What Is the Best Method for Assessing the Long-term Outcome of Surgery for Accessory Pathways and Atrioventricular Junctional Reentrant Tachycardias?

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The success of surgery for supraventricular tachycardia (SVT) is evaluated by a variety of methods in different hospitals. Unfortunately, the predictive values of these methods are not known. We therefore compared the various methods in 261 patients undergoing surgery for SVT at Westmead Hospital since 1981. Surgical outcome was assessed by early tests during the first week after surgery (serial 12-lead electrocardiograms, telemetric monitoring of the electrocardiogram, and electrophysiological study performed using epicardial wires); later tests at 6 months after surgery (12-lead electrocardiograms and electrophysiological study); and symptomatic review done by telephone interview at a median of 34 months after surgery. Early tests were obtained in 97%, later tests were obtained in 76%, and symptomatic review was obtained in 98% of patients. All of the examined tests were inaccurate methods of surgical assessment compared with the late electrophysiological study. A large proportion of the patients proven to be surgical failures at the late electrophysiological study were not detected by early tests (83%), by later electrocardiograms (66%), or by symptomatic assessment (41%). Accurate assessment of surgical outcome requires a late electrophysiological study to permit comparison of surgical techniques. Late electrophysiological study also provides accurate information on the current risks and benefits of proposed surgery for communication to patients to enable them to make an informed decision on future treatment. Most patients are willing to have a late electrophysiological study and usually benefit from clarification of their true surgical outcome. (Circulation 1991;83:528–535)

Surgical cure of tachycardias due to accessory pathways and, more recently, atrioventricular (AV nodal) junctional reentry has been attempted using a variety of operative techniques since 1967.1,2 Determination of the best surgical technique and communication of the risks and benefits of surgery to the patient require accurate assessment of surgical outcome. To date, most reports have used the results of operative mapping, early electrocardiography, and early electrophysiological study to judge operative outcome.1–34 However, the predictive value of these tests for determining long-term outcome has not been determined. Early studies may be inaccurate predictors of long-term outcome. Operative trauma or perioperative edema around either the accessory pathways or the AV node may transiently inhibit function of the arrhythmia circuit and therefore masquerade as a surgical success at these early tests. Symptomatic follow-up may also be an inaccurate method of surgical assessment because postoperative palpitations may be due to a variety of arrhythmias other than that for which surgical cure was attempted3 and surgical failures may be asymptomatic.

To determine the accuracy of current methods of assessing surgical success or failure, we compared the results of early studies done during the first week after surgery (intraoperative electrophysiological...
study, telemetric monitoring of the electrocardiogram, serial 12-lead electrocardiograms, and electrophysiological study done using epicardial wires attached at surgery) with studies done 6 months after surgery (12-lead electrocardiogram and electrophysiological study) in 261 patients who had surgery for supraventricular tachycardia at our hospital since 1981. The correlation with symptoms on prolonged follow-up was also assessed.

Methods
We reviewed all 261 patients who underwent surgery for supraventricular tachycardia at our hospital between October 1981 and February 1989. Surgical dissection for AV and ventriculoatrial accessory pathways was performed using the endocardial approach described by Sealy and Gallagher. Surgical dissection for AV junctional reentrant tachycardia (also known as AV nodal tachycardia) was performed using the technique we described. Patients who had surgery for atrial tachycardias or tachycardias due to nodoventricular fibers were not included in this analysis. Intraoperative mapping was performed using a hand-held probe using previously described techniques. After the dissection, all patients had additional intraoperative electrophysiological assessment to confirm the initial success of surgery. All patients had telemetric monitoring of the electrocardiogram for at least 5 days after surgery and had serial 12-lead electrocardiograms during the week after surgery. The results of telemetric monitoring and the serial electrocardiograms in this period were grouped together for analysis and termed “the early electrocardiogram.” An electrophysiological study was performed 1 week after surgery, in the drug-free state, using epicardial wires placed during surgery.

A late, 6-month postoperative electrophysiological study while off all antiarrhythmic agents was requested of all patients. Quadriipolar electrodes were positioned in the high right atrial appendage and the right ventricular apex, and a bipolar catheter was positioned at the His-bundle region. Unless there was definite ventriculoatrial dissociation during this study, a coronary sinus electrode was also inserted. The stimulation protocol has been described. Briefly, it consisted of assessment of antegrade and retrograde conduction by insertion of extrastimuli after a stable drive train of eight beats. The initial extrastimulus was introduced 550 msec after the drive train and then at decreasing intervals to atrial and ventricular refractoriness. AV and ventriculoatrial Wenckebach thresholds were also determined. Repeated burst atrial and ventricular pacing close to the Wenckebach thresholds was then performed in an attempt to induce tachycardias. All patients who had surgery for atrioventricular junctional reentrant tachycardia were also assessed during intravenous infusion of 5 μg/min isoproterenol and after 1 mg i.v. atropine if no arrhythmia was inducible in the base-line state. All induced arrhythmias were mapped in detail.

A late electrocardiogram was also taken at the time of admission for the 6-month postoperative electrophysiological study.

The presence of any function of an attempted accessory pathway, no matter how compromised, either on the electrocardiogram or at the electrophysiological study was regarded as a surgical failure. Accessory pathways located at different sites to those attempted at surgery were not regarded as surgical failures but rather defined as mapping failures. In cases with AV junctional reentrant tachycardia, surgical failure was defined as the ability to induce three or more beats of AV junctional reentrant tachycardia. Persistent dual AV nodal pathways and less than three apparently AV junctional echo beats were not regarded as surgical failures.

Patient follow-up was performed by telephone interview using a standard questionnaire. The