Non-fluoroscopic mapping as a guide for atrial ablation: current status and expectations for the future

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Non-fluoroscopic mapping systems: historical background

In the early 1990s, catheter ablation was limited to accessory pathways, atroventricular nodal re-entrant tachycardia and atrial tachycardia (AT)/flutter, all of which were based on standard electrophysiological mapping systems. Subsequently, expansion of ablation included atypical flutters, ventricular tachycardia, and atrial fibrillation (AF). Because conventional fluoroscopic catheter mapping has limited spatial resolution and involves prolonged fluoroscopy, a non-fluoroscopic electroanatomic mapping technique has been developed to overcome these drawbacks. As a result, the past decade has witnessed the development of an increasing number of AF ablation procedures largely based on anatomic considerations which prompted the explosive development of computer-based mapping for increasing accuracy.1–31 Three-dimensional (3D) mapping technology advances our understanding of AF and increases the safety, efficacy, and efficiency of radio frequency (RF) ablation allowing the construction of 3D geometry to guide catheter navigation and ablation lesion placement.

Non-fluoroscopic mapping systems as a guide for atrial fibrillation ablation

For ablation to be successful, two factors need to come together: detailed mapping and the ability to navigate catheters that deliver energy to specific targets. Therefore, 3D mapping systems constitute an important component of many AF ablation strategies permitting navigation to anatomic structures relevant to AF ablation. This is the reason why these systems have suddenly become crucial, being used in most EP laboratories. As the catheter is moved inside the heart, 3D mapping systems continuously analyse its location and orientation and present these data to the user on the monitor of a graphic workstation, permitting navigation without
fluoroscopy. Since the ideal system has not yet been devised, at present operator experience and preference remains one of the most important differentiating factors. Detail of anatomical reconstruction should be considered as an important challenge for any 3D mapping system. Ideally, the system should be able to reproduce exactly the actual anatomy with its complexities as well as to extract any relevant electrophysiological characteristics of the electrogram at each site providing real-time parametric displays for evaluation and treatment of an arrhythmia.

Detailed anatomic and activation maps are partly operator- and partly machine-dependent. Defining accurate anatomical geometries is dependent on the ability of the operator, it is particularly important to recognize potential anatomical variants that are common in patients undergoing AF ablation. Image integration of electroanatomical map with computed tomography or magnetic resonance imaging as in CARTOMerge and EnSite-NavX integration system may allow identification of the true chamber geometry with potential anatomical variations [particularly of the pulmonary veins (PVs)] independent of the operator’s experience. However, this integration strategy requires the undertaking of several expensive processes, and at present it may not be essential.

Accuracy is another challenge of 3D mapping systems. An accurate and reproducible documentation of both the timing and the amplitude of recorded electrograms is highly desirable for any mapping system. The accuracy and resolution of the virtual anatomy mainly depends on the number of points collected by the operator to create the surrogate geometry. The more the points, the closer the image rendering comes to reconstructing the actual anatomy without distortion. If an inadequate number of points is acquired in reconstructing a map, it will not be accurate and may underestimate the true anatomical size making it not useful or even dangerous during ablation. If a greater force is applied, then the virtual chamber may be deformed, and thus both the surface and volume will overestimate the reality.

Interpolation between collected points is also an important challenge of the CARTO system greatly contributing to the construction of detailed 3D maps. The algorithm used to interpolate graphically between three and more points may be crucial to reconstruct a surface segment, with its related volume, preserving the complexity of the actual anatomy. To improve the accuracy of the virtual anatomy on which electrophysiologists are working, interpolation between points should be used minimally, which may result in a longer procedure in order to collect a sufficient number of points, particularly in areas with complex structures such as the PVs and/or valves. Incorrect interpolation from insufficient numbers of points may result in distorted anatomy without interstructure delineation, whereas interpolation between points along an uncomplicated area plays a less important role readily producing a clear image of that surface.

Currently available electroanatomic mapping systems for atrial fibrillation ablation

There are currently four main 3D mapping systems and each tool to some extent plays a part in a modern Electrophysiological (EP) laboratory to facilitate AF ablation: CARTO (Biosense-Webster, Diamond Bar, CA, USA), NavX system (St Jude Medical, St Paul, MN, USA), RPM (Boston Scientific, Natick, MA, USA), and LocaLisa (Medtronic, Minneapolis, MN, USA). CARTO and NavX technologies are the main mapping systems now routinely used for AF ablation in our laboratory (Figures 1–3). Emerging technologies such as navigation and ablation with magnetic fields (Stereotaxis, Inc., St Louis, MO, USA) have recently been introduced in our laboratory and are likely to have an impact on our approach to imaging and AF ablation. Remote mapping has been combined with CARTO, which has been specially modified to be able to function in the magnetic environment.

