THE ROLE of the surgeon in the treatment of cardiac arrhythmias has changed dramatically during the past decade. Although arrhythmia therapy remains primarily within the realm of the nonsurgeon because of the availability and effectiveness of numerous pharmacologic agents, the number of surgical procedures used specifically for the treatment of refractory tachyarrhythmias has proliferated dramatically since 1978. Although the development of these surgical techniques has paralleled the evolution of our understanding of cardiac arrhythmias and the availability of progressively more sophisticated methods for their electrophysiologic evaluation, a paradox has arisen in the field of cardiac arrhythmia surgery. Most supraventricular tachyarrhythmias are readily characterized and understood, but the surgical procedures for their correction are complex and not easily mastered. As a result, few surgical teams are adept at performing the techniques required for treatment of tachyarrhythmias due to Wolff-Parkinson-White (WPW) syndrome, ectopic atrial foci, atrioventricular (AV) node reentry, and atrial flutter/fibrillation. Conversely, ventricular tachyarrhythmias are frequently difficult to characterize and localize electrophysiologically and their basic mechanisms are poorly understood. Yet almost any surgical intervention designed specifically to treat ventricular tachycardia will either ablate, isolate, or alter the anatomic-electrophysiologic substrate sufficiently to alleviate the patient’s symptoms or to enhance the effect of subsequent pharmacologic therapy.

This apparent inverse relationship between the complexity of the arrhythmia and the simplicity of its surgical treatment is the result of certain fundamental differences in the anatomic-electrophysiologic substrates responsible for supraventricular and ventricular tachyarrhythmias. Perhaps the most important difference from the surgeon’s standpoint is the fact that the anatomic substrate responsible for most supraventricular tachycardias (Kent bundle in WPW syndrome, dual AV node conduction pathways in AV node reentry tachycardia, latent cell rests and/or fibrosis in automatic atrial tachycardias, etc.) cannot be visualized. This fact dictates an absolute dependence on precise electrophysiologic mapping for localization of the invisible anatomic substrate. Compounding the problem for surgeons is the paucity of surgical experience that can be accumulated by a given surgeon because most supraventricular tachyarrhythmias can be controlled medically and the indications for surgical intervention are thus more narrow.

Although most ventricular tachyarrhythmias are also responsive to drug therapy, the sheer volume of patients suffering from coronary artery disease results in larger numbers of patients with refractory ischemic ventricular tachycardia who must be treated surgically. The anatomic substrate associated with ventricular tachycardia (endocardial fibrosis) is easily identified and most accessible, and its removal, encirclement, or thermoablation is a straightforward surgical exercise that does not necessarily require electrophysiologic mapping for a successful outcome.

This apparent paradox of supraventricular tachyarrhythmias being easily understood but difficult to treat surgically and ventricular tachyarrhythmias being poorly understood and easily treated surgically is responsible for much of the present confusion regarding the status of cardiac arrhythmia surgery. Is this type of surgery experimental or has it been developed to such an extent that it can be considered as another service-related area of cardiac surgery? Are sophisticated and expensive electrophysiologic mapping systems essential to the success of cardiac arrhythmia surgery? Are genuine advances being made in cardiac arrhythmia surgery or are we expending too much time, effort, and
money on an extremely small number of patients without regard for the potential prevention of the 300,000 deaths caused by arrhythmias that occur each year in this country? To address these questions, one should have at least a working knowledge of the evolution of cardiac arrhythmia surgery to its present state and a reasonable idea of the direction that the current state of the art is likely to take us in the future.

This discussion will not address the role of antitachycardia pacemakers, internal cardioverters, or automatic internal defibrillators, since the implantation of these devices does not represent a surgical procedure designed to ablate arrhythmias permanently. The surgical techniques used for the treatment of torsades de pointes associated with the long QT syndrome (left stellate ganglionectomy) and for nonischemic ventricular tachycardia arising in the right ventricle (right ventricular isolation procedures) will not be discussed because of their rarity and the relative early stages of their development.

Supraventricular tachyarrhythmias

Indications for surgery. The major indication for surgical intervention in supraventricular tachyarrhythmias remains medical refractoriness. Other common surgical indications include patient intolerance to drug therapy, detrimental side-effects of antiarrhythmic agents, and poor patient compliance. Major additions to these surgical indications include (1) recurrent supraventricular tachycardia associated with the WPW syndrome in young, otherwise healthy patients and (2) spontaneous atrial fibrillation associated with AV node bypass tracts (James fibers) or total accessory pathways (Kent bundles) that conduct rapidly enough antegrade to allow the induction of ventricular fibrillation from the atrium.

