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Myocardial scar imaging by standard single-energy and dual-energy late enhancement CT: Comparison with pathology and electroanatomic map in an experimental chronic infarct porcine model

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ABSTRACT

Background: Myocardial scar is a substrate for ventricular tachycardia and sudden cardiac death. Late enhancement CT imaging can detect scar, but it remains unclear whether newer late enhancement dual-energy (LE-DECT) acquisition has benefit over standard single-energy late enhancement (LE-CT).

Objective: We aim to compare late enhancement CT using newer LE-DECT acquisition and single-energy LE-CT acquisitions with pathology and electroanatomic map (EAM) in an experimental chronic myocardial infarction (MI) porcine study.

Methods: In 8 pigs with chronic myocardial infarction (59 ± 5 kg), we performed dual-source CT, EAM, and pathology. For CT imaging, we performed 3 acquisitions at 10 minutes after contrast administration: LE-CT 80 kV, LE-CT 100 kV, and LE-DECT with 2 postprocessing software settings.

Quynh A. Truong, Wai-ee Thai, Conor D. Barrett and Stephan Danik contributed equally to the work.

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Myocardial infarction
Myocardial scar

Results: Of the sequences, LE-CT 100 kV provided the best contrast-to-noise ratio (all $P \leq .03$) and correlation to pathology for scar ($\rho = 0.88$). LE-DECT overestimated scar (both $P = .02$), whereas LE-CT images did not (both $P = .08$). On a segment basis ($n = 136$), all CT sequences had high specificity (87%–93%) and modest sensitivity (50%–67%), with LE-CT 100 kV having the highest specificity of 93% for scar detection compared to pathology and agreement with EAM ($\kappa = 0.69$).

Conclusions: Standard single-energy LE-CT, particularly 100 kV, matched better to pathology and EAM than dual-energy LE-DECT for scar detection. Larger human trials as well as more technical studies that optimize varying different energies with newer hardware and software are warranted.

1. Introduction

Myocardial scar is a substrate for ventricular tachycardia (VT) and sudden cardiac death. Scar-related VT may be due to nonischemic etiologies, but the most common cause is prior myocardial infarction (MI).[1] Substrate mapping, with electroanatomic mapping (EAM) that combines activation maps with voltage maps, is useful in patients with scar-related VT.[2] However, point-by-point mapping with EAM is time consuming and requires hours of fluoroscopic time, even in the hands of skilled electrophysiologists.

Because iodinated contrasts have similar kinetics as gadolinium, late enhancement of iodine with standard single-energy cardiac CT (LE-CT) acquired 10 minutes after contrast administration is an alternative for myocardial scar detection in those with contraindications to magnetic resonance imaging (MRI).[3,4] With the advent of dual-source CT, 2 X-ray tubes and detectors are mounted perpendicular to each other, allowing the newer application of dual-energy CT scanning (DECT). With DECT, each X-ray tube can emit a different tube potential, thus allowing for scanning with 2 energy levels simultaneously.[5] As tissues in the body and iodine-based contrast media have unique absorption characteristics when penetrated with different X-ray energy levels, DECT allows for delineation of the iodine content within the myocardium and appears to have a promising role for late enhancement (LE-DECT) myocardial scar imaging.[6]

Because preprocedural scar imaging with CT may be helpful for electrophysiologists tackling a complex VT ablation case,[7] both LE-CT and LE-DECT protocols have been reported to yield high accuracy and good correlation to late gadolinium enhancement cardiac MRI (LE-MRI) and histopathology for the detection of myocardial scar in the reperfused chronic MI model.[3,4,6] Thus, we sought to determine whether LE-CT or LE-DECT was optimal for use with EAM in an experimental study in pigs. In the chronic MI porcine study, we compared standard single-energy LE-CT and dual-energy LE-DECT protocols for assessing myocardial scar size and their diagnostic accuracy for scar detection compared to pathology. We also assessed the diagnostic accuracy of EAM to pathology and compared the agreement between these CT protocols and EAM for scar detection.

2. Methods

In 13 swine (Yorkshire or Yorkshire mix, 77% male, 30–50 kg), we used a closed-chest coronary artery occlusion-reperfusion technique to induce an ST-elevation MI. Procedure-related death occurred in 2 animals after acute infarction due to ventricular arrhythmias. After 4 to 6 weeks of reperfusion, 11 animals survived and underwent CT imaging and EAM before sacrifice. For this study, we included data from 8 pigs, for which we had all 4 modalities available for analysis: LECT, DECT, EAM, and pathology. All procedures were performed with the pigs under general anesthesia. This animal study protocol was approved by the Hospital Subcommittee on Research Animal Care, which conforms to the United States Department of Agriculture Animal Welfare Act, Partners Healthcare System Policy on Humane Care and Use of Laboratory Animals, the "Institute for Laboratory Animal Research Guide for the Care and Use of Laboratory Animals," and other applicable laws and regulations.

2.1. *Chronic MI protocol*

In a closed-chest ischemia-reperfusion porcine model, we used standard cardiac catheterization technique to create an ST-elevation MI with balloon occlusion and transcatheter intracoronary injection of ethyl alcohol of a left coronary vessel, either left anterior descending or left circumflex artery.[8] Selective coronary angiography of the left coronary system was performed before balloon angioplasty (Boston Scientific, Maple Grove, MN) of the mid-distal left anterior descending artery or diagonal branch ($n = 7$) or left circumflex artery ($n = 1$). In all 8 animals, coronary artery occlusion was achieved via balloon inflation at 6 to 10 atmospheres for a mean duration of 53 ± 40 minutes. In 7 animals, supplemental transcatheter intracoronary injection of 70% ethyl alcohol (Owens & Minor, Mechanicsville, VA; mean volume of 0.6 ± 0.1 mL) was given to further induce myocardial necrosis. Acute MI was documented by the presence of new ST elevations in contiguous leads during continuous surface electrocardiographic monitoring, and reperfusion of the occluded vessel was confirmed by repeat coronary angiography. The animals were then housed for 4 to 6 weeks to allow the infarction to mature.[3,6,9]