. Technical principles

sCTMPI demonstrates myocardial attenuation abnormalities during the early arterial phase of the first-pass contrast enhancement and provides the static myocardial distribution of iodinated contrast material [13]. DECT generates a snapshot of the iodine distribution in the myocardium using simultaneous acquisitions of the same body region at two different kV values. The energy-dependent attenuation of materials can be obtained when exposed to two different photon energy levels [14]. Technical advancement in CT enables simultaneous use of two different tube voltages and the elimination of misregistration artifacts, thus different x-ray absorption characteristics are acquired in the same anatomic location with two different X-ray spectra [14,15]. Dual energy image acquisition can be obtained with 5 different modality: (1) dual x-ray source system with two different tubes; (2) single source system with rapid tube potential switching between projection views; (3) single source with dual-layer detector; (4) single source scanner with tube potential switching between gantry rotations; and (5) twin beam dual-energy with pre-filtration.

Dual source CT (DSCT) scanner uses a CT system where two x-ray sources and two detectors are mounted on the same gantry. Each x-ray source has its own high-voltage generator, allowing independent control of tube potential and tube current [14]. DSCT has a 90° angular offset between the two acquisition systems, which limits the space of the gantry and restricts the field of view for cardiac DECT. This limitation has been address slightly between each generation of DSCT, in which the 1st generation DSCT increased from 26 cm and then to 35 cm in 3rd generation DSCT [16]. DSCT scanners present a challenge in regards to temporal resolution for cardiac DECT since it reduces the temporal resolution by the separate use of x-ray source and detector during DECT acquisition. For example, temporal resolution in 1st generation DSCT is increased from 83 to

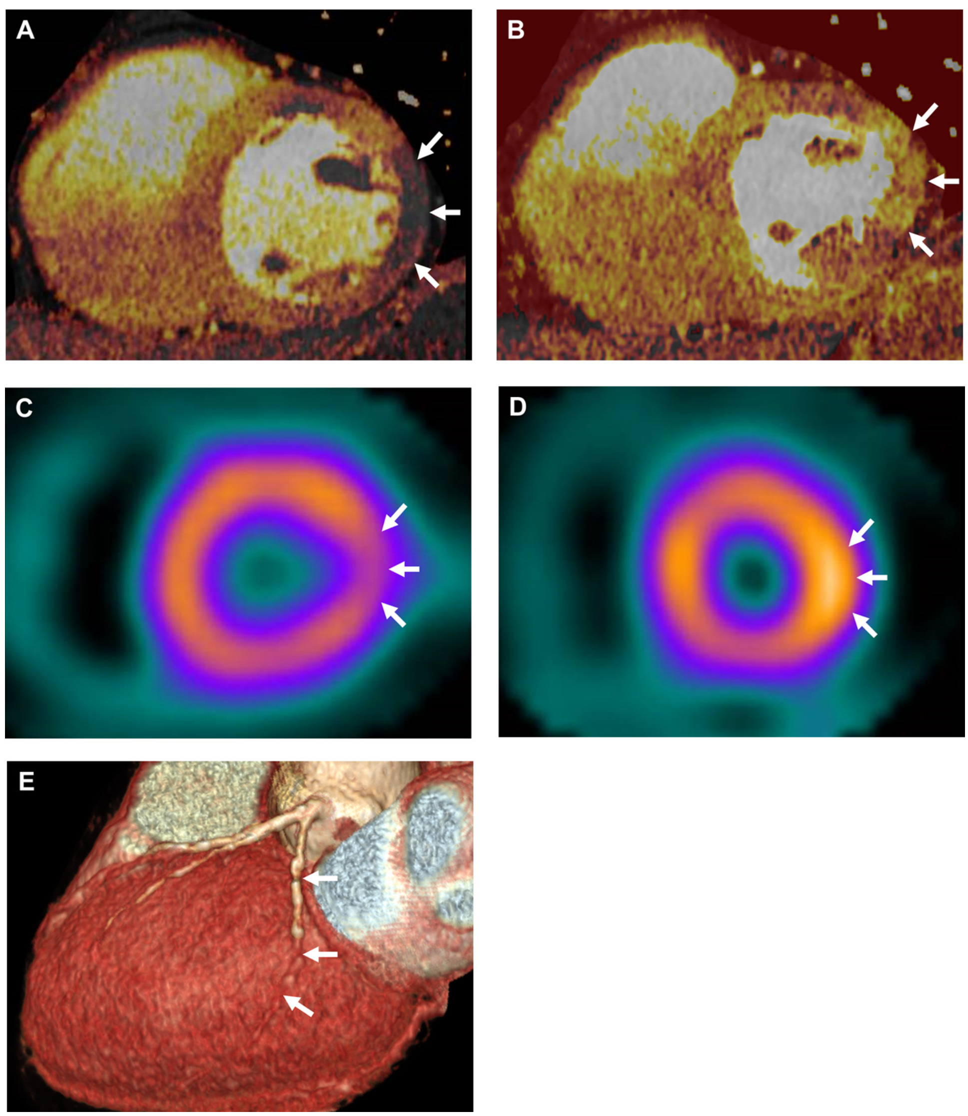

Fig. 1. Stress dual-energy iodine distribution map in a 72-year-old man shows well-defined area of decreased iodine content (arrows) in the lateral wall of the left ventricular myocardium (A). Rest dual-energy iodine map in same patient reveals that the decrease of iodine content in the myocardium is reversible (B), which suggests the myocardial ischemia in the lateral wall. Rest (C) and stress (D) single-photon emission computed tomography images shows reversible perfusion decreases (arrows) at mid lateral wall, corresponded with the dual-energy CT iodine map. Volume rendering image shows diffuse luminal irregularities and intermediate-to-severe stenosis in the left circumflex artery (E).