The inclusion of young patients whose arrhythmias might be controllable with antiarrhythmic agents clearly represents a liberalization of previous surgical indications. It should be remembered, however, that regardless of the age at which the reciprocating tachycardia of the WPW syndrome becomes a clinical problem, it is a congenital heart anomaly. As with other congenital cardiac disorders, its presence is usually better tolerated in younger patients and its surgical correction is more hazardous in the elderly. Few cardiologists or surgeons would elect to treat an atrial septal defect medically, yet in the absence of associated anomalies, the physical disability, magnitude of operation, operative mortality and morbidity, and surgical cure rate are similar for surgical correction of the WPW syndrome and closure of an atrial septal defect.

We believe that surgery for WPW syndrome is no longer an experimental procedure and that any relatively young individual with symptoms requiring medical therapy and with no associated anomalies should be considered a surgical candidate. We view surgical division of the accessory pathway in such patients as the conservative alternative to a lifetime of dependence on antiarrhythmic drugs.

Status of current surgical procedures for supraventricular tachyarrhythmias

WPW syndrome. By far the most common supraventricular tachyarrhythmia corrected surgically is that associated with the WPW syndrome. The experimental demonstration that this arrhythmia is caused by the presence of an anatomic accessory pathway capable of conducting electrical activity and thus is responsible for ventricular preexcitation when it conducts antegrade and for reciprocating tachycardia when it conducts retrograde was perhaps the single most important event in the subsequent development of all types of arrhythmia surgery. The spatial-temporal separation of the normal conduction system and the accessory pathway provided the optimal set of circumstances for three equally important goals to be realized: (1) the entire reentrant circuit responsible for the tachycardia could be mapped electrophysiologically, thereby providing electrophysiologists with a model of other types of reentrant arrhythmias, (2) the precise location of the only abnormal anatomic structure in the circuit (accessory pathway) could be identified, and (3) surgical intervention could be confined within specific anatomic boundaries with reasonable expectation that the abnormal anatomic structure could be divided, leaving the normal conduction system intact.

Whereas the ultimate perfection of the surgical technique originally applied by Sealy in 1968 required several years, the success rate of the present procedure now approaches 100%. Although it was necessary to reoperate on 19.5% of the first 200 patients in the Duke series, only one reoperation has been required to divide the accessory pathway in the last 110 patients treated by the author, that instance being necessitated by the fact that the initial operation was performed from outside the heart rather than by the standard intracardiac approach used in all other patients.

Guiraudon has recently reported an external, closedheart approach for the division and/or cryoablation of accessory pathways. Sealy first used a similar approach in the initial 40 patients in the Duke series and we continued to combine external dissection and cryosurgery with the intracardiac technique until 1981. The external approach was abandoned because our experi-
ence taught us that external dissection can lead to devastating hemorrhagic complications in patients with a friable epicardial peel that will not hold sutures adequately and in the presence of an intramural coronary artery or coronary sinus. This complication was especially problematic (and on two occasions, fatal) in elderly patients. Guiraudon’s patients ranged in age from 6 to 56 years with a mean age of 29 years. Only two patients were over 41 years old, both being 56 years of age. None of the patients had coexisting heart disease, only one patient had multiple (two) accessory pathways, and none had septal pathways. This spectrum of patients is not representative of the cumulative experience of Dr. Sealy and the author in the Duke series or of the author’s combined series at Duke and in St. Louis. Fifteen percent of our patients have had multiple accessory pathways, 7% Ebstein’s anomaly, 3% Mahaim fibers, 6% cardiomyopathies, 3% coronary artery disease, 3% sick sinus syndrome, 6% aortic or mitral valve disease, and 1% ventricular septal defects. The age range is from 9 months to 74 years. Thus the potential hazards and significant limitations of Guiraudon’s technique would not seem to warrant the abandonment of our current approach that has been successful in dividing 137/138 accessory pathways in the last 110 consecutive patients.

Other investigators3-5 have reported the use of catheter-delivered electric shocks to accessory pathways for the treatment of WPW syndrome. Although the concept of ablating accessory pathways without resorting to a formal cardiac surgical procedure is attractive, the feasibility of such an approach should be placed into perspective in relation to the established nonpharmacologic methods of treating WPW syndrome. Of the 10 patients known to have been so treated, nine continue to have ventricular preexcitation (accessory pathway conducts antegrade) and one had apparent rupture of the coronary sinus requiring pericardial drainage. A cardiac arrhythmia surgeon with these results might find his referrals dwindling, but such courageous and innovative techniques warrant continued experimental evaluation in hopes that a feasible alternative to surgery might one day be developed, especially for the treatment of refractory supraventricular tachyarrhythmias in patients with compromised cardiac performance.

