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Integrated Assessment of Left Ventricular Electrical Activation and Myocardial Strain Mapping in Heart Failure Patients

A Holistic Diagnostic Approach for Endocardial Cardiac Resynchronization Therapy, Ablation of Ventricular Tachycardia, and Biological Therapy

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ABSTRACT

OBJECTIVES This study sought to test the accuracy of strain measurements based on anatomo-electromechanical mapping (AEMM) measurements compared with magnetic resonance imaging (MRI) tagging, to evaluate the diagnostic value of AEMM-based strain measurements in the assessment of myocardial viability, and the additional value of AEMM over peak-to-peak local voltages.

BACKGROUND The in vivo identification of viable tissue, evaluation of mechanical contraction, and simultaneous left ventricular activation is currently achieved using multiple complementary techniques.

METHODS In 33 patients, AEMM maps (NOGA XP, Biologic Delivery Systems, Division of Biosense Webster, a Johnson & Johnson Company, Irwindale, California) and MRI images (Siemens 3T, Siemens Healthcare, Erlangen, Germany) were obtained within 1 month. MRI tagging was used to determine circumferential strain (E_{cc}) and delayed enhancement to obtain local scar extent (%). Custom software was used to measure E_{cc} and local area strain (LAS) from the motion field of the AEMM catheter tip.

RESULTS Intertechnique agreement for E_{cc} was good ($R^2 = 0.80$), with nonsignificant bias (0.01 strain units) and narrow limits of agreement (-0.03 to 0.06). Scar segments showed lower absolute strain amplitudes compared with nonscar segments: E_{cc} (median [first to third quartile]: nonscar -0.10 [-0.15 to -0.06] vs. scar -0.04 [-0.06 to -0.02]) and LAS (-0.20 [-0.27 to -0.14] vs. -0.09 [-0.14 to -0.06]). AEMM strains accurately discriminated between scar and nonscar segments, in particular LAS (area under the curve: 0.84, accuracy = 0.76), which was superior to peak-to-peak voltages (nonscar 9.5 [6.5 to 13.3] mV vs. scar 5.6 [3.4 to 8.3] mV; area under the curve: 0.75). Combination of LAS and peak-to-peak voltages resulted in 86% accuracy.

CONCLUSIONS An integrated AEMM approach can accurately determine local deformation and correlates with the scar extent. This approach has potential immediate application in the diagnosis, delivery of intracardiac therapies, and their intraprocedural evaluation. (J Am Coll Cardiol EP 2017;■:■-■) © 2017 The Authors. Published by Elsevier on behalf of the American College of Cardiology Foundation. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

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ABBREVIATIONS AND ACRONYMS

AEMM = anatomo-electromechanical mapping

AUC = area under the curve

CMR = cardiac magnetic resonance

CRT = cardiac resynchronization therapy

E_{cc} = circumferential strain

LAS = local area strain

LGE = late gadolinium enhancement

ROC = receiver-operating characteristic

UEG = peak-to-peak unipolar voltage

ΔUEG = change in peak-to-peak unipolar voltage

The in vivo recognition of viable tissue, quantification of the scar burden, evaluation of abnormal mechanical contraction, and simultaneous identification of abnormality in left ventricular electrical activation is of paramount importance in several invasive and electrophysiological procedures that may include delivery of biological therapy (1–3), ablation of ventricular tachycardia (4–6), and endocardial cardiac resynchronization therapy (CRT) (7–11). In daily clinical practice, this information is acquired by means of different and complementary cardiac imaging modalities. Among the various cardiovascular imaging modalities, cardiac magnetic resonance (CMR) is the gold standard for both myocardial scar delineation and myocardial strain quantification. Despite technological advancements in the integration of the information retrieved from CMR or 3-dimensional echocardiography to make them available during invasive procedures (i.e., identifying the target for delivery of biological therapy, or the best location of endocardial CRT implantation), these approaches are still error-prone, hampering the spatial accuracy in delivering the therapy. Furthermore, time resolution for strain assessment of CMR is still limited. Finally, a significant number of heart failure patients are excluded from CMR imaging due to nonconditional devices, and the diagnostic accuracy of CMR is jeopardized by device- or lead-related shadowing.

The capability of in vivo objectively quantifying myocardial strain and identifying nonviable myocardium while evaluating electrical activation on a beat-to-beat basis would overcome these limitations. This would constitute a completely novel approach to improve diagnostic capability, possibly delivery of intracardiac therapies, and improve the acute evaluation of the therapy effectiveness. Therefore, the aims of the present study were to: 1) test the accuracy of endocardial strain measurements based on anatomo-electromechanical mapping (AEMM) data compared with CMR; 2) evaluate the diagnostic value of AEMM-based strain measurements in the assessment of myocardial viability; 3) compare the diagnostic value of AEMM-based strain with local unipolar voltages in the delineation of myocardial scar; and 4) to evaluate the accuracy AEMM strain combined with voltages in the identification of myocardial scar.

METHODS

POPULATION. Thirty-three consecutive patients with moderate-to-severe heart failure referred to the Division of Cardiology, Fondazione Cardiocentro Ticino, Switzerland, for nonpharmacological treatment between 2012 and 2016 were retrospectively included in this study. All patients were on stable drug therapy (>3 months) and underwent standard 12-lead electrocardiography, a clinically indicated CMR study, an electrophysiological study including AEMM of the left ventricle, and coronary angiography. AEMM was performed prior to the implantation of a CRT device in 25 cases or the delivery of biological therapy in 8 cases.

The Institutional Review Board approved the study, and informed consent was obtained before the intervention.

CARDIAC MAGNETIC RESONANCE. CMR was performed using a 3T scanner (MAGNETOM Skyra, Siemens Healthcare, Erlangen, Germany) equipped with a standard torso coil. Steady-state free-precession cine CMR of the left ventricle was acquired in 3 long-axis and in a stack of short-axis slices spanning the left ventricle base to apex (retrospective gating, temporal resolution 25 to 40 ms, voxel size 1.2 mm × 1.2 mm × 8 mm).

Thereafter, grid-tagged image acquisition was performed using the same slice prescription as for the cine imaging with 6- to 8-mm tag spacing over 25 cardiac phases (temporal resolution 34 to 46 ms).

Finally, short-axis late gadolinium enhancement (LGE) images were obtained 7 to 12 min after the intravenous bolus injection of gadolinium (gadobutrol, 0.2 mmol/kg body weight). Inversion times were

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