Treatment of arrhythmias by radiofrequency ablation

Cardiac arrhythmias in children are often caused by the presence of an anatomical connection between the atria and ventricles known as accessory pathways. When these pathways conduct impulses antegrade or retrogradely, they manifest themselves as Wolff-Parkinson-White syndrome on the surface electrocardiogram (ECG) but some only conduct retrogradely, in which case the ECG is normal when in sinus rhythm, although they still carry the potential for a re-entrant circuit manifesting in tachycardia. Accessory pathways occur in around 1-5 per thousand population and two thirds are symptomatic. Apart from accessory pathways, there are other forms of re-entrant tachycardias involving the atrioventricular node or the ventricles. In addition, some patients have tachyarrhythmias as a result of an irritate focus either in the atria or ventricles. These mechanisms, once identified and located, can be removed and the risk of tachycardia abolished. Presentation can be in fetal life, at birth, later on in childhood, or adulthood. Some lose the potential to develop arrhythmias as they grow older but may recur later. Less than 3% of arrhythmias in children are fatal or accompanied by major complications, unless associated with congenital or structural heart defects or after cardiac surgery. They are, however, disturbing to the patients and their unpredictability undermines patient and family confidence. Individual attacks may respond to vagal manoeuvres but sustained or recurrent tachycardias require treatment with prophylactic antiarrhythmic drugs with the occasional need for intravenous treatment or direct current (DC) cardioversion for an acute episode. Patients and children find antiarrhythmic drug treatment undesirable and procedures to cure arrhythmias, especially in children are, therefore, very welcome.

Radiofrequency
In the 1980s cures for arrhythmias were achievable either by open heart surgery or using DC shocks delivered through percutaneously introduced wires. The former is a major undertaking and the latter is associated with morbidity related to barotrauma. Radiofrequency current is one of several forms of electrical currents that can generate electrical energy and, depending on the physical characteristics, this can be used for three purposes—namely, electrosurgical cutting, fulguration, or desiccation. It is the latter form at a frequency of around 400 KHz that is used for the treatment of arrhythmias and is delivered through a specially designed catheter wire which is introduced percutaneously. The size of the lesion created depends on several factors including the output used, tissue contact, electrode size, duration of application, and system impedance. The lesion produced is usually between 3 and 4 mm, has sharp edges, and is homogenous. The local temperature reached is normally around 70°C and some ablation catheters have inbuilt thermistors to monitor this.

Patient selection
Natural history studies show that when tachycardia presents in infancy, there is spontaneous resolution of the mechanism responsible for the arrhythmia in up to 50% of patients. It is, therefore, appropriate to manage these children conservatively. Some, however, should be offered a permanent cure by ablating the accessory pathway or the irritable focus. These include incessant or potentially fatal arrhythmias, intolerance to antiarrhythmic drug treatment, patient preference, or in advance of planned cardiac surgery.

The anatomical substrates amenable to radiofrequency ablation treatment include accessory pathways, for example, overt Wolff-Parkinson-White syndrome or a concealed pathway, focal atrial tachycardia, the permanent form of junctional reciprocating tachycardia, atrioventricular node re-entry tachycardia—the where the atrioventricular node consists of electrically separate components, namely fast and slow conducting pathways. More recently, some patients with atrial flutter have also benefited from radiofrequency ablation and this may have particular relevance after some forms of heart surgery for congenital heart defects such as the Fontan operation. Very rarely, deliberate destruction of the atrioventricular node may be necessary for uncontrolled atrial fibrillation, although this is rarely indicated in children. Ventricular tachycardia in the paediatric age group is uncommon and, when associated with a structurally normal heart, this is usually benign and the mechanism is often a focus situated in the right ventricular outflow tract; this can be cured by radiofrequency ablation after a mapping procedure to identify the earliest activation point.
Technique

The procedure can be performed under sedation and local anaesthesia applied to the site of entry of the mapping and ablation catheters, although general anaesthesia is commonly used in children as these procedures can take several hours to perform. The number of mapping catheters varies depending on the underlying arrhythmia but, of particular benefit in children, is the use of a 'single catheter' technique pioneered by Kuck and Schluter. Adequate anticoagulation is mandatory especially for left sided lesions. The catheters are positioned under fluoroscopic control and electrophysiological studies performed to establish the mechanism(s) of the arrhythmia. In patients with accessory pathways, precise mapping is achieved by identifying the site of shortest interval between the atria and ventricles (or between the ventricles and atria in concealed accessory pathways) as well as by locating a pathway potential. Methods used for locating the tachycardia source for arrhythmias of a focal nature, irrespective of their position, include searching for earliest activation site during tachycardia as well as pace mapping.