Supraventricular arrhythmias other than WPW syndrome. Techniques have now been developed and applied clinically for the surgical treatment of refractory automatic atrial tachycardias and for AV node reentry tachycardia. The procedures, however, remain largely experimental with the exception of the discrete cryo-
surgical technique that we have used for the treatment of AV node reentry tachycardia. After the comprehensive electrophysiologic and histologic evaluation of this procedure in animals,6,7 we applied the procedure in four patients with AV node reentry tachycardia, three of whom were undergoing operation primarily for surgical correction of WPW syndrome. Postoperative electrophysiologic studies in all four patients documented the persistence of only a single AV conduction pathway, and AV node reentry tachycardia could not be induced during the postoperative study. No spontaneous AV node reentry tachycardia has occurred in any of these patients, the longest follow-up being 2 years. This procedure was developed because the only previous surgical methods for treating medically refractory AV node reentry tachycardia were elective His bundle cryoablation or endocardial catheter ablation of the His bundle, both requiring insertion of a permanent pacemaker system. The discrete cryo-surgical technique alters the input pathways of the AV node and ablates one limb of the reentrant circuit without interrupting atrioventricular conduction and thus avoids the necessity for postoperative antiarrhythmic drugs, antitachycardia pacing devices, or permanent pacemaker systems. Narula4 has applied similar approaches in closed-chest animals with a laser catheter, a promise of exciting clinical possibilities for the future.

Automatic atrial tachycardias are frequently suppressed by general anesthesia and as a result, intraoperative mapping to localize their site of origin is usually not possible. However, if the arrhythmia persists intraoperatively so that it can be localized precisely, simple surgical excision or isolation of that part of the atrium or local cryoablation will cure the problem. If the arrhythmogenic myocardium cannot be localized intraoperatively, elective cryoablation of the His bundle may be the only alternative. However, the majority of these arrhythmias originate in the body of the left atrium. Since the sinoatrial node, intranodal conduction routes, and AV node–His bundle complex reside either in the right atrium or atrial septum, the entire left atrium can be isolated surgically from the remainder of the heart, which then persists in normal sinus rhythm regardless of the presence or absence of tachycardia in the left atrium.

After developing the technique for left atrial isolation in 19799 and evaluating its hemodynamic effects for over 3 years, we applied it clinically on December 6, 1982. The patient has remained in normal sinus rhythm on no antiarrhythmic medications postoperatively, despite the presence of incessant tachycardia.
confined to the left atrium. She has suffered no adverse hemodynamic sequelae, having returned to her hobby of skydiving. The left atrial isolation procedure has also shown promise experimentally for the control of atrial flutter/fibrillation associated with mitral valve disease.

Ventricular tachyarrhythmias

With the advent of coronary artery bypass grafting in the late 1960s, it seemed apparent that ischemic ventricular tachycardia would be easily corrected by this new procedure, since the basis for the arrhythmia (myocardial ischemia) could be alleviated by myocardial revascularization. During the 1970s, however, it became apparent that thoracic sympathectomy, coronary artery bypass grafting, myocardial infarct resection, left ventricular aneurysm resection, or a combination of these procedures could not attain acceptable success and mortality rates. During the same period the reentrant basis of refractory ischemic ventricular tachycardia was established, at once improving the conceptual basis of the mechanism of ventricular tachycardia while demonstrating our ignorance of the uncharted interplay between the autonomic nervous system, endogenous humoral stimulants, intracellular electrophysiology, extracellular electrophysiology, the specialized conduction system, coronary artery disease, myocardial ischemia and infarction, and normal myocardial conduction.

Despite our poor understanding of the complex interrelationship of these variables in the genesis of ischemic ventricular tachyarrhythmias, the clinical problem of medically refractory ventricular tachycardia remained, demanding that some type of reasonably effective, nonpharmacologic therapy be developed. Sophisticated methods for evaluating ventricular tachycardia preoperatively (an outgrowth of methods used earlier for supraventricular tachyarrhythmias) and for inducing and mapping the ventricular epicardium, endocardium, and transmural myocardium intraoperatively provided means of “localizing the site of origin” of the ventricular tachycardia at the time of surgery. These electrophysiologic techniques could then guide the surgeon to the arrhythmogenic myocardium, where a direct surgical procedure could be applied to ablate or isolate the region.

