# New insight into scar-related ventricular tachycardia circuits in ischemic cardiomyopathy: Fat deposition after myocardial infarction on computed tomography–A pilot study

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**BACKGROUND** Myocardial fat deposition (FAT-DEP) has been frequently observed in regions of chronic myocardial infarction in patients with ischemic cardiomyopathy. The role of FAT-DEP within scar-related ventricular tachycardia (VT) circuits has not been investigated.

**OBJECTIVE** This pilot study aimed to assess the impact of myocardial FAT-DEP on local electrograms and VT circuits in patients with ischemic cardiomyopathy.

**METHODS** Contrast-enhanced computed tomography was performed in 22 patients with ischemic VT. Electroanatomic map points were registered to the corresponding contrast-enhanced computed tomography images. Myocardial FAT-DEP was identified and characterized using a postprocessing image overlay that highlighted areas below 0 Hounsfield units (HU). The mean attenuation of local myocardial regions corresponding to sampled electrograms was measured on short-axis images. The associations of mean attenuation with bipolar and unipolar amplitudes, left ventricular wall thickness, and VT circuit sites were investigated.

**RESULTS** Of 1801 electroanatomic map points, 519 (28.8%) were located in regions with FAT-DEP. Significant differences were observed in mean intensity (23.2 ± 35.6 HU vs 81.7 ± 21.9 HU; $P < .001$), bipolar (0.75 ± 0.83 mV vs 2.9 ± 2.4 mV; $P < .001$) and unipolar (3.1 ± 1.7 mV vs 7.4 ± 4.3 mV; $P < .001$) amplitudes, and left ventricular wall thickness (5.2 ± 1.7 mm vs 8.2 ± 2.5 mm; $P < .001$) between regions with and without FAT-DEP. Lower HU was strongly associated with lower bipolar and unipolar amplitudes ($P < .0001$, respectively). Importantly, FAT-DEP was associated with critical VT circuit sites with fractionated or isolated potentials.

**CONCLUSION** FAT-DEP was associated with electrogram characteristics and VT circuit sites. Further work will be needed to determine whether FAT-DEP plays a causal role in the generation of ischemic scar–related VT circuits.

**KEYWORDS** Ventricular tachycardia; Ischemic cardiomyopathy; Fat; Computed tomography; Magnetic resonance imaging

**ABBREVIATIONS** **ARVC** = arrhythmogenic right ventricular cardiomyopathy; **CE-CT** = contrast-enhanced computed tomography; **CT** = computed tomography; **EAM** = electroanatomic map; **FAT-DEP** = fat deposition; **HU** = Hounsfield units; **ICD** = implantable cardioverter-defibrillator; **ICM** = ischemic cardiomyopathy; **LGE-CMR** = late gadolinium–enhanced cardiac magnetic resonance; **LV** = left ventricle/ventricular; **VT** = ventricular tachycardia

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## Introduction

Myocardial fat deposition (FAT-DEP) or lipomatous metaplasia has been frequently observed in regions of chronic myocardial infarction in patients with ischemic cardiomyopathy (ICM).[1–7] Baroldi et al[1,2] have shown that myocardial regions with FAT-DEP coexist with areas of fibrosis that form the substrate of life-threatening reentrant ventricular tachycardia (VT). Similar to FAT-DEP, ischemic scar-related

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VTs occur more often late after the onset of myocardial infarction. Previous reports[8,9] have shown the association of ischemic scar on late gadolinium–enhanced cardiac magnetic resonance (LGE-CMR) with local electrogram characteristics such as bipolar and unipolar voltage, electrogram duration, and fractionated or isolated potentials. Critical VT circuit sites associate closely with conducting channels within scar identified on LGE-CMR. In a recent study, Pouliopoulos et al[10] have demonstrated that increased intramyocardial adipose tissue in sheep is significantly associated with altered electrophysiological properties such as slower conduction velocity and lower electrogram amplitude and has an impact on scar-related VT circuits. Computed tomography (CT) offers higher spatial resolution and can identify fat tissue on the basis of CT attenuation density values (in Hounsfield units [HU]).[3–6] In addition, contrast-enhanced computed tomography (CE-CT) can accurately define anatomical structures including chamber boundaries and coronary arteries, which can be integrated into electroanatomic mapping (EAM) systems. The limitations of CT include ionizing radiation and lower contrast-to-noise ratio. However, recent technological advances with multidetector scanners have mitigated both these issues. This pilot study aimed to (1) quantitatively examine the association of FAT-DEP on CE-CT with local electrogram characteristics and (2) define the association of FAT-DEP with reentrant VT circuits in patients with ICM.

