Substrate Mapping and Catheter Ablation of Ventricular Tachycardia after Right Ventriculotomy

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Tetralogy of Fallot is one of the most common forms of cyanotic congenital heart disease, estimated to occur in 0.26 per 1000 live births. Long-term survival depends on definitive surgery; happily, survival after complete repair can now be expected in 98% of cases. Initial surgery may be palliative with the placement of a shunt, but complete repair is now offered in infancy with the expectation of survival well into adulthood. Although tetralogy patients occasionally require permanent pacemakers for atioventricular block, and many will need to undergo periodic pulmonic valve and conduit replacement, by far the most worrisome problem such patients face is the prospect of sudden death. In the early days of corrective surgery, when this catastrophic outcome was first observed, it was initially hypothesized that atrioventricular block might be responsible. Subsequently, attention shifted to the problem of malignant ventricular arrhythmias. It is now widely accepted that ventricular tachycardia in such patients is the likely cause of sudden death and is likely to be macroreentrant in nature.

Although clear risk factors within the tetralogy population have been identified, sadly attempts using antiarrhythmic agents to prevent sudden death in tetralogy of Fallot patients have been disappointing, and high-risk patients are increasingly being referred for implantation of implantable cardioverter-defibrillators. Whereas this approach seems reasonable and may indeed be lifesaving, patients may well experience inappropriate defibrillator shocks, and one would like to be able to offer definitive therapy such as ablation of the tachycardia circuit. Groundbreaking work in the area has been performed with the use of intraoperative mapping and surgical ablation, especially in Toronto, Canada. In addition, many individual case reports and a few series describe the use of radiofrequency ablation in tetralogy of Fallot patients. These ablation attempts are technically difficult because of the fact that the ventricular tachyarrhythmias induced at electrophysiology study are often poorly tolerated, and uncertainty may exist in matching clinical rhythms to those induced at electrophysiology study.

In this issue of Circulation, Zeppenfeld and colleagues report a “substrate mapping” approach to the management of patients with tetralogy of Fallot and other forms of congenital heart disease. The 11 patients reported have in common the use of some form of right ventriculotomy as part of the definitive surgical repair, of whom 9 patients had some form of tetralogy of Fallot. Substrate mapping refers to a technique in which the congenital, surgical, and electrophysiological anatomy is evaluated without the necessity of inducing the patient’s clinical tachycardia. The method depends on the fact that macroreentrant circuits are constrained by anatomic features, either natural or surgically created, and that these constraints naturally create isthmuses where catheter ablation can logically be directed. Ideally, one would like to demonstrate that any given isthmus is part of the clinical tachycardia circuit by entrainment mapping, but this may be difficult to achieve, and the technique of substrate mapping offers an alternative approach to the identification of target isthmuses by entrainment. In the field of postoperative arrhythmia management, the effective use of substrate mapping was beautifully demonstrated by Nakagawa et al with voltage mapping in a 3-dimensional anatomic display in patients after the Fontan atrio pulmonary connection. In the present study, Zeppenfeld et al have used similar techniques in the right ventricle, using bipolar voltages of <1.5 mV to identify areas of possible patch and/or scar. They have extended the technique through the use of high-amplitude unipolar pacing from such low-voltage sites, and electrically unexcitable sites are thus confirmed as likely areas of patch and/or scar. The electroanatomic map thus generated is used to identify likely isthmuses to be targeted for ablation. The investigators used either large-tip radiofrequency catheters or cooled-tip radiofrequency technology at such sites and reported excellent results.

What is most interesting to this reader is the investigators’ demonstration that, in their patients, only a limited number of anatomic/surgically created isthmuses were possible, as shown in Figure 1 of the article. This observation is consistent with the experience with intraatrial tachycardia (flutter) in patients after major atrial surgery. In that situation (with the exception of the Fontan patients), the number of possible isthmuses has proven to be limited to only 3 to 4 regions, including the standard cavotricuspid isthmus and gaps between the atriotomy and the tricuspid annulus, inferior vena cava, and superior vena cava. Naturally occurring anatomic barriers in the right ventricle are limited, and the placement of a single ventriculotomy, outflow tract patch, or transannular patch, along with closure of the ventricular septal defect, would be expected to create only a limited number of possible tachycardia circuits. Catheter ablation has...
previously proven to be a powerful technique for delineating the important features of macroreentrant circuits in common arrhythmias such as atrial flutter. In the present work of Zeppenfeld et al we once again see the potential of radiofrequency ablation to teach us about basic arrhythmia mechanisms. Furthermore, in addition to being a report of an elegant and effective means of treating postoperative ventriculotomy patients, the present clinical study gives us the opportunity to think about possible ways to avoid the creation of such ventricular tachycardia circuits at the time of initial surgical repair.

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References

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