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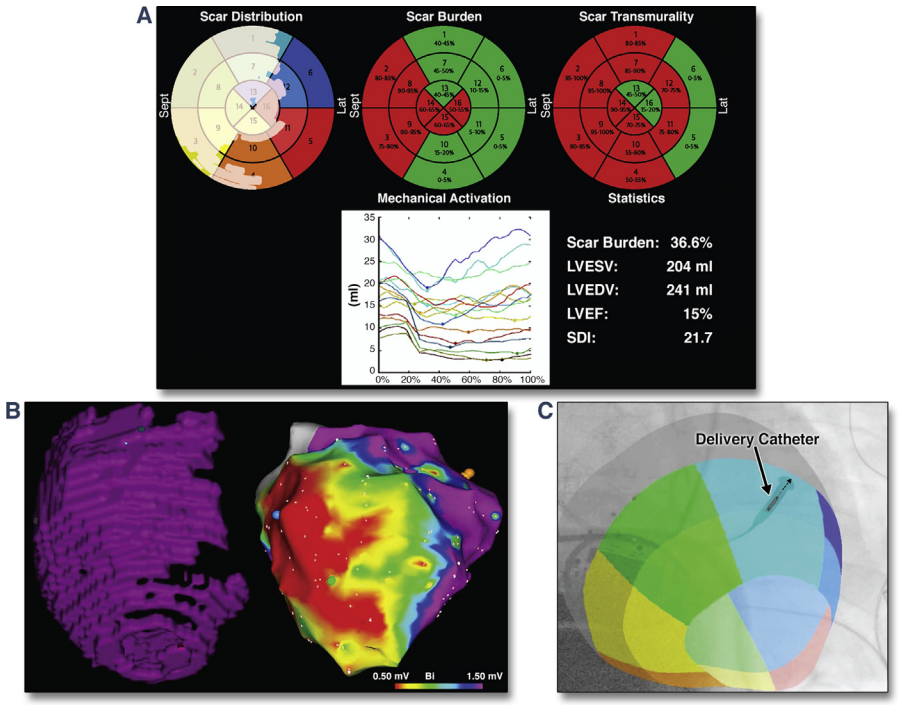
Image Integration to Guide Wireless Endocardial LV Electrode Implantation for CRT

Suboptimal left ventricular (LV) lead placement in myocardial scar (fibrosis) is associated with cardiac resynchronization therapy (CRT) nonresponse (1). Image guidance (echocardiography and cardiac magnetic resonance [CMR]) avoiding fibrosis and targeting late mechanical activation may improve response (2). LV endocardial stimulation delivers effective CRT with rapid, physiological conduction and greater electrical and hemodynamic effects (3). Endocardial access without the constraints of the coronary sinus enables access to the optimal stimulation site (3). Leadless LV endocardial stimulation with a transcatheter-delivered electrode synchronously stimulates the LV in conjunction with a pre-existing pacing system (WiCS-LV, EBR Systems, Sunnyvale, California) (4). We describe wireless LV electrode implantation using our in-house, purpose built, multimodality imaging guidance platform (Department of Imaging Sciences, King's College London and Siemens Healthineers, London, United Kingdom). This enables rapid processing, analysis, and overlay of CMR sequences displaying myocardial fibrosis and mechanical dyssynchrony onto a 3-dimensional shell merged with fluoroscopy for real-time guidance (Siemens Magnetom Aera 1.5-T magnetic resonance imaging scanner and Artis-Q biplane Combi Suite, Siemens Healthcare, Erlangen, Germany). This was integrated with LV endocardial voltage mapping for corroboration of myocardial scar (**Figure 1**).