In 1978, Guiraudon et al. reported the technique of encircling endocardial ventriculotomy (EEV), and soon afterwards Josephson et al. described the technique of subendocardial resection, frequently termed the endocardial resection procedure (ERP). Both of these reports represented milestones in the surgical treatment of ischemic ventricular tachycardia because they emphasized a more direct, scientific approach to the problem. The EEV was subsequently demonstrated to be associated with an unacceptably high incidence of low output syndrome postoperatively and has been abandoned by most surgeons in favor of the ERP. However, the EEV may still be used for posterior left ventricular aneurysms and/or myocardial infarcts with refractory ischemic ventricular tachycardia if the precise region of arrhythmogenesis cannot be identified. The ERP has proved to be a satisfactory technique whether applied as a localized or generalized procedure and is the most commonly used technique. However, when applied locally, as originally described, the surgical cure rate (no postoperative inducible or spontaneous ventricular tachycardia and no antiarrhythmic drugs required) is only 60%. Another 25% of patients can be controlled with medicine postoperatively, increasing the effective control rate to approximately 85% overall.

Neither the EEV nor the ERP can be applied to all areas of the heart such as the aortic or mitral valve anulus and the papillary muscles. Moreover, the endocardial resection procedure frequently fails because ventricular tachycardia may arise from intramural or even subepicardial layers of the left ventricular wall. As a result, we have used endocardial, transmural, and/or epicardial cryoablative techniques either as primary or adjunctive procedures (with EEV and/or ERP) to control refractory ischemic ventricular tachycardia with a surgical cure rate of 85%.12, 13

The presence of a visible anatomic substrate (endocardial fibrosis) that is known to harbor all or a portion of the reentrant circuit responsible for ischemic ventricular tachycardia provides the surgeon with a means of focusing the surgical intervention without the assistance of intraoperative mapping techniques. This fact has led to the increasingly common practice of simply resecting or encircling the fibrotic myocardium for treatment of ischemic ventricular tachycardia while making no attempt at precise localization of the arrhythmogenic myocardium. These surgical procedures without electrophysiologic guidance, while not as effective as electrophysiologically guided ones, have one major advantage: they can be used, with reasonable results, for urgent or emergent cases to solve a lethal problem in institutions with no electrophysiologic mapping capabilities. Under such circumstances, procedures without electrophysiologic guidance are most appropriate. The superior results attained with electrophysiologically guided surgery, however, warrant the continued concentration of the majority of
these procedures in institutions with intraoperative mapping capabilities.

**Summary and conclusions**

Successful surgical treatment of all forms of supraventricular tachyarrhythmias is dependent on accurate electrophysiologic guidance. Surgery for WPW syndrome is no longer experimental and should be offered to (1) patients with medically refractory reciprocating tachycardia associated with the syndrome, (2) patients with spontaneous atrial fibrillation who are at risk for sudden death, (3) patients with drug intolerance, and (4) young, otherwise healthy patients with symptoms that warrant more than minimal medical therapy. The current results of surgery for WPW syndrome would seem to lessen the likelihood that a major new method of superior nonpharmacologic treatment will emerge in the near future.

Surgery for most other types of supraventricular tachyarrhythmias remains experimental and should be applied only under the most controlled circumstances and after satisfying the most rigid criteria for surgical intervention, the main indication being absolute medical refractoriness. The single exception at the present time is surgery for AV node reentry tachycardia, which appears to be easily cured by the new technique of discrete cryosurgery of the peri-AV nodal region of the lower right atrial septum.

In a majority of patients, ventricular tachycardia can be successfully ablated surgically without the use of electrophysiologic mapping to guide the surgeon. If such an approach is taken, however, the surgical treatment of these complex arrhythmias becomes a completely service-oriented exercise. Although delivery of such a service is of undeniable importance, the potential for learning more about these complex and lethal arrhythmias is lost unless each patient is studied as comprehensively as possible. Since 1978, fewer than 500 patients worldwide have been treated by one of the direct endocardial surgical techniques. If we are going to propose an intelligent approach to the numerically overwhelming problem of sudden death from cardiac causes, it is mandatory that we subject every patient with the unique clinical problem of refractory ischemic ventricular tachyarrhythmia to extensive electrophysiologic study. We must remember that the only true model of ischemic ventricular tachycardia is the human being. The immediate benefits of our present state of knowledge may be offered with gratifying results to a few patients. However, unless these operations are performed in association with the appropriate electrophysiologic studies, we may be doing an immense disservice to a much larger group of future patients. Just as the electrophysiologic expertise and surgical principles learned from the earlier approaches to surgery for WPW syndrome paved the way for the wider application of ventricular tachycardia surgery, scientific approaches to the latter problem will hopefully guide us toward the development of electrophysiologic predictors of sudden cardiac death. The establishment of such electrophysiologic indexes, based on a more complete understanding of ischemic ventricular tachyarrhythmias, might then lead to the development of pharmacologic and/or nonpharmacologic measures to prevent sudden deaths caused by arrhythmia.

**References**

The status of surgery for cardiac arrhythmias.

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