Since one of the obvious disadvantages of the electroanatomic mapping systems explosion is cost, the question arises as to whether or not 3D technology is essential for AF ablation and which system is most economic. At present, many ablation techniques are based increasingly

Figure 1 Pre-ablation colour-coded voltage 3D maps of the left atrium using different electroanatomic guidance systems (CARTO, A and NavX, B) is shown in the postero-anterior anatomic view. Red represents the lowest voltage. On the right, multiple ostia and/or very late confluence of the left superior pulmonary vein and both right-sided pulmonary veins are evident; the reference NavX catheter (in yellow) is placed in the coronary sinus.
Figure 2  Colour-coded electroanatomic voltage 3D remaps (CARTO, on the left and NavX, on the right) showing the typical lesion set as performed by circumferential pulmonary vein ablation. Four discrete orifices have been tagged on the CARTO map, permitting separate ablation lines to be created around each vein >1 cm from the PV ostia. Under NavX guidance, the lesion set has been easily tailored according to the patient’s anatomy. Note that areas inside the ablation lines converted to red in both maps, indicating electrical isolation with no potentials (<0.1 mV). The dark red dots (on the left) and white dots (on the right) denote ablation points and the anatomic contiguity of these points.

Figure 3  Colour-coded pre-ablation impedance 3D map showing pulmonary vein–left atrium junction as defined by CARTO system in different views. The pulmonary vein ostia are depicted in blue.
on anatomical considerations, which require the placement of ablation lesions at specific anatomical targets. Therefore, advantages of 3D systems appear to be evident in guiding such complex procedures. Initially, PV focal ablation and isolation did not require 3D mapping systems but the more distal strategy of PV isolation, which encompasses the antral region, requires exact anatomical identification of the PV ostia and PV–left atrium (LA) junctions.

In the last 2 years, the role of 3D mapping has become indeed essential in patients with long-lasting or permanent AF, who require addition of linear lesions to various anatomical locations regardless of the ablation strategy.9,12,20 The ability to identify and navigate to the required detailed anatomical position and then maintain stable catheter contact on targeted areas has become crucial for deploying multiple lesions in such a patient population. To improve safety and efficacy of the procedure, newer software versions have recently been developed for impedance maps,14,24,26 fractionation and/or dominant frequency maps, or integration of 3D systems with CT/MRI. However, since CT or MRI is acquired before generation of 3D maps, we believe that clinical utility of these new systems will largely depend on the accuracy of image integration of these two processes. In addition, PVs are not static structures being affected by respiration with variable change in ostial diameter during inspiration affecting CT/MRI integration with 3D electroanatomical mapping systems.

**Mapping and navigation under CARTO or NavX guidance**

In the late 1990s, we first used the CARTO system for reconstruction of the right atrium and LA for AF ablation.2–4 At present, the CARTO system has become widely used in AF ablation procedures, particularly where point-to-point mapping and accurate electroanatomic correlation are required. This system determines the location and orientation of the mapping/ablation catheter (Navistar) using three ultra-low magnetic fields emitted from a unit mounted under the patient table. Location sensors housed in the catheter tip detect the strengths of these magnetic fields and allow computation of catheter position in 3D space as well as catheter orientation. A 3D map is generated by first placing the catheter under fluoroscopy guidance in the coronary sinus (CS) as anatomical landmark. Other points are collected at each point and all together create a voltage, representation of endocardial voltage distribution

3D map, however, needs to be further refined by manual point-by-point acquisition, particularly in delineating challenging areas such as the mitral annulus with its isthmus, the ridge between left atrial appendage (LAA) and left superior pulmonary vein (LSPV) and the septal region. The length of the mitral isthmus is highly variable, up to 50 mm, in patients with normal hearts and the isthmus may be even longer in patients with a dilated LA predisposing to incomplete block.
With both 3D systems, when mapping the right inferior or superior PVs far-field electrical activity may be recorded from the proximal electrodes. So when validating this region, it is important to push the catheter deeper into the vein in order to reduce this influence.

