New Directions in Intraoperative Mapping and Surgical Treatment of Ventricular Tachycardia

Albert L. Waldo, MD; Lee A. Biblo, MD; and Mark D. Carlson, MD

In this issue of Circulation, Littmann et al provide a significant advance in our efforts to understand and treat ventricular tachyarrhythmias. In our judgment, there are several aspects of this presentation that are important and unique. First, in this prospective study, critical portions of the reentrant circuit were located on the ventricular epicardium in a surprising number of ventricular tachycardias. Second, this study demonstrates not only the value but also the practicality of multisite mapping (multiplexing) techniques to record from a large number of sites simultaneously during the ventricular tachycardia. Third, this study confirms the value of identifying a critical component of the reentrant circuit, the area of slow conduction, in order to ablate that site and thereby prevent recurrence of the tachycardia. Fourth, the study provides a significant advance in the surgical treatment of ventricular tachyarrhythmias.

Epicardial Location of All or a Critical Portion of the Ventricular Tachycardia Reentrant Circuit

In the Harris two-stage left anterior descending artery occlusion model of ventricular tachycardia in the canine heart, the surviving epicardium overlying the area of the infarct serves as the locus for inducible, sustained monomorphic reentrant tachycardia. Based on this well-studied canine model of reentrant ventricular tachycardia, it is reasonable to suspect that reentrant ventricular tachycardia circuits might exist on the ventricular epicardium in patients as well. However, most cardiac mapping studies of ventricular tachycardia in patients have used either an endocardial catheter electrode or an intraoperative hand-held probe electrode to perform sequential site mapping. These mapping studies have demonstrated or assumed that the ventricular tachycardia reentrant circuit is either completely or partially (a critical part) on the ventricular endocardium. As is evident from the study by Littmann et al, critical portions of the reentrant circuit of ventricular tachycardia may indeed be present on the ventricular epicardium in some patients. This finding is quite important because an epicardial location of a ventricular tachycardia reentrant circuit makes the critical portion(s) of the reentrant circuit far more accessible to surgical intervention and thus to successful ablation.

Of importance would be to identify an epicardial location of all or part of the ventricular tachycardia reentrant circuit before surgery. Current transvenous catheter electrode techniques used at the time of electrophysiological study clearly are limited in this regard. Thus, preoperative identification of epicardial reentrant circuits will require further technological advances. For instance, body surface potential mapping might be used in this regard, but that will first require a solution to the inverse problem, that is, the ability to reconstruct the sequence of epicardial ventricular activation from information recorded simultaneously from a large number of electrodes on the body surface. In addition, other methods may be developed to identify patients whose ventricular tachycardia reentrant circuit is epicardially located.

Multisite Mapping—Value and Practicality

One of the recognized difficulties of intraoperative mapping as part of the surgical treatment of ventricular tachycardia has been the limitation of sequential site mapping. This requires that mapping be performed over many beats by moving a hand-held electrode from preselected sites defined by an anatomic grid. The relative imprecision of the technique, the difficulty of intraoperatively constructing a sequence of activation map, and the very long time needed to create a complete map (30–40 minutes is not unusual) are only some of the very obvious problems associated with this technique. In addition, the mapping virtually always has to be performed during cardiopulmonary bypass. This long period on cardiopulmonary bypass has likely contributed to the relatively high perioperative mortality (8–17%) associated with surgical treatment of ventricular tachycardia.

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Littmann et al\textsuperscript{1} used a multiplexing (multisite) recording system with a relatively small number of electrodes (56). As sophisticated as this system is, it is clear from examination of the details of the sequence of activation maps in their study that a still more sophisticated system capable of mapping from many more sites is desirable. In fact, most systems used in studying experimental models of arrhythmias use more than 200 electrodes, and as many as 512 electrodes are not thought to be too much. Clearly, multisite mapping systems capable of recording from very large numbers of electrodes in combination with electrode arrays designed to permit recording from densely located electrodes would provide more detailed sequence-of-activation data and a greater understanding of the tachycardia's reentrant circuit and its critical components. Nevertheless, even with only 56 electrodes, the investigators were able to use the mapping technique to localize the reentry circuit to the epicardium and identify critical components of the reentrant circuit, particularly the area of slow conduction. In short, what this study shows is that multisite mapping techniques are important, and constitute a major advance in our ability to identify and treat ventricular tachycardia reentrant circuits surgically. Undoubtedly, as these systems become more sophisticated, they will permit us to map ventricular tachycardia better and faster, regardless of whether the reentrant circuit lies on the epicardium or endocardium.