Once the catheter is positioned on target, radiofrequency energy is applied in the form of continuous, unmodulated current at 500 KHz at between 20 and 40 watts for a period of between 20 and 60 seconds. If the ablation is in sufficient proximity to the substrate, a response is usually achieved within six seconds. Several applications of radiofrequency may be required.

Electrophysiological studies are then performed to confirm the result and, if there is no evidence of substrate or inducibility of tachycardia half an hour after the ablation, the procedure is terminated.

Problems

There are specific problems relating to this technique in children. These include logistical problems with small vein size which can allow a limited number and size of wires. Congenital heart defects, for example, Ebstein's anomaly and abnormalities of venous connections, for example, azygous replacement of the inferior vena cava, pose specific technique hurdles.

Results

The original larger series were conducted in adults but there are increasing number of publications in children. The overall success rate is in the order of 90%, although some 15% will require a second procedure for recurrence of the original lesion or because of dual pathology (for example, multiple pathways or atrioventricular node re-entry tachycardia in association with an accessory pathway). Success rate depends on operator experience, complexity of substrate, associated structural heart problems and precise mapping, which may need patience and perseverance. Most patients are in hospital for 24–36 hours.

Follow up studies confirm a high level of cure.

Complications

Major complications are rare and include damage to vessels by the catheters; the use of smaller and fewer catheters together with anti-coagulation reduced these complications. Thromboembolic episodes are also preventable. Rare reports of perforation and tamponade have been documented and, for ablation close to the atrioventricular node, there is a risk of heart block for which a permanent pacemaker may need to be implanted. Fatalities, though extremely uncommon, have been described and small patients (under 15 kg) or those with associated complex congenital heart disease appear to be at higher risk. Although difficult to quantify, the effect of radiation exposure must be taken into account. This can be quite significant but comparable with other interventional procedures and it can be considerably reduced with experience, audit, and awareness. Potentially, the lesion created by radiofrequency could itself become a focus for tachycardia, although this is only a theoretical risk. Similarly, the proximity of the coronary arteries to the atrioventricular groove, where accessory pathways are ablated, could be a trigger to coronary artery disease later on in life although this is pure speculation. Nevertheless, it is prudent to apply the minimum number of ablations.

Current practice

Radiofrequency ablation treatment has revolutionised management of arrhythmias resulting in a cure in over 90% of cases. Apart from life threatening and incessant arrhythmias, the technique is established for patients with recurrent tachyarrhythmias that require prophylactic antiarrhythmics for an indefinite period. Although the threshold for performing ablation will be reduced and less symptomatic patients will be offered this technique as a cure, it is important to bear in mind the natural history of these arrhythmias, some of which disappear spontaneously especially when they present in utero or the neonatal period. Generally, therefore, this form of treatment is offered to school age children unless indicated earlier. With an average of 30 such procedures being performed in the West Midlands annually, one would anticipate some 350 children benefiting from radiofrequency ablation nationwide.

Apart from radiofrequency achieving a cure, there are other implications in relation to quality of life resulting from disappearance of symptoms and avoiding the need for drug treatment. It has also been shown to be a cost effective technique and this aspect becomes more important when treating young patients who would otherwise have required many years of drug treatment, admissions to hospital for treatment of acute episodes and, not to mention, the social and career implications associated with arrhythmias.

Future

The technique will continue to evolve with more emphasis on catheter design specifically for paediatric patients and to include temperature sensing. Quicker methods of mapping using computer techniques will make the procedures quicker, more successful, and safer with shorter fluoroscopy time. Whether other ablation modalities, such as microwave or laser energy will be developed further, the role of catheter ablation is now well established as a cure for the majority of arrhythmias with radiofrequency energy likely to remain the energy source.

As the number of children likely to benefit from this technique is small, these procedures should be performed in a limited number of centres in order to achieve reproducible results of the highest calibre. Apart from the need for suitable equipment for these procedures, the support of an experienced electrophysiologist, who is often an adult cardiologist, ensures the best recipe for success.

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