LAA is one of the latest areas to be mapped, which is easy to be identified since its potentials are characteristically not fractionated and of high amplitude. Every effort should be made to define the ridge between LAA and LSPV accurately, which characteristically shows potentials that are higher and more fractionated than in the rest of the atrium, but smaller than those of LAA. If the ridge is not accurately reconstructed, the left-sided circumferential lesion line may be deployed too close to the LAA or within the PV ostium either of which may result in poor efficacy and/or major complications.

The septal area, which is close to the inferior portion of the right inferior PV, also represents a difficult region for both mapping and ablation and, therefore, should be accurately reconstructed and defined by manually acquiring a sufficient number of points by stable catheter–wall contact. When reconstructing the roof with CARTO, a sufficient number of points should be collected to avoid an incorrect interpolation of points, which may generate inaccurate geometry potentially predisposing to residual conduction gaps. In experienced hands a complete CARTO or NavX map is usually performed in less than 10 min (Figure 1).

CARTO or NavX systems as a guide for atrial fibrillation ablation

Three-dimensional mapping and navigation are indeed crucial if not essential to reach targeted areas safely for successful ablation. Having navigated to the area of interest, it is necessary to be able to apply a safe, reliable, and effective form of energy with high success rate deploying contiguous lesions with the lowest risk of complications. This requires procedural skills and expertise to maintain a stable catheter position, catheter contact as well as precision in localization of targets. Our standard set of lesions to isolate triggers while modifying the substrate, includes contiguous, point-by-point circumferential lines around the left- and right-sided PVs, 1–2 cm from their ostia, additional linear lesions in the posterior wall between superior and inferior PVs, and the mitral isthmus line to modify the substrate further and to prevent potential post-ablation LA tachycardias (Figure 2).

The NavX technology allows the use of any catheter ablation technique including balloon catheters (Figure 4),
whereas the CARTO technology uses only proprietary catheters.

Over recent years, we and almost all electrophysiologists exclusively use open irrigated-tip catheters with an irrigation rate of 2–50 mL/min to maintain the desired power. Irrigation allows performance of deeper lesions at lower power settings, compared with non-irrigated 4–8 mm tip catheters used in the past. When ablation starts, the irrigation rate of the catheter tip is raised to 17 mL/min and RF energy is delivered with a dragging technique under continuous 3D guidance. Visualization of ablation lines by 3D map facilitates the creation of a continuous line and helps to avoid repeated unnecessary energy delivery at sites that have already been targeted. Usually, we tailor ablation lines according to each patient’s anatomy and elicitation of vagal reflexes (Figure 5). To minimize the risk of oesophageal injury, in the posterior LA, the power is set lower whenever ablation is performed. In our centre, only one case of a non-fatal atrio-oesophageal fistula has occurred out of more than 15 000 patients undergoing circumferential pulmonary vein ablation (CPVA).32

We first reported a detailed ‘autonomic map’ of the LA as a target for ablation (Figure 5) and we have found that, like the LSPV, the septal region is richly innervated. Once the lesion set is complete, we accurately revisit the lesion lines and encircled areas to check for residual conduction gaps and apply RF where needed. The mitral isthmus line is validated by activation and voltage maps and differential pacing manoeuvres.8 In many patients, all endpoints are reached at the end of the procedure and double potentials or no potentials are found on the targeted areas.

**CARTO and NavX technology: advantages and disadvantages**

Although no present mapping system combines all desirable characteristics, the advantages, disadvantages, and the unique features of each of the two major mapping and navigation systems will be discussed on the basis of our experience. The CARTO system was first used in the middle 1990s for ablation of several arrhythmias and in the late 1990s for AF ablation,2 and the principle of catheter navigation is represented by a magnetic field. The NavX system is an alternative 3D mapping system, which has recently been introduced in EP laboratories and its principle of catheter localization is by an electric field.19 They use different technologies, software, and energy sources, which necessarily lead to different advantages and disadvantages (Table 1). We believe that everybody who uses these technologies should know when to use them and how they work, their advantages, and also their potential or inherent limitations.
limitations without abrogating all responsibilities to the device or the industry. Although we have used the CARTO system for many years, we routinely use both systems.

