

Navigation Systems in Current Electrophysiology

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For years, fluoroscopy was the only way that arrhythmic substrates could be located and the spatial position of catheter electrodes determined in clinical electrophysiology. The position of substrates and electrodes with respect to the cardiac shadow and bone structures on an essentially 2-dimensional image was the only imaging support for the electrophysiologist interpreting anatomical localization.¹ This started to change towards the end of the 90s with reports of the first clinical applications of the so-called navigation systems, with computerized mapping independent of fluoroscopic control. Electroanatomical mapping with the CARTO^{®2} system (Biosense, CordisWebster), noncontact mapping³ (ENSITE[®]; Endocardial Solutions Inc.), the LocaLisa^{®4} system (Medtronic), and 3-dimensional real-time positioning⁵ (RPM[®]; Real-Time Position Management System; Boston Scientific, S.A.) are currently the main technical developments applicable in clinical electrophysiology. They were introduced into Spain slowly at first—in 2001, only 26% of Spanish laboratories had any sort of navigation system, and the use of these systems was limited (only 7 out of 182 patients with atrial tachycardias underwent procedures with such systems).⁶ One year later, the number of such systems available in Spain had doubled.⁷ The CARTO^{®2} and ENSITE[®] systems are more widely used in Spanish laboratories than other systems. Internationally, the CARTO system is the most widely used: 169 citations since 1997 in MEDLINE describe clinical use of this system—well ahead of the 13 citations for the LocaLisa system in the same database.

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Electroanatomical mapping with the CARTO system allows simultaneous, point-by-point, acquisition of activation, propagation and endocardial voltage maps in different arrhythmic substrates, with a complete three-dimensional chamber reconstruction. The relevant electrophysiological information that identifies early activation (activation maps), reentrant circuits (propagation maps) or regions of endocardial scarring that mark tissue isthmuses (voltage maps) can be presented as an image that facilitates the integration of functional and anatomical information, particularly in complex mapping. Such mapping is almost essential in techniques such as circumferential ablation of pulmonary veins, for which the CARTO system provides the best definition of the substrate. In recent years, in our experience, this system has become an important tool in the ablation of substrates of ventricular and atrial tachycardias.^{8,9} Conventional mapping is often limited by the display of information, and it is not unusual to have to subsequently correct by hand the activation times of certain endocardial points. The technique is costly because it requires a special catheter with a sophisticated sensor embedded in its distal electrode and this may limit its use in smaller laboratories. As with other systems, few randomized studies have been carried out to back up its use. Such studies should not be done on unselected consecutive populations.¹⁰ Mapping should be reserved for the most complex substrates, which are appearing more frequently. Furthermore, the usefulness of mapping becomes more apparent as we gain experience and are able to use it more often. The CARTO-XP[®] version allows the system to review the 8 previous mapping cycles at each point. On the other hand, the multi-electrode QuickStar[®] catheter, with 26 electrodes and application of the QuickMap[®] software, allows rapid chamber reconstruction from a small number of electrode positions within the chamber. However, the usefulness of these advances in electromagnetic mapping has yet to be tested by greater clinical experience.

The original work of Abello et al¹¹ is an interesting contribution to the use of a navigation system that has received little coverage in the *REVISTA ESPAÑOLA DE CARDIOLOGÍA*. The authors analyzed the results from radiofrequency ablation of sustained ventricular tachycardias in an initial population of 32 patients with structural heart disease. They compare the results of a first group of 10 patients who underwent interventions supported with the LocaLisa system with a second control group of 22 patients who underwent a conventional procedure. The lack of significant differences in success of the ablation procedure between the two groups (around 70%) is not surprising in such a small population. The authors found that the catheter could be accurately repositioned at relevant points of the reentrant circuit using the navigation system, something which has also been confirmed by other investigators. Thus, reliable repositioning of the catheter at any point of interest can now be achieved with a margin of error of 2 mm. The authors did not obtain the expected decrease in fluoroscopy time with the use of the navigation system in this descriptive study. This was their first experience with the technique, so their study failed to reflect one of the main contributions of this catheter navigation technology. The system allows the position of up to 10 electrodes to be controlled in a simultaneous biplanar image, but the lack of a three-dimensional chamber reconstruction is evident in the 2 images presented, pointing to one of the main limitations of the system. On the other hand, given that the navigation system does not depend on the type of catheter used, the procedure is considerably cheaper and so will be accessible to most laboratories. This probably explains why, in 2002, it was one of the most widely used system in Spain, not far behind the CARTO system.⁷ However, the superiority of other technologies casts a shadow over future development of this navigation system conceived by Fred Wittkampf at the University Hospital of Utrecht. The lack of a rough reconstruction of the chamber for easier visualization in this simple system is overcome with the new EnSite NavX[®] surface electrode kit, which is able to reconstruct the chamber in three-dimensions in real time. The signal emitted by the 3 surface electrode pairs allows visualization of up to 8 catheters of any type and 64 electrodes in three-dimensional space. Likewise, the system is able to display computed tomography images on screen simultaneously for anatomical correlation.

Although electroanatomical reconstruction with the CARTO system is a very significant advance in its current state, its resolution, as with all sequential systems, depends on the time available to acquire the endocardial data points. Therefore, use of this system for mapping during tachycardia is very limited with hemodynamically unstable or unsustained arrhythmias. Obviously, the ideal mapping system should collect simultaneous data from the whole of the heart

surface for high resolution maps allowing display of the catheter position. The technological developments of noncontact mapping (EnSite 3000[®]; Endocardial Solutions Inc.) are an attempt to reach this ideal. Placement of a multielectrode probe inside the desired heart chamber is required. Endocardial electrograms from the probe are reconstructed at more than 3000 points on the virtual endocardium with mathematical methods based on the inverse solution of the second Green formula.³ Beat-to-beat sequences of the whole heart chamber are therefore reconstructed. The accuracy of the reconstruction of electrograms decreases above a certain distance between the probe and the endocardium. More experience with the technique will help hone the spatial resolution in diseased hearts. In the near future, the EnSite Array[®] mode, in combination with the EnSite NavX system mentioned earlier, will allow mapping of a single beat. Finally, the RPM system provides an interesting and rapid ultrasound reconstruction of the chamber. A three-dimensional anatomical model of one or several chambers can be created in real time from 11 ultrasound transducers located in the 3 catheters comprising the reference system. With this anatomical model, the system is able to reconstruct an isochronous activation map and a voltage map. The clinical experience with this system is currently limited.

Apart from the extensively used techniques such as fluoroscopy guidance and intracardiac echocardiography, navigation systems are the first heart imaging technique in the electrophysiology laboratory that incorporate relevant electrical information. These technological developments should shorten fluoroscopy time, but actual decreases will not occur unless we become accustomed to limiting the use of fluoroscopy as much as possible. Furthermore, solid training in arrhythmias is, without doubt, the best way to ensure good and reliable application of these systems—none of these systems can guide the cardiologist through blank spots in his or her training. Within cardiology, some will look on electrophysiologists as colleagues with a vivid imagination. Hopefully, navigation systems will reduce the imagination and effort required to integrate three-dimensional anatomical and electrical information on the substrate and make the process more accurate. They are therefore of obvious value and open the doors to more advanced electrophysiology. We therefore welcome them.

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