Radiofrequency Catheter Ablation for Supraventricular Tachycardia
Should It Be Used in Infants and Small Children?

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Catheter ablation for nonpharmacological management of pediatric patients with tachyarrhythmias has evolved during the past approximately 10 years. Direct-current energy ablation was initially used in some patients with drug-refractory, life-threatening tachyarrhythmias such as junctional ectopic-focus tachycardia and also for some children with left ventricular dysfunction due to incessant tachycardias (eg, the permanent form of junctional reciprocating supraventricular tachycardia and atrial ectopic-focus tachycardia). The extensive lesions and less-than-ideal results from direct-current energy prompted research and development of alternative energy sources that led quickly to clinical application of radiofrequency energy ablation of tachyarrhythmias in adults in the late 1980s. This apparently safer and more successful technique revolutionized the treatment of not only adults but also children and adolescents with supraventricular tachycardia in the 1990s.

The 1992 report of ventricular tachycardia and sudden death during late follow-up of pediatric patients who had undergone direct-current ablation emphasizes the dangers of the direct-current ablation method but also serves as a warning against premature acceptance of any ablation technique because adverse effects may be detected only during late follow-up.

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In 1990, the Pediatric Electrophysiology Society initiated the Radiofrequency Catheter Ablation Registry to determine the immediate success and complication rates, to monitor technical alternatives, and especially to provide a cohort of young patients for long-term follow-up. Results from the first 20 months of the Registry (725 procedures in 652 patients; age, 20 days to 20 years; median, 13.5 years) were recently published. The immediate and short-term success rates were similar to those in adults, and the acute complication rate of 3.7% as well as the total (including complications detected during follow-up) complication rate of 4.8% were acceptably low.

From the Registry data and other reports of radiofrequency catheter ablation in pediatric patients, practice patterns have emerged regarding indications for the procedure. As with most new options of treatment, a spectrum of opinion among cardiologists has developed regarding recommending radiofrequency catheter ablation for pediatric patients who have supraventricular tachycardia.

Although no data exist regarding actual practice patterns, it is likely that recommendations by pediatric cardiologists reflect a spectrum of opinion regarding indications for the procedure. No doubt some do not recommend the procedure for anything other than life-threatening symptoms because long-term follow-up data are not yet available to warrant elective application. With reassuring short-term follow-up, other cardiologists are quick to recommend the procedure as an appealing alternative to antiarrhythmic drug therapy as well as to the other acceptable management option of "no treatment." Others view radiofrequency ablation as the treatment of choice even in some children with infrequent, self-terminating symptoms for whom pharmacological treatment might not have been traditionally recommended. The infant with drug-refractory tachycardia represents a focal point for the debate over indications for radiofrequency catheter ablation, which begins with the definition of drug refractory.

Some would define drug refractory as symptomatic or frequent asymptomatic recurrent tachycardia after a trial of two or three drugs. In contrast, others believe that virtually all antiarrhythmic drugs and drug combinations need to be exhausted and, moreover, that daily recurrent tachycardia in some patients is an acceptable treatment end point. Some cardiologists also are willing to wait for several weeks while attempting multiple drug regimens, even for patients with incessant tachycardia and left ventricular dysfunction, on the premise that all infants can eventually be successfully treated with an antiarrhythmic drug regimen. Justification of this approach is based on two considerations: (1) the favorable natural history of infants with supraventricular tachycardia and (2) the risk of the procedure, both immediate and long term.

According to most natural history studies, 60% to 90% of infants with the common type (ie, those that utilize a fast-conducting retrograde accessory atrioventricular pathway) of supraventricular tachycardia no longer need antiarrhythmic drug therapy after a year or even a few months of treatment. Approximately 20% to 50% of infants with the uncommon types of supraventricular tachycardia (ie, atrial ectopic focus, permanent form of junctional reciprocating type) similarly improve or resolve. In the Registry, the imme-

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mediate complication risk of the procedure is statistically greater in children who weigh less than 15 kg. Two of the four deaths in the Registry were in children in this weight group. A compelling argument can thus be made to search aggressively for satisfactory pharmacotherapy for infants with supraventricular tachycardia to avoid needless short-term and potential long-term risks of ablation.

The divergence of opinions available for and against radiofrequency catheter ablation in infants and in small children speaks to the need for more data regarding radiofrequency energy and the immature myocardium. Saul and his coinvestigators, in this issue of Circulation, report important infant lamb experiments that provide important relevant data.

First, the investigators applied radiofrequency current through a catheter electrode with a tip-mounted thermistor probe to multiple areas on the epicardial surface of the left ventricle in 15 lambs. The experiments were carried out under direct observation using well-controlled constant contact pressure in vivo, a method previously not reported. In contrast to reported results in adult animals where a linear relation has been demonstrated for lesion depth as well as for width, a sigmoid effect of temperature on lesion depth (with saturation of the temperature effect above 80°C) was found in the lambs. Because this naturally perfused epicardial method has not been reported previously, it is possible that the method is the explanation for this major difference in findings. Another plausible reason for the difference relates to animal age/maturity. Saul and associates offer an intriguing explanation when they refer to the work of Rakusan et al,27,28 who found increased capillary density in immature myocardium that could provide increased local heat transfer.

The second set of experiments provide provocative clinically relevant data with implications about radiofrequency ablation in infants and small children.