In individual cases we prefer to adopt one system instead of the other according to our extensive experience and the patient’s characteristics. Unlike NavX technology, the CARTO system allows the calculation of the percentage of the encircled ablated area, which has been demonstrated to be a strong predictor of the long-term success in patients undergoing CPVA. By selecting and tagging all points inside and around the lesions with an amplitude of less than 0.1 mV, the CARTO software calculates the ablated surface area in square millimetres of 3D reconstruction inside the identified region of interest (Figure 6).

Both systems allow reliable monitoring of the ablation catheter offering a proximity indicator that, based on the intensity of the colour of the tip, allows the operator to monitor the optimal tissue contact of the ablation catheter. Although lesion markers can be tagged to see continuity of ablation lines, with the NavX system, simultaneous voltage caliper displays can be used to see the effect on the local electrogram during RF applications. Therefore, catheter displacement and insufficient wall contact are readily recognized, resulting in significant reduction in radiation exposure, procedure duration, and reduced RF energy delivery.

Fluoroscopy time and radiation dose are usually much lower with CARTO and NavX guidance than with the conventional mapping system, thus exposing patients to the least amount of radiation. These reductions are achieved without compromising the duration, effectiveness, or safety of the procedure regardless of the 3D systems. The major limitation of CARTO is the need for point-to-point mapping. Creation of these maps is slow and requires a sustained stable rhythm particularly for AT mapping, but the final anatomical and activation maps are very accurate. Sequential acquisition of points by NavX may represent an important advance making the procedure faster than by CARTO. Uncomplicated anatomical areas of the LA can be quickly reconstructed by NavX system, but the final NavX map should often be refined by point-by-point acquisition, which is much slower with NavX than CARTO.

Introduced recently is the CARTO XP system involving a novel 26-electrode mapping catheter (Qwikstar, Biosense Webster) which allows acquisition of multiple distinct electroanatomic points simultaneously from each electrode, thus potentially reducing the number of point-by-point acquisitions. Further studies are required to demonstrate the usefulness of this new mapping system which uses fewer point-by-point acquisitions than with the bipolar catheter alone (Navistar).

A further advance of CARTO technology has been the combination of the CARTO mapping catheter with the magnetic system Stereotaxis for guiding remote AF ablation. Despite these advances, we believe that CARTO technology should be revisited and updated since the system uses only proprietary catheters but it does not allow visualization of catheter shape, which is important for performance of safe RF applications.

Unlike the CARTO system, an important advantage of the NavX technology is that patient movements do not affect the reconstruction of the map since the CS reference catheter moves equally in relation to the surface patches. However, if during NavX mapping the CS reference catheter inadvertently moves from a distal to a more proximal position, the resulting NavX map will have to be repeated. The function of respiratory compensation by the NavX technology represents another advantage, which minimizes respiratory artifact or movements. Usually, we apply this function when ablating the posterior wall to maintain catheter stability and better wall contact since the occurrence of pain may cause the patient to change respiratory frequency. In contrast, the potential limitation of NavX technology is that map acquisition is based on impedance values and increased external or intrathoracic impedance gradients may affect the NavX map overestimating the actual anatomy. In our experience, NavX maps of obese patients and/or patients with chronic pulmonary disease frequently are not as accurate as CARTO maps in delineating the septum and the LA roof. Knowing these limitations, in experienced hands, both systems can be safely and effectively used in all patients undergoing AF ablation, but less experienced operators

Figure 6  Post-ablation voltage CARTO 3D map showing how to calculate the per cent (%) of ablated areas (33% of the left atrium in this patient), which represents the surface area in square mm of the total 3D area inside circumferential lesions or lines.
should undergo adequate training before using available 3D mapping systems for AF ablation.

**Electroanatomic mapping systems in patients with permanent atrial fibrillation**

The use of 3D mapping systems in patients with long-lasting or permanent AF is indeed crucial to ablation therapy and complete achievement of all endpoints including non-inducibility of both AF and AT. Usually, further linear lesions are deployed in the LA, which require exact catheter positioning and stable wall contact particularly at challenging sites. This makes the procedure longer than usual lasting at least 2 h for sinus rhythm conversion and non-inducibility. Lesion lines are validated by electrophysiological criteria and differential pacing manoeuvres. The demonstration of complete block is defined by the presence of continuous wide double potentials along the ablation line separated by an isoelectric interval during pacing from the LAA. Navigation and ablation for epicardial and/or endocardial disconnection of CS constitute one of the most difficult targets. By roving the mapping catheter from distal to proximal positions, we can rapidly reconstruct the CS anatomy, and under NavX guidance, we can see both the CS reference catheter and the ablation catheter (Figure 7). The endpoint for CS disconnection is complete abolition of all atrial potentials within the CS. Usually, we deliver two short low-energy sequential RF applications (usually between 15 and 30 W) by dragging the catheter in a distal to proximal direction, instead of performing a single RF application, in order to keep the temperature down and avoid potential complications. As the ablation starts, the rate of irrigation is set at 30 mL/min and the maximum power setting is 30 W. Safety inside the CS is crucial, particularly along the epicardial aspect of its structure.