**Localization of Critical Components of the Reentry Circuit**

Littmann et al\textsuperscript{1} used multisite mapping techniques and entrainment mapping techniques to identify a critical component of the reentry circuit, namely, the area of slow conduction. Having identified the area of slow conduction, they were able to ablate this site using yttrium aluminum garnet (YAG) laser techniques to cure the patient. Thus, this study provides yet another confirmation of both the ability to localize and the importance of localizing critical components of the reentry circuit. Localizing a critical component of the reentrant circuit was first done clinically using the relatively crude technique of catheter mapping to identify an area of slow conduction in the ventricular tachycardia reentrant circuit on the endocardial aspect of the left ventricle. Once localized, this area could then be ablated using catheter ablation techniques.\textsuperscript{17-19} Recently, a critical area of slow conduction in the atrial flutter reentrant circuit was identified and ablated using catheter ablation techniques.\textsuperscript{20} Thus, techniques such as mapping and entrainment that can identify and localize these critical components of the reentrant circuit provide important practical tools to be used to guide treatment. Finding the keystone in the reentrant arch and ablating it offers definitive therapy to the patient.

**Surgical Treatment of Ventricular Tachycardia**

Ventricular tachycardia has been treated surgically for many years. Initially, treatment was limited to empirical surgical resection of ventricular aneurysms. There is ample evidence that this technique was rather hit-or-miss, and that electrophysiologically directed approaches to surgical treatment of ventricular tachycardias are preferable and more effective.\textsuperscript{21} Intraoperative electrophysiological mapping techniques to guide ventricular tachycardia surgery were first performed in the mid-1970s. Since that time, many large series of surgical treatment of ventricular tachycardia have been presented and analyzed.\textsuperscript{10-16} In short, surgical treatment cures at least two thirds of patients, and several investigators have achieved cures in a still higher percentage of patients. Additionally, if a cure is not effected by surgical treatment, drug therapy often becomes effective when it was not effective prior to surgery.

Nevertheless, surgical treatment of ventricular tachycardia has been relatively unsatisfying for several reasons. First, the cure rate remains lower than is desirable. Second, there is a remarkably high perioperative mortality rate, ranging from 8% to 23% in most series.\textsuperscript{10-16} Third, when the ventricular tachycardia surgery has failed, the reasons for failure have not been understood, because the same combined electrophysiological and surgical approach to treatment was used for both those who were cured and those who were not. Thus, it was clear that we had to know more about the nature of ventricular tachycardia reentrant circuits. Identifying a critical portion of the reentrant circuit, the area of slow conduction, may indeed be the key and, as demonstrated by Littman et al,\textsuperscript{1} can lead to effective therapy.

Thus, the study by Littmann et al\textsuperscript{1} is a significant advance in the surgical treatment of ventricular tachycardia because: 1) the demonstration that a critical portion of the ventricular tachycardia reentrant circuit is accessible to surgical treatment from the epicardium should make ventriculotomy unnecessary in these cases, thereby favorably impacting morbidity and mortality; and 2) the decreased time on cardiopulmonary bypass and the potential need to ablate only a small area of myocardium should also lead to a significant decrease in the mortality associated with the procedure. When it becomes possible prospectively to identify patients in whom a critical portion of the reentrant circuit is on the ventricular epicardium, we will be better able to select patients for surgery with a high likelihood of effecting a cure with an acceptable morbidity and mortality.

**Conclusions**

In our judgment, this study\textsuperscript{1} is a new direction in our understanding of the diagnosis and treatment of ventricular tachyarrhythmias. Littmann et al clearly show the value of multisite mapping techniques, because their data show that critical portions of the reentry circuit are amenable to surgical treatment because they are located on the epicardium. It should be anticipated that as even more sophisticated multisite mapping techniques become available, still better data for surgical treatment of ventricular tachyar-
Arrhythmias will be provided. Finally, as we continue to understand the nature and mechanism of ventricular tachycardia, application of new technology and techniques will undoubtedly improve surgical treatment. The ability to cure a patient is always desirable if it can be done with an acceptable risk. Littmann and colleagues have given us a preview of the future of surgical treatment of arrhythmias.

References
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A L Waldo, L A Biblo and M D Carlson

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