Changes in Pediatric Electrophysiology: Can Big Advances Come in Small Packages?

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Sparky Anderson, a Baseball Hall of Fame manager and self-professed novice of the English language, once said, “Things change, so change with ‘em.” But is “change for change’s sake” always for the best? Electrophysiology (EP) techniques have advanced exponentially since the first human intracardiac recordings in the 1960s. In the 1980s, EP transitioned from the purely diagnostic to the therapeutic. The advent of intracardiac catheter ablation introduced a revolution in the management of arrhythmias. Several technological advances (i.e. smaller diameter, more pliable catheters, temperature-controlled radiofrequency ablation) have markedly improved efficacy and safety.

However, not all innovations have stood the test of time or proven worthwhile. The initial use of direct current shock (supplied by a standard external defibrillator) for intracardiac procedures caused extensive tissue injury. More recent advances, such as microwave catheter ablation, are hindered by omnidirectional energy delivery and rapid energy decay. Additionally, the initial enthusiasm for atrial fibrillation ablation targeted at the pulmonary veins was subsequently tempered by inadvertent pulmonary vein stenosis and the risk of collateral tissue injury. Catheter ablation problems are magnified in pediatrics, where a smaller heart size and thinner myocardium reduce the margin for error. Despite the challenges of pediatric ablation, it is central to definitive therapy. Pediatric electrophysiologists have adopted some innovations that initially were developed by our adult colleagues. Two of the more recent breakthroughs, cryothermal ablation and the routine use of three-dimensional (3D) mapping to decrease radiation exposure, have gained broader acceptance in pediatric EP. However, in the era of health-care cost containment, are these adopted “changes” worthwhile?

Cryothermal ablation is often deemed a recent advance in cardiac arrhythmia management. However, open surgical cryoablation of the atrioventricular (AV) node and accessory pathways was first introduced more than 30 years ago.2,3 The first transcatheter intracardiac human cryoablation was described in 20014 and subsequently gained Food and Drug Administration (FDA) approval for adults in 2003. Since then, a wide variety of arrhythmias (atrial fibrillation, automatic atrial tachycardia, atrioventricular nodal re-entry tachycardia (AVNRT), atrioventricular re-entry tachycardia (AVRT), and ventricular tachycardia (VT)) have been treated; yet, broad use of cryoablation is not widely accepted. Nevertheless, it is the pediatric EP specialists who are actively pushing the envelope and incorporating cryothermal ablation into standard pediatric EP practice.

A PubMed search engine study helps prove the association between pediatric EP practice and cryothermal ablation. When the search words “cardiac,” “heart,” or “cardiology” were entered along with the term “cryoablation,” or when the phrases “cardiac cryoablation” or “cryothermal ablation” were entered, 946 references appeared. Filtering these by pediatric cases showed that 215 (23%) references addressed children and young adults. When a similar search is performed for radiofrequency ablation, the pediatric patients are included in less than half that percentage, suggesting that the contribution of pediatrics on cryothermal ablation is significantly greater than that on radiofrequency ablation. The same search performed using Google Scholar showed that 47% of all cryotherapy...
articles included children compared with 11% in radio-frequency ablation.

Although it is difficult to be certain why many pediatric EP subspecialists have gravitated toward cryothermal ablation, there are several plausible theories. The first concerns safety. The reversible nature of the cryothermal lesion (short and relatively warmer cryothermal applications result in transient loss of function), and proposed attenuated tissue injury coupled with the stable catheter position during ablation applications make cryothermal ablation a safer choice in hearts with thinner myocardium and smaller distances between the arrhythmia substrates and normal susceptible tissue (i.e., AV node, sinoatrial node, phrenic nerve, and coronary arteries). The second concerns time allotment per case. Generally, adult EP centers have larger patient volumes; thus, time may be a more valuable commodity in the adult world. With this in mind, cryothermal ablation lesions range from 3 to 6 min whereas radio-frequency lesions range from 30 to 60 s. In a field where intervals are measured in milliseconds, this relatively small difference in ablation time may seem like an eternity. Finally, other possible reasons include the expense of this new technology, the learning curve, and the early reports of lower cryothermal ablation efficacy. To address these latter theorized downsides of cryothermal ablation, the expense of the cryothermal ablation equipment and catheters could be considered relatively minor compared with other recent ablation technologic advances such as Stereotaxis or Hansen Medical. Although there is a learning curve for cryothermal ablation, it centers primarily around differing endpoints, specifically with AVNRT, where accelerated junctional rhythms do not occur during energy application. And finally, with regard to efficacy, early reports of lower success and higher recurrence rates were associated with the 4-mm tip ablation catheter. But results similar to radiofrequency ablation have been seen when larger (6 mm and 8 mm) tip catheters are used and multiple applications are delivered around the site of success to compensate for tip stability during cryothermal applications.