A 61-year-old man with prior anterior myocardial infarction complicated by severe mitral regurgitation underwent surgical revascularization and mitral valve repair but remained breathless (New York Heart Association functional class III) with severely depressed LV function (echocardiographic LV ejection fraction 23%). Electrocardiography demonstrated bifascicular block (right bundle branch block and left anterior fascicular block) with QRS duration 168 ms. CMR LV ejection fraction was 15% with >50% transmural, late gadolinium enhancement in the basal to apical anterior and septal segments. He underwent CRT-defibrillator implantation but due to LV lead displacement was approved for the WiCS-LV system. Contact mapping was performed identifying regions of low voltage (bipolar scar map) and electrical latency (local activation time) using CARTO 3 (Biosense Webster, Diamond Bar, California). A scar mask from pre-procedural CMR merged with the voltage map demonstrated excellent visual agreement (**Figure 1B**). Acute hemodynamic response (AHR) (dP/dt_{max}) measured with a RADI (RADI Medical Systems, St. Jude Medical, Sylmar, California) pressure wire in the LV compared biventricular to baseline AAI pacing in addition to electrical latency and paced QRS (pQRS) duration. Two anteroseptal sites in scar (American Heart Association [AHA] segments 2 and 8) demonstrated electrical latency (83 and 153 ms); capture was achieved only at 10 V with a worsened AHR (-4% and -3%) and prolonged pQRS duration (200 ms). Four sites out of scar on the anterolateral, inferolateral, and inferior endocardial surface (AHA segments 6, 11, 4, 10) had more favorable electric and hemodynamic properties; the anterolateral site was optimal with electrical latency of 101 ms, capture threshold 3 V, improved AHR of 8%, and pQRS duration of 120 ms (**Figure 1B**, orange tag). The WiCS-LV electrode was implanted in this region (**Figure 1C**). Procedure duration was 180 min, radiation dose was 2,012 cGy cm^2, and fluoroscopy time was 19 min. It was complicated by a femoral artery pseudoaneurysm (12-F access, closure with Perclose ProGlide suture system, Abbott Vascular, Abbott Park, Illinois) requiring surgical repair. Despite extensive myocardial infarction, the patient remodeled with improvement of echocardiographic LV ejection fraction to 35%. This demonstrates integration of advanced imaging data to guide delivery of a wireless LV electrode for CRT. This was the second of 8 cases completed at our institution; we employ this approach where pre-procedural CMR is available. Future work will refine and streamline this process to identify the optimal LV endocardial pacing site.

FIGURE 1 Multimodality Imaging Platform to Guide LV Endocardial Electrode Implantation



(A) Custom-built guide cardiac resynchronization therapy software platform detailing distribution, burden and transmurality of cardiac magnetic resonance (CMR)–derived myocardial fibrosis demonstrating full thickness of anteroseptal infarct. Segments with >50% scar burden or transmurality are colored **red** and those with <50% scar burden or transmurality are **green**. **(B)** CMR-derived scar mask **(left, purple)** alongside a contact bipolar voltage scar map (low voltage in **red** or **yellow** as per scale) with excellent agreement (both in left anterior oblique view). **(C)** CMR-derived 3-dimensional shell split into 16 American Heart Association segments, overlaid onto fluoroscopy in real time to facilitate WiCS-LV (EBR Systems, Sunnyvale, California) delivery. Colors correspond to those in the bullseye plot entitled scar distribution **(A)**. WiCS-LV delivery catheter with electrode in situ, positioned in the anterolateral position (**orange tag** on CARTO 3 [Biosense Webster, Diamond Bar, California] map) **(B)**. LVEDV = left ventricular end-diastolic volume; LVEF = left ventricular ejection fraction; LVESV = left ventricular end-systolic volume; SDI = systolic dys-synchrony index.

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https://doi.org/10.1016/j.jcmg.2017.01.015

Please note: This feature is based on research, and is not commercially available. Due to regulatory reasons its future availability cannot be guaranteed. Drs. Behar, Mountney, Panayiotou, Rhode, and Rinaldi, and Mr. Toth are listed as co-inventors on a patent application for the Guide CRT platform. Dr. Mountney and Mr. Toth are employees of Siemens. Dr. Claridge has received fellowship support from St. Jude Medical. Prof. Rinaldi has received research funding from Siemens. All other authors have reported that they have no relationships relevant to the contents of this paper to disclose.

