How to perform noncontact mapping

Larry A. Chinitz, MD, Jesse S. Sethi, MD

From the New York University Medical Center and the Leon H. Charney Division of Cardiology, New York University School of Medicine, New York, New York.

Introduction

The anatomic and electrophysiologic complexity of arrhythmias subject to evaluation and catheter-based therapy has increased over the past several years. Use of advanced mapping systems, capable of three-dimensional rendering of cardiac chambers and superimposition of electrical information, are not designed to replace conventional mapping techniques but to be used as an adjunctive tool in the analysis and treatment of complex arrhythmias. EnSite 3000 (Endocardial Solutions, Minneapolis, MN) was the first component of the EnSite mapping system capable of advanced electroanatomic evaluation through novel catheter design and capabilities.

The unique features of this system allow it to acquire data simultaneously from an entire cardiac chamber, often in a single cardiac cycle. This can be most useful in difficult arrhythmias where mapping is hampered by hemodynamic instability, sporadic ectopic beats, or multiple rhythm morphologies. The safety and utility of the EnSite system have been evaluated in animal studies and validated against conventional mapping in humans.[1,2] The system has facilitated successful ablation of both focal and reentrant arrhythmias.[3,4] It has been particularly useful in patients with multiple foci and/or unique anatomy such as prior cardiac surgery involving atriotomy scars or repair of congenital cardiac malformations (Figures 1 and 2). More recently, the array has been deployed in the left atrium to help elucidate the origins of focally initiated atrial fibrillation, ascertain conduction block across linear lesions delivered in the posterior left atrium and mitral isthmus, and provide guidance in the treatment of left atrial flutter (Figure 3).

The promise of single-beat global mapping, on its own, may be considered an overstatement. In order to achieve the objective of the noncontact mapping technology, it is important to have a clear understanding of the mechanisms of signal acquisition, as well as its constraints and limitations.

KEYWORDS Noncontact Mapping; Endocardial Solutions; EnSite; Unipolar electrograms; Activation mapping; Substrate mapping; Voltage Mapping (Heart Rhythm 2006;3:120–123)

Address reprint requests and correspondence: Dr. Larry A. Chinitz, Leon H. Charney Division of Cardiology, New York University Medical Center, 403 East 34th Street, New York, New York 10016.

E-mail address: Larry.Chinitz@nyumc.org.

Signal acquisition

The EnSite Array uses a catheter-based, noncontact multielectrode array (MEA), a reference patch electrode, amplifiers, filters, and a computer workstation. The system can simultaneously reconstruct more than 3,000 electrograms, translating them into a three-dimensional graphical representation of the cardiac chamber, either in an isochronal or isopotential mode. The MEA is mounted on a 9Fr catheter and consists of a 7.5-mL ellipsoid balloon surrounded by 64 electrically insulated wires. Each wire has a break in its insulation, allowing it to function as a unipolar electrode. The unipolar signals are recorded using a ring electrode as reference, located 16 cm proximal to the MEA. The array can be positioned in any cardiac chamber and sample electrophysiologic signals from the endocardial surface, feeding them into its amplifier. Data generated by the potential field are sampled at 1.2 kHz and filtered between 0.1 and 300 Hz. However, the cavitary potentials detected by the array are of relatively low amplitude and frequency and therefore are not easily interpretable in their raw form.[5] The EnSite workstation analyzes and mathematically transforms the endocardial signals. The system uses an inverse solution to Laplace's equation to ascertain how a signal detected by the array would appear on the endocardial surface. Ultimately, through its signal processing, the EnSite system allows for visualization of very small potentials (voltage sensitivity 10 μV) even at significant distances from the MEA. This is achieved through a redundancy in which a summation from all 64 electrodes is used in the reconstruction of potentials from a single site. Using these techniques, 3,360 virtual electrograms are produced and updated 1,200 times per second.

In complex substrate-related arrhythmias (i.e., arrhythmogenic right ventricular dysplasia), use of activation mapping alone is insufficient for rhythm analysis or directing lesion delivery. Recently, Dynamic Substrate Mapping has been introduced, which allows the creation of voltage maps from a single cardiac cycle. This feature provides the capability of identifying low-voltage areas, as well as fixed and functional block, on the virtual endocardium through noncontact methodology (Figure 1). When combined with the activation sequence, substrate mapping provides essential information for guiding ablation, even when the arrhythmia

1547-5271/$ -see front matter doi:10.1016/j.hrthm.2005.10.030

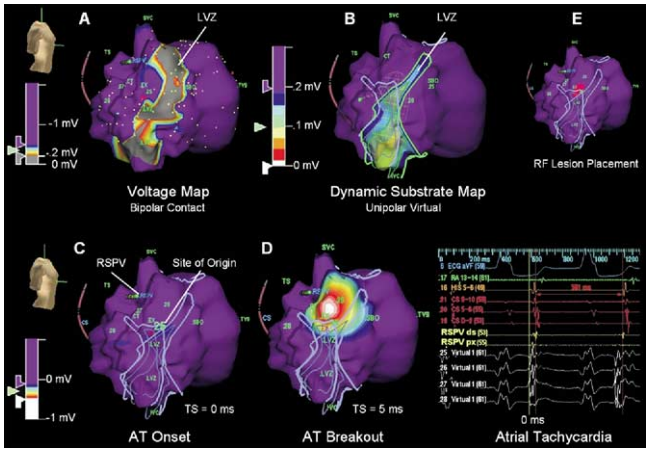

Figure 1 Focal right atrial tachycardia associated with an atriotomy scar. Bipolar voltage map **(A)** compared with Dynamic Substrate Mapping **(B)** showing the focal site of origin **(C)** and breakout **(D)** adjacent to the superior aspect of the scar. EnSite was able to guide successful lesion delivery to the border zone of the scar (E). TS = time step.