In the 19 infant lambs of the second experiment, radiofrequency current was applied in a manner similar to that used clinically in patients (to the endocardial surface through a transvenous catheter with a 4-mm tip electrode). Multiple applications of radiofrequency current were given with the non-thermistor/thermocoupled catheter-tip electrode positioned on the endocardial surface of the atrium, ventricle, and along the atrioventricular annulus. Three groups of lambs were euthanized acutely, after 1 month, and after 8.5 months. Interesting findings are related both to lesion size and to histology.

Although Saul and his coauthors write that the atrial lesions (width only) and ventricular lesions (both width and depth) "clearly increased simultaneously with cardiac and whole body growth," it was not truly possible for the investigators to know if the actual lesions produced were in fact increasing in size. Therefore, it is more accurate to conclude that the mean lesion size was statistically different at the two follow-up intervals, and from this it is reasonable to conclude that the lesions appeared to have increased during animal growth.

Other limitations in methodology call for caution in interpretation of these data. While it is admirable that the investigators monitored the number of radiofrequency applications, only 65% (52% on the atrioventricular [AV] groove, 66% in the atrium, and 79% in the ventricle) were identified at postmortem examination. As is supported by the statistically fewer identifiable lesions on the AV groove, it appears that it was more difficult to maintain catheter position (and therefore electrode contact) on the AV groove. Therefore, bias may have existed toward concluding that the mean values for AV groove lesion size were not larger among the three groups. A better record of successful application and lesion production may have been achieved by using a thermistor or thermocoupled ablation catheter.

For these methodological reasons and because it is difficult to quantify histological data, caution is needed also when making conclusions based on the histological findings. Nevertheless, Saul and associates have delineated apparent differences between immature animals and those reported for adult animals showing more invasiveness (especially in the ventricle) in the immature myocardium. Their discussion and explanations for the differences are excellent and plausible, based on previously reported histological studies and radiofrequency energy, physical dynamics studies.

Although the limitations of this animal study are essential considerations, Saul and his coinvestigators have provided pediatric cardiologists with important data that directly impact the management of infants and small children with tachyarrhythmias. The authors state: "...the recommendation to attempt to avoid intervention in the youngest patients should probably be followed until technical improvements allow for real-time assessment of lesion size during the ablation procedure." This seems to understate the implications of the study. Even without the lamb data, the case can be made for avoiding radiofrequency catheter ablation in virtually all infants. This is based on the natural history data (also cited by the authors in their discussion), the premise that virtually all supraventricular tachycardias can be controlled with antiarrhythmic drugs, the Registry-demonstrated increased complication risk in children who weigh less than 15 kg, and these lamb data that provide concern for potential future adverse effects related to the extensive and possible growth-related expanding myocardial lesions.

If indeed there are some infants and small children who are candidates for radiofrequency catheter ablation, the data from this lamb study by Saul et al deserve discussion. If the procedure is performed in patients of this age group, Saul and coauthors appropriately emphasize that every attempt should be taken to ablate as close as possible to the AV groove, avoiding the ventricular muscle, and utilizing as many technical advancements (eg, small, thermistor/thermocoupled catheters and short application of low-power current) as possible to minimize lesion size.

To be fair, various authors have concluded that although radiofrequency catheter ablation is rarely needed in infants and small children, it can be successfully performed with acceptable success and complication rates when no therapeutic alternative exists.5,6,11,13,14,29 Although some data exist that have shown a low risk and high success of treating infants exclusively with the drug therapy approach, it could be argued that the risk has not been adequately studied and may in some cases be equal to or greater than that of radiofrequency catheter ablation. Also, the cost of each approach is an issue. The cost comparison is unknown between an ablation procedure and possibly weeks of hospitalization while finding a successful drug regimen. Although it has been shown that radiofrequency catheter ablation is cost-effective in children when compared with surgery as well as to years of...
medical outpatient follow-up, this has not yet been reported for infants with drug-refractory tachycardia.\textsuperscript{30,31}

Under what circumstances, then, do the data warrant recommending the procedure in infants? Agreement appears to exist that it should not be offered as an equally good or preferred therapeutic option for patients in this age group who present with supraventricular tachycardia and who respond favorably to antiarrhythmic drug therapy. Disagreement centers on the following issues: (1) the definition of drug refractory and what constitutes an acceptable medical treatment end point, (2) the definition of life threatening (eg, does this include severe left ventricular dysfunction from incessant tachycardia?), (3) speculative assessment of the risks and cost comparison between exhaustive drug therapy and radiofrequency catheter ablation, and (4) speculation about long-term risks to patients in this age group who have undergone radiofrequency ablation.

Until agreement is reached on operating definitions and more data put speculation to rest, the sobering animal and clinical studies should be considered before performing radiofrequency catheter ablation in infants and small children. Rare situations may warrant recommending the procedure. Infants and small children with congenital heart disease who need intracardiac access and who have undergone radiofrequency catheter ablation and the risks associated with certain procedures in this age group may also have an accessory AV pathway that may be candidates for preoperative catheter ablation because the risk of additional surgery at the time of operation may be greater than the risk of the catheter ablation. Aside from such unusual extenuating circumstances, the current information does not appear to warrant radiofrequency ablation in infants with drug-refractory supraventricular tachycardia at this time.

References


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