3D mapping is the second innovation that pediatric electrophysiologists have adopted and has important applications for young patients, especially for reducing radiation exposure. The use of 3D mapping began in the late 1990s and had become more widespread by the early 2000s. Currently, there are two main modalities of 3D mapping. The first, non-contact mapping, used by Endocardial Solutions (now part of St. Jude Medical, St. Paul, MN), uses an intracardiac balloon array that allows thousands of virtual unipolar reference points. This

Figure 1: 3-dimensional image (St. Jude NavX, left panel anterior-posterior view, right panel left anterior oblique view) of right atrium in patient who underwent non-fluoroscopic mapping and ablation procedure for atrioventricular nodal re-entrant tachycardia. The blue dot is the first successful cryothermal ablation site, which is surrounded by subsequent cryothermal applications, shown in light green and white. The yellow dot is a cryothermal ablation area, which resulted in transient prolongation of the PR interval. Atrial voltage mapping is included to improve differentiation in this image. The voltage scale is in the right panel. (His = area of His potentials, CS = coronary sinus, SVC = superior vena cava, IVC = inferior vena cava)
methodology projects these reference points onto the surface of the reconstructed geometry of the heart, previously obtained by an MRI or CT before the case or acquired during the procedure by roving catheters or intracardiac echocardiograms. The second type of mapping, contact mapping, may be determined by comparing changes in impedance between reference patches placed on the outside of the chest (NavX, St. Jude Medical), or by utilizing a positional localization from standard references within an electromagnetic field outside of the body (Carto, Biosense Webster, Diamond Bar, CA).

These 3D mapping techniques (Figure 1) have been adopted by both pediatric and adult electrophysiologists, although they may have specific advantages in pediatrics. In particular, 3D mapping allows localization of normal and abnormal substrate with accuracy within a few millimeters. Such accurate substrate localization has shown some significant advantage in pediatric patients with smaller hearts where slight movements are difficult to track fluoroscopically. The second advantage, especially important in the pediatric population, is the ability to decrease radiation exposure. Recent studies suggest children are potentially at greater risk of radiation-induced injuries, in part due to their longer lifespan, allowing time for development of neoplasms. In part, these concerns prompted the FDA to announce the Initiative to Reduce Unnecessary Radiation Exposure from Medical Imaging in 2010, requiring guidelines for device manufacturers and healthcare providers to mitigate radiation exposure for fluoroscopic procedures. It was likely that these concerns prompted the first series of radiation-free ablation procedures to be published by pediatric centers. Since then, adult groups have reported reduced fluoroscopy in multiple arrhythmias, including atrial fibrillation cases. However, current 3D mapping techniques are not without limitations. Owing to the catheter tracking and geometry based on impedance across the chest, the surface geometry and catheter positioning may shift following patient movement, surface patch repositioning, respirations, or guidewire placement within the heart. Additionally, this is responsible for the loss of 3D catheter positioning while the catheter is within a sheath. Finally, the absence of 3D mapping-compatible supplies (i.e. transseptal needles, steerable sheaths) limits the use of 3D mapping techniques to their full capabilities without the use of additional imaging modalities, such as intracardiac echo or fluoroscopy. Innovations in non-fluoroscopic tracking of sheaths, needles, and wires may allow the majority of EP cases to be carried out in a radiation-free environment.

To say that the incorporation of cryothermal ablation and radiation-free EP procedures is clearly an overstatement. But, these advances, which continue to be cultivated by the pediatric electrophysiologist, show that a change in philosophy may be coming. Whether these are “change for change’s sake” or something that the EP profession as a whole will have to “change with em” is yet to be determined.

References