**Electroanatomic mapping systems: the remap process after atrial fibrillation ablation**

After completing the ablation procedure, usually a single voltage remap is reconstructed to validate the complete bipolar voltage abatement along lesion lines and within isolated regions. The remap process requires the acquisition of new points on the existing geometry to provide voltage measurements and the per cent of encircled areas on the CARTO map (Figure 6). The purpose of this phase is to make sure that all targeted areas are

![Figure 7](image-url)

**Figure 7** Posterior view of post-ablation monochromatic anatomical NavX 3D map performed during atrioventricular showing the standard circumferential pulmonary vein ablation set of lesions (radio frequency applications marked by white dots) and coronary sinus mapping and ablation (marked by red dots) under NavX guidance (right panel). Conversion to stable sinus rhythm occurred during radio frequency applications into coronary sinus before completing coronary sinus disconnection. The ablation catheter tip is in green while the coronary sinus reference catheter in yellow. Surface leads I, III, AVF, and V1 are recorded with simultaneous bipolar intracardiac electrograms.
Electroanatomic mapping systems: management of post-ablation atrial tachycardia

We have extensively used both CARTO and NavX systems (Figures 8–11) to map endocardial circuits during sustained post-ablation AT in patients who had undergone AF ablation.8,14,19,21,23 A minimum of 50 points and coverage of at least 90% of the tachycardia cycle length (TCL) is required for a complete map. Usually, early and late activation sites during tachycardia are coloured red and purple, respectively. If the tachycardia is known to be in the LA, then an LA map alone is created. If the chamber of origin is in question, separate activation maps of the right atrium, LA, or CS are created. Three-dimensional mapping systems have demonstrated that these ATs are mostly due to macro-reentrant (mapped cycle length >80% TCL) or to a focal/micro-reentrant (mapped cycle length <80% of TCL) pattern with earliest atrial activation on prior circumferential lesions. In focal/micro-reentrant ATs, local atrial electrograms at the site of earliest atrial activation appear of low amplitude and/or fragmented or with double potentials. Macro-reentrant circuits, which are due to single or multiple conduction gaps, usually transect previously deployed lesions at least twice (in two gaps or one large gap) and are not located adjacent or tangential to lesions. In these cases, ablation of sites with earliest atrial activation that demonstrate concealed entrainment with post-pacing interval (PPI)~TCL and mid-diastolic or long fractionated electrograms results in AT termination. After focal/micro-reentrant ATs, the commonest post-ablation AT is macro-reentrant mitral annular tachycardia.8 Entrainment with PPI~TCL from three or more sites around the superior and inferior mitral annulus, with an activation time around the mitral annulus similar to TCL strongly suggests a mitral annular AT. In patients with macro-reentrant LA tachycardias, we perform linear lesions connecting two adjacent non-conductive structures and rarely is peri-mitral re-entry stopped by redrawing the left isthmus line. In focal or micro-reentrant tachycardia related to gaps in prior ablation lines, usually we eliminate gaps by a single RF application and consolidate the ablation effect by extending ablation to a short line. Despite restoration of sinus rhythm and non-inducibility of AT, sometimes 3D mapping may reveal remaining conduction gaps, which are closed by further RF applications. RF ablation with a 4 mm tip catheter is often sufficient, but creation of large linear lesions may require 8 mm or tip-irrigated catheters, especially with a relatively broad isthmus.