## Methods

### Study patients

The institutional review board of Johns Hopkins University approved the retrospective study protocol. All patients had provided written informed consent. The study included 22 patients with ICM (mean age 66 ± 9 years; 21 men), who had CE-CT before catheter ablation of scar-related VTs and 20 patients with ICM (mean age 70 ± 8 years; 16 men) without a history of VTs as an age-matched control group. CE-CT was performed for 3-dimensional anatomical guidance during VT ablation (22 patients) or assessment of coronary artery stenosis (20 patients). Of 22 patients with ischemic scar-related VTs, 19 patients had implantable cardioverter-defibrillator (ICD) or biventricular ICD systems. A subset of 10 patients underwent both LGE-MRI and CE-CT examinations.

### CE-CT examinations

All CE-CT examinations were performed with a 320 detector-row CT scanner (Aquilion ONE, Toshiba Medical Systems Corporation, Otawara, Japan). Iodinated contrast was injected intravenously. The scan parameters were as follows: collimation 320 × 0.5 mm, rotation time 500 ms, temporal resolution 125–250 ms, voltage 100–120 kV, and current 350–500 mA. The image data were reformatted into short-axis images with 8-mm slice thickness to match the slice thickness of LGE-CMR images.

### CMR studies

CMR examinations were performed with a 1.5-T CMR scanner (Avanto, Siemens, Erlangen, Germany). In patients with ICD systems, potential risks were explained and CMR were performed using our established protocol.[11] Standard steady-state free precession cine images were acquired in multiple cardiac planes. Ten minutes after the injection of the contrast medium, LGE-CMR images were obtained in short axis with a segmented inversion-recovery gradient-echo turbo fast low-angle shot sequence with TR 1 R-R interval, TE 1.04 ms, flip angle 25°, average in-plane resolution 1.3 × 1.3 mm, slice thickness 8 mm, and inversion time typically 240–360 ms.[8]

### CT image analysis

CT data sets were reconstructed in 8-mm-thick slices in the short-axis imaging plane by using a dedicated workstation (Ziostation, Ziosoft, Inc, Tokyo, Japan). The mean intensity of each of 20 radial sectors per 8-mm short-axis plane was measured. Areas of myocardial FAT-DEP were identified using a postprocessing image overlay that highlighted areas between intensity of −180 and 0 HU.[3,6,12] Identification of FAT-DEP was confirmed when the intensity met our criteria for an area larger than 1 $mm^2$. Sectors with calcification were also identified.

### CMR image analysis

For the subset of patients with LGE-CMR, QMass MR (Medis Medical Imaging Systems, Leiden, The Netherlands) was used to measure scar transmurality. Candidate hyperenhanced regions were identified as scar if the mean intensity of the hyperenhanced region was >3 SDs above the mean intensity of remote normal myocardium.[9] Scar transmurality was determined as described previously.[13]

### Electrophysiological study

In patients with ICD systems, tachyarrhythmia therapies were disabled before the procedure. Ventricular programmed stimulation to induce VT was performed with up to triple extrastimuli. If the induced VT sustained without hemodynamic collapse, EAM was performed during the tachycardia. Otherwise, substrate mapping was performed during sinus rhythm or ventricular pacing.

### Three-dimensional EAMs and electrogram characteristics

A 3-dimensional EAM system (CARTO, Biosense Webster, Inc, Diamond Bar, CA) was used to create endocardial voltage maps in the left ventricle (LV) during sinus rhythm or ventricular pacing by using a 3.5-mm-tip electrode (ThermoCool, Biosense Webster, Inc). The reconstructed LV shell was registered to the LV EAMs.[8,9] Registration accuracy was determined using statistical summation on the EAM system. Local bipolar and unipolar voltage and duration were measured (Figure 1B).[8,9,14] Bipolar and unipolar electrograms were filtered at 10–400 and 1–240 Hz, respectively. Electrogram duration was measured from the onset to the end of the electrogram deflections at 400 mm/s speed. Fractionated