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Prognostic Value of Demand Stress Real-Time Perfusion Imaging in Patients With Advanced Kidney Disease Undergoing Renal Transplantation

Cardiovascular disease accounts for 50% to 60% of all deaths in patients with end-stage renal disease (ESRD) (1). By adding myocardial perfusion (MP) imaging to wall motion (WM) analysis, real-time myocardial contrast echocardiography (RTMCE) increases the diagnostic sensitivity and prognostic value of the stress echocardiogram (2,3). However, its prognostic value in ESRD patients has not been defined. From the renal transplant database at the Nebraska Medical Center, patients with ESRD that underwent renal transplantation (RT) and stress RTMCE preoperatively between November 2008 and January 2014 were retrospectively identified (N = 487 patients). Patients' demographics, comorbidities, and transplantation data were retrospectively retrieved from the electronic medical records.

Patients undergoing treadmill stress RTMCE underwent a symptom-limited Bruce protocol. Patients undergoing dobutamine stress echocardiography received intravenous dobutamine infusion with increasing doses at 3-min intervals up to 50 μ/kg/min combined with atropine. The contrast agent was Definity (Lantheus Medical, North Billerica, Massachusetts) administered as a 3% intravenous continuous infusion. Both MP and WM were analyzed simultaneously during the replenishment phase of contrast following high mechanical index impulses using a 17-segment model (3,4). Any abnormal MP or WM response had to be confirmed by a second independent expert reviewer, blinded to angiographic or clinical outcome data. Fixed or inducible segments were considered abnormal. All patients had baseline biplane Simpson's measurements of ejection fraction, left atrial volume index, and diastolic function using current guidelines (4). Any subsequent angiograms were interpreted by an experienced interventional cardiologist, with 70% diameter stenosis in proximal or mid portions of the epicardial vessels or major branches considered significant. Patients were followed up for the primary outcome variable, event-free survival (EFS), defined as time from transplant to the incidence of myocardial infarction, heart failure hospitalization, or all-cause mortality. Kaplan-Meier method was used to estimate survival distributions and the log-rank tests were used to compare EFS distributions. Multivariate Cox regression models of EFS were

TABLE 1 Univariate Cox Model for Time From RT to Cardiac Events (n = 47 With MACE)

		Univariate			Multivariate		
	Total (N = 487)	HR	95% CI	p Value	HR	95% CI	p Value
Age, yrs	53.2 ± 12.1	1.02*	1.00–1.04	0.05	1.03*	1.00–1.06	0.023
Male	292 (60)	1.47	0.80–2.70	0.21			
CAD	101 (21)	3.4	2.00–5.90	<0.0001			
Diabetes mellitus	176 (36)	3.56	1.97–6.45	<0.0001	2.59	1.37–4.88	0.0033
Hypertension	456 (93)	1.25	0.30–5.15	0.76			
Hyperlipidemia	283 (58)	2.14	1.11–4.12	0.023			
Months between stress test and RT	11.2 ± 11.0	1.02†	1.00–1.04	0.054	1.02†	1.00–1.04	0.046
Abnormal stress test and no revascularization‡	43 (9)	2.92	1.48–5.75	0.0020	1.75	0.86–3.57	0.12
Abnormal stress test (inducible perfusion defect or WMA)	53 (11)	2.82	1.48–5.37	0.0016			
Abnormal stress test (inducible perfusion) ≥2 segments vs. <2 segments	42 (9)	2.63	1.30–5.31	0.0072			
Stress test/DD							
Abnormal stress/grade 0–1	40 (8)	2.43	1.15–5.17				
Abnormal stress/grade 2–3	13 (3)	5.10	1.78–14.6	0.0052			
Normal stress/grade 2–3	51 (10)	1.41	0.50–4.03				
Normal stress/grade 0–1	383 (79)	Ref.	—				

Values are mean ± SD or n (%). *1-year increase. †1-month increase. ‡Compared to normal or revascularized.

CAD = coronary artery disease; CI = confidence interval; DD = diastolic dysfunction; HR = hazard ratio; MACE = major adverse cardiovascular event; RT = renal transplantation; WMA = wall motion abnormal.