Remote mapping and ablation with stereotaxis

Remote magnetic technology may facilitate both navigation and ablation in patients with AF independently of operator dexterity. The magnetic navigation system (Niobe; Stereotaxis) uses two permanent magnets to create in the ‘navigate’ position a relatively uniform magnetic field (0.08 T) of 15 cm inside the chest of the patient in which an extremely soft catheter with magnetic mass in the tip and distal shaft can be manoeuvred. The system consists of two independent but communicating components: the Niobe® Stereotaxis MNS (Stereotaxis, Inc.) which is connected by a 4–8 mm catheter (NaviStar-RMT, Biosense Webster, Inc.) and combined with an electroanatomic mapping system (CARTO-RMT, Biosense Webster, Inc.), which was specially modified to be able to function in this magnetic environment. The Niobe system is managed by a computer interface system (Navigant), which changes the two magnets’ orientation and thus the magnetic tip orientation. The three magnets located in the distal portion of the catheter can be deflected in any direction and once steered by the magnetic system can be advanced and retracted by a computer-controlled catheter advancer system (Cardiodrive, Stereotaxis) to allow truly remote catheter navigation without the need for manual manipulation. All magnetic field vectors can be stored and, if necessary, reapplied while the magnetic catheter is automatically navigated. Once the trans-septal sheath is positioned,
the operator leaves the interventional room to perform mapping and ablation from the control room. After synchronizing with respiratory and cardiac cycles, right and left anterior oblique images are transferred to the Navigant screen for orientation and navigation. PV location can be selected by a preset magnetic field vector, and while navigating several points are continuously acquired by the NaviStar-RMT magnetic catheter. An accurate electroanatomical map can be performed using an automated mapping function present in the Navigant software specifically designed for mapping the LA. Sequential acquisition of many points by stable wall contact of the catheter tip permits rapid creation of accurate and detailed cardiac geometry even in difficult areas for optimal RF applications and achievement of all endpoints (Figure 12). Currently, we perform remote

Figure 9 Activation (A1–A3) and voltage (B1–B3) 3D maps by CARTO system of a left atrial macro-reentrant atrial tachycardia in previously ablated areas. The voltage map in different views clearly demonstrates that right superior pulmonary vein and right inferior pulmonary vein (white arrows) were reconnected after the index procedure. RSPV, right superior pulmonary vein; RIPV, right inferior pulmonary vein. 

Figure 10 Electroanatomical isochronal NavX 3D map of post-ablation atrial tachycardia (cycle length, 280 ms) in a patient who had undergone circumferential pulmonary vein ablation. This anterior view highlights the site of earliest atrial activation, which was mapped to the inferior part of the right superior pulmonary vein. The white dots mark the site of successful ablation (lower panel). The mapped atrial tachycardia cycle length was < 60% of the atrial tachycardia cycle length, which suggests a micro-reentrant pattern due to residual conduction gaps.
ablation by 8 mm tip catheter with a target temperature of 65°C and a power limit of 50 W. The combined system is very useful for constructing an accurate electroanatomic map while acquiring more points in the time usually taken for a map made manually.

Preliminary results from our laboratory suggest that remote ablation by 8 mm tip catheter is a simple, safe, and useful approach for patients with paroxysmal AF requiring a short learning curve.27,31 In our experience, remote navigation by the 'softer touch' of the Navistar-RMT catheter causes less deformation of cardiac chambers, compared with manual mapping, which results in a more accurate reconstruction, reduced endocardial trauma, and minimal fluoroscopic time. Remote ablation by 8 mm tip catheter results in achievement of all endpoints and the risk of cardiac perforation is even lower. Irrigated tip catheters have recently been approved in Europe giving further advantages for both patients and operators.

Future directions and expectations

Increasing complexity of ablation procedures for AF requires considerable technical expertise and multiple mapping and ablation tools to ensure efficacy as well as safety. Knowledge of the normal anatomy and increased understanding of the range of normal variations in anatomy supports the concept that patients undergoing AF ablation have accurate 3D mapping during the procedure to allow effective planning of the ablation strategy. Our own experience suggests that intensive training courses are also important to convey information on how to navigate and ablate using 3D systems, thus allowing reproducibility of detailed maps with improved outcomes. At present, integration of 3D mapping with CT/MRI is desirable but perhaps not essential. Future image integration technologies with automatic segmentation, robust registration software, and the possibility to integrate into a single display many imaging technologies are promising tools to reduce procedure times increasing the number of AF ablation procedures that can be safely performed in a day. However, further studies are required to demonstrate that this translates into improved outcomes with cost savings. We believe that development and widespread use of navigation systems such as the Stereotaxis system, particularly when used in conjunction with accurate electroanatomic mapping and irrigated tip catheters, will improve outcomes while minimizing complications and that these results may be quickly seen even with relatively inexperienced operators.

Conflict of interest: none declared.

References


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