PEDIATRIC ELECTROPHYSIOLOGY

Advances in Catheter Ablation for the Treatment of Arrhythmias in Children

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The classification and treatment of supraventricular tachycardia (SVT) in children has been advanced greatly with the application of electrophysiology studies and catheter ablation techniques. It is now well known that the mechanism of SVT in children varies with age (Figure 1). Tachycardia caused by an accessory connection, accounts for approximately 75 percent of SVT in newborn and young children, but only 45 percent in adults. Atrioventricular node reentry tachycardia is relatively rare in children younger than 2 years of age, while it accounts for greater than 50 percent of SVT in adults. Primary atrial tachycardia accounts for 10 percent to 15 percent of SVT at all ages. The incidence of atrial flutter (also known as intra-atrial reentry tachycardia [IART]) following operation for congenital heart disease increases with age. Long-term follow-up studies have shown that the incidence of IART following the Mustard or Senning intra-atrial baffle procedure is 10 percent to 14 percent, and as high as 29 percent following the Fontan procedure.

The natural history of SVT in children also varies with age and the mechanism of tachycardia. For example, infants who present with Wolff-Parkinson-White syndrome (SVT caused by an accessory connection and ventricular pre-excitation, as indicated via electrocardiogram) have a 30 percent chance of complete resolution by 12 months of age with no need for lifelong therapy or interventions. On the other hand, if SVT is present in a child who is 5 years of age or older, 78 percent to 90 percent continue to have recurrent SVT at follow-up. For most children with SVT, sudden death is not an issue; however, it has been reported in children with Wolff-Parkinson-White syndrome. In one study, the prevalence of sudden death was 2.3 percent, and the mean age of these patients was 11 to 12.3 years. Furthermore, a mortality rate of up to 20 percent is associated with the development of IART following surgery for congenital heart disease.
Radiofrequency Catheter Ablation: Treatment of Choice

Radiofrequency catheter ablation (RFA) is preferred by many as the treatment of choice in symptomatic patients with SVT who are 4 years of age or older. It also can be performed in children younger than 4 years of age who suffer from SVT that is refractory to anti-arrhythmic medications. The basis for RFA is the application of high-frequency waveforms via an intracardiac catheter in order to achieve tissue heating and desiccation of a targeted area (such as an accessory connection). The procedure consists of the placement of three to five electrophysiology catheters (ranging from 2F to 8F in size) into the heart via the femoral or internal jugular veins (Figure 2). In smaller children, in which access is limited, a transesophageal pacing catheter may be used in addition to the intracardiac catheters. The catheters are positioned in specific areas in the heart and used as landmarks to help locate the abnormal tissue that is causing the arrhythmia and serve as a "road map" to guide the ablation catheter to the targeted area.

RFA was first performed in children in 1990, and since 1991, the Pediatric RF Ablation Registry has collected data from more than 49 centers and involved more than 7,000 procedures. Overall success rates for RFA of accessory connections and atrioventricular node reentry tachycardia are greater than 90 percent, while rates of major complications are
low (<3 percent) and occur mainly in children younger than 4 years of age. The use of RFA for IART that occurs after surgery for congenital heart disease is encouraging, but the results have not been as successful. Acute success rates approach 80 percent, but there is a 40 percent recurrence rate. Some of the factors that limit long-term success in this population include the inability to create transmural radiofrequency (RF) lesions (owing to the thickness of the atrial tissue) and the inability to apply adequate amounts of energy (owing to low-blood-flow states). Also, identification of anatomical boundaries and definition of the arrhythmia circuit in the presence of complex anatomy following surgery is challenging and time consuming.

**DEVELOPMENT OF MAPPING SYSTEMS**

The recent development of three-dimensional mapping systems has helped to overcome some of the limitations encountered with conventional RFA. One such system, the CARTO Electrophysiological Mapping System ( Biosense Webster, Diamond Bar, Calif.), underwent early development at the University of Chicago under the supervision of David Wilber, MD. This system operates by first generating a low-intensity magnetic field around the patient. A special ablation catheter is then positioned inside the heart and has a sensor at the tip that enables real-time display of the catheter position within a computer-generated three-dimensional model of the heart. During real-time mapping, electrical activity is recorded at any given point and is associated with its anatomical location. This activity then can be displayed in color isochromes, allowing for a three-dimensional image of the electrical activation of the heart (Figure 3). Voltage mapping also can be performed simultaneously to identify areas of presumed scar tissue within the heart.

The technique of “scar mapping” has provided valuable information regarding the mechanism of IART following surgery for congenital heart disease. Once the arrhythmia circuit has been defined, RF lesions can be applied in a linear fashion between two anatomic boundaries, scars, or in channels of conducting tissue within scars. The goal is to create a “roadblock” so that the arrhythmia circuit is interrupted. This system offers the advantage of obtaining a permanent record of the detailed electro-anatomical features of the heart and allows for better definition of an arrhythmia focus or circuit. Less fluoroscopy is required because of the real-time display of the catheter, and procedure times often are shortened.

Another three-dimensional mapping system available is the EnSite 3000 System (Endocardial Solutions, St. Paul, Minn.), which is a noncontact mapping system and offers the advantage of obtaining a three-dimensional map of specific cardiac chambers in a single beat. This method may be preferable in patients with nonsustained or poorly tolerated arrhythmias. A newer system, Realtime Position Management (Cardiac Pathways, Sunnyvale, Calif.), creates the three-dimensional image of the heart using ultrasound sensors mounted in the ablation catheter and two reference catheters. This system has the advantage of improved catheter...
navigation without the use of fluoroscopy and the ability to recall catheter positions.

**ADVANCES IN CATHETER TECHNOLOGY**

Advances in catheter technology are helping to overcome some of the limitations of conventional RFA for children with SVT and for patients with IART who have had surgery for congenital heart disease. RF energy application is limited when excessive heating occurs at the catheter tip, resulting in the formation of coagulum. This problem often is encountered in areas within the heart where there is low blood flow and decreased tip cooling, which sometimes is seen following the Fontan operation.

New ablation catheters have been developed recently to help address this problem. One such system, the Chilli Cooled Ablation System (Cardiac Pathways), uses an internal circulating fluid system during application of RF energy (Figure 4, p. 7). This cools the tip of the catheter and allows for higher energy delivery without the formation of coagulum. In vivo studies have shown that up to 100 percent greater lesion depth can be achieved using this system compared with conventional RFA. This is particularly useful in patients who have undergone the Fontan operation, and has resulted in successful RFA of IART when conventional RFA has failed. Also, alternative sources of energy delivery are being developed to overcome the limitations of RFA. These include cryoablation, which operates on the basis of tissue cooling instead of heating, and ultrasound ablation, both of which currently are in trials at the University of Chicago.

In conclusion, RFA can be performed safely in children with good success rates and a low rate of SVT recurrence. It is regarded by many, as the preferred method of treatment for SVT for symptomatic children who are 4 years of age or older. The success of RFA for IART following surgery for congenital heart disease is improving, owing to the development of three-dimensional mapping systems and advances in catheter design. Further success may be possible with the development of alternative energy sources for catheter ablation.

**REFERENCES**