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Non-invasive cardiac mapping in clinical practice: Application to the ablation of cardiac arrhythmias

Rémi Dubois, PhD,* Ashok J. Shah, MD, Mélèze Hocini, MD, PhD, Arnaud Denis, MD, Nicolas Derval, MD, Hubert Cochet, MD, PhD, Frédéric Sacher, MD, PhD, Laura Bear, PhD, Josselin Duchateau, Msc, Pierre Jais, MD, PhD, Michel Haissaguerre, MD, PhD

IHU LIRYC, Electrophysiology and Heart Modeling Institute, Fondation Bordeaux Université, France
Hopital de Cardiologie du Haut Lévêque, CHU de Bordeaux, France
Université de Bordeaux, INSERM U1045, CRCTB, France

Abstract Ten years ago, electrocardiographic imaging (ECGI) started to demonstrate its efficiency in clinical settings. The initial application to localize focal ventricular arrhythmias such as ventricular premature beats was probably the easiest to challenge and validates the concept. Our clinical experience in using this non-invasive mapping technique to identify the sources of electrical disorders and guide catheter ablation of atrial arrhythmias (premature atrial beat, atrial tachycardia, atrial fibrillation), ventricular arrhythmias (premature ventricular beats) and ventricular pre-excitation (Wolff–Parkinson–White syndrome) is described here.

Keywords: Non-invasive mapping; Cardiac arrhythmia; ECGI

Introduction

A recently developed, ECG-based, three dimensional (3D) electrocardiomapping modality named electrocardiographic imaging (ECGI) has refined non-invasive diagnosis of heart rhythm disorders [1–3]. Our clinical experience in using this non-invasive mapping technique to identify the sources of electrical disorders and guide catheter ablation of atrial arrhythmias (premature atrial beat, atrial tachycardia, atrial fibrillation), ventricular arrhythmias (premature ventricular beats) and ventricular pre-excitation (Wolff–Parkinson–White syndrome) is described below.

Mapping technique

A vest embedded with 252 electrodes is applied to the patient's torso and connected to the non-invasive system which records 252 unipolar electrocardiograms. A non-contrast thoracic CT scan obtains high-resolution images of the heart and the vest electrodes. The 3D epicardial bicameral (atria or/and ventricles) geometries are reconstructed from segmental CT images (Fig. 1). The relative positions of body surface electrodes can be visualized on the torso geometry. The mapping system solves for an 'inverse solution' to reconstruct epicardial potentials (ECVue™, CardioInsight Technologies Inc., Cleveland, OH), unipolar electrograms, and activation maps from torso potentials for at least one beat/cycle using mathematical reconstruction algorithms [2,4].

Atrial arrhythmias

Atrial fibrillation

In the area of atrial fibrillation (AF), noninvasive ECG mapping facilitates catheter ablation by contributing to our understanding of AF pathophysiology. Currently, pulmonary vein (PV) isolation remains the cornerstone of catheter ablation for AF [5]. Recently, there is emerging evidence that AF may be driven and maintained by localized reentrant and focal sources in the atria [6–8].

Mapping dynamic localized AF sources proved to be difficult using single point catheters, regional multielectrode catheters [7], or surgical plaques [6] and remained limited due to several factors, such as the inability to map both atria simultaneously, catheter contact issues, and limited surgical access [9]. With the advent of noninvasive mapping, AF is mapped beat-to-beat in a panoramic fashion, allowing for the identification of potential driving sources [10,11].

* Corresponding author at: IHU LIRYC, PTIB, Hopital Xavier Arnozan, 33604 Pessac Cedex, France.
E-mail address: remi.dubois@espci.fr

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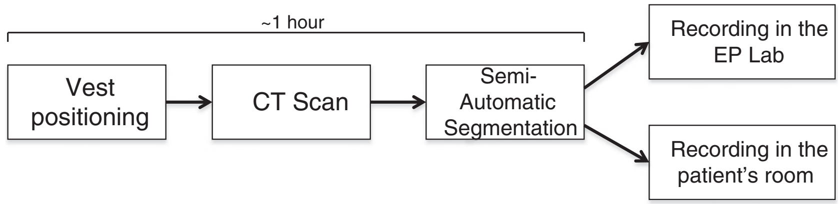

Fig. 1. Workflow for ECGI mapping.

Non-invasive mapping approach

Atrial cardiac potentials are much finer compared to ventricular potentials. To noninvasively map the atria accurately, several key barriers need to be overcome [9,11,12]. Consecutive windows with R-R pauses longer than 1000 ms during AF are analyzed. To avoid QRST interference, only the T-Q segments are selected for analysis. In patients with rapid ventricular rates, diltiazem may be administered to slow atrioventricular (AV) conduction in order to create adequate recording windows [11]. Filtering processes are applied to remove artifacts in signal morphology [9,10].