is nonsustained. Finally, the most recent version of the EnSite software provides the capability of point-by-point contact mapping, allowing the creation of activation and voltage maps by acquiring serial contact electrograms and displaying them on the virtual endocardium. This has utility in adding detail, familiarity, and validation of the information obtained by the noncontact method.

Geometry creation and catheter localization

The noncontact mapping catheter is equipped with a balloon at the tip, over which the MEA is mounted. The catheter is

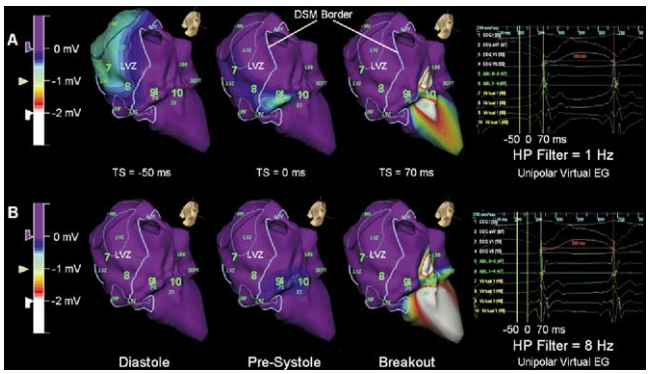

Figure 2 Ischemic ventricular tachycardia (VT) activation map shown at high-pass (HP) filtering of 1 Hz **(A)** and 8 Hz **(B)** with Dynamic Substrate Mapping (DSM) defining scar within the *light blue border*. Filtering at 1 Hz shows the low-frequency repolarization wave (time step [TS] = −50 ms) and clearly defines presystolic activation at TS = 0 (time step with 0 ms at the onset of QRS). Raising the filter to 8 Hz eliminates the repolarization wave but shifts the visualization of presystolic activity away from the critical low-frequency, slow conduction zone.

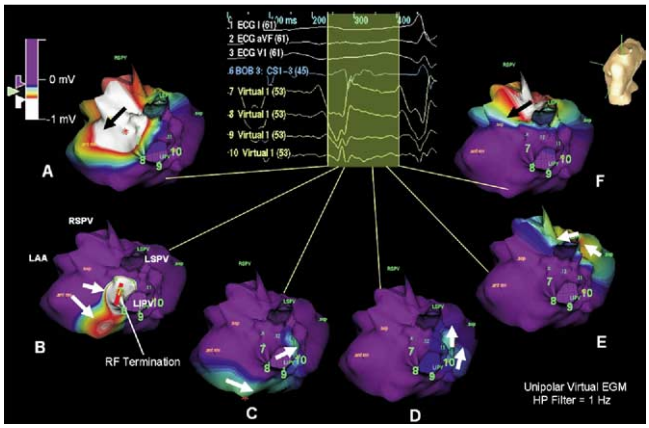

Figure 3 Postablation left atrial flutter traversing around and between the left superior and inferior veins as well as across the isthmus between the left inferior pulmonary vein and the mitral annulus. Radiofrequency termination was achieved at the carina of the left-sided veins. HP = high pass.

advanced through a special 9Fr sheath into the chamber of interest and deployed by injection of a 30/70 mixture of contrast media and saline. The distal catheter is anchored within the cardiac chamber using the pigtail configuration at its tip or with a guidewire placed through the end of the catheter. The position of the array in the chamber must be secured to avoid significant movement that will invalidate the electrical and anatomic information. The array must be positioned as close as possible to the area of interest within the chamber because the accuracy of the map is sensitive to the distance between the center of the balloon and the endocardium being mapped. Moreover, for the endocardial surface in question to be effectively mapped, it must be in direct line of sight to the MEA through the blood pool. The system provides a constant display of the distance between the mapping catheter and the center of the balloon, providing feedback on the relative accuracy of the map. For the purpose of providing a global chamber map, we prefer to initially deploy the MEA in a very central location within the chamber of interest. However, without a modified MEA position, focal activity originating within the atrial appendage, mitral or tricuspid valve, or distal superior vena cava may not be adequately visualized. Thus, the MEA position may need to be altered after the area of interest is ascertained. Due to the high profile of the balloon, care must be taken to avoid obstruction of vessels or valves and to achieve appropriate anticoagulation with frequent monitoring of activated clotting times.

The system can locate any conventional catheter with relation to the MEA using an impedance-based technology. Through this technique, a low-current, 5.68-kHz "locator" signal is emitted from the roving catheter electrode (up to four electrodes may be located). The signals are passed between the catheter electrodes and the ring electrodes proximal and distal to the array. The system calculates the signal angles and locates the position of each electrode in space, updating its position 400 times per second. The