Activation maps are computed utilizing the intrinsic deflection-based method on unipolar electrograms (−dV/dTmax) [9,11,12]. Phase mapping algorithms can be applied to reconstructed global atrial signals to create AF maps, a representation of the wavefront is computed from the isophase values corresponding to $\pi/2$ [11]. Movies of wave propagation patterns are then displayed on the biatrial geometry individualized for each patient.

With the above technique, two general types of AF drivers have been identified: (1) reentrant, when a wave is observed to fully rotate around a functional core on phase progression; and (2) focal, when a wavefront originates from

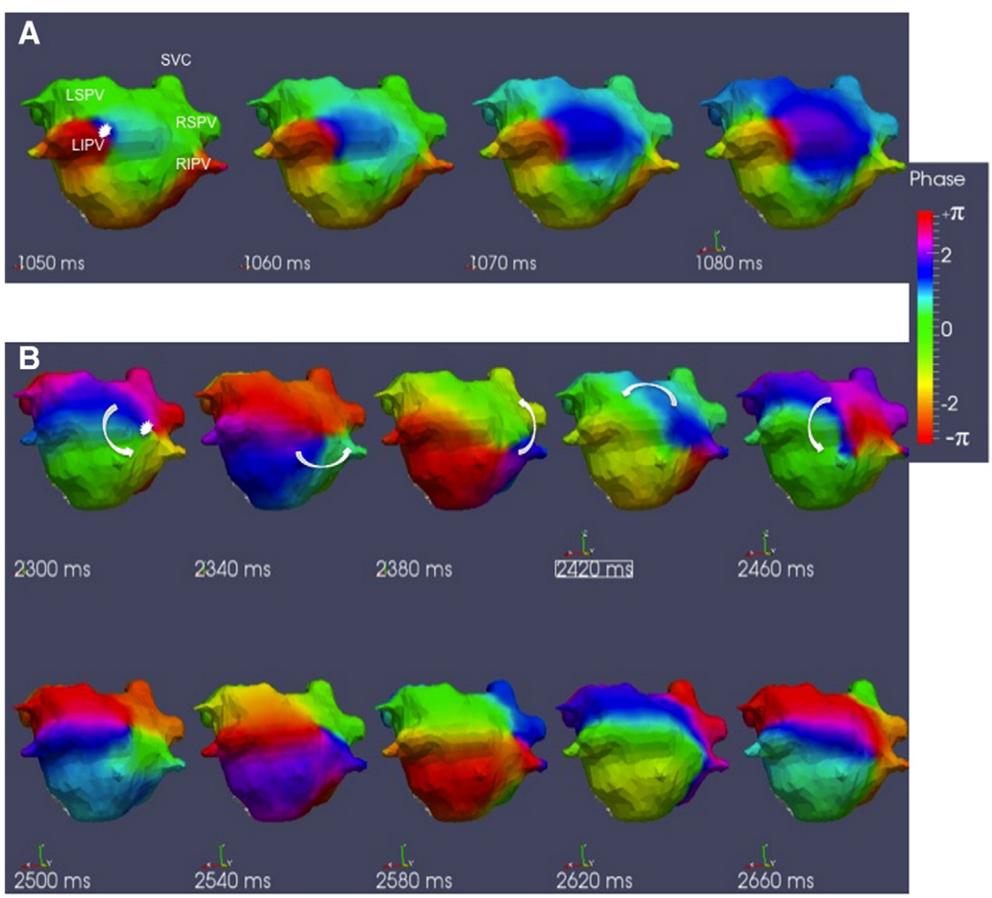

Fig. 2. Phase mapping showing posterior view of left atrium during paroxysmal AF. Panel A shows serial snapshots of a single wave emerging out of the left inferior PV (white star) and reaching right veins in 30 ms while it expands radially to the roof and inferior walls. Panel B shows serial snapshots of two successive rotations (white arrows) of a rotor located near the ostia of right veins. The core of the rotor (white star at the center of rainbow-colored phases of rotor) is seen meandering in a small region in this example. The blue wave indicates the depolarizing front, which makes one full rotation in 160 ms. The phases of wave propagation are color-coded using rainbow scale. The blue color represents depolarizing wave and the green represents the end of repolarization. The wavefront can be read by following the blue color. The time (ms) at the bottom of each snapshot represents the moment in the time-window when the snapshot was taken. Abbreviations: LSPV, left superior pulmonary vein; LIPV, left inferior PV; RSPV, right superior PV; RIPV, right inferior PV, SVC, superior vena cava. From Haissaguerre et al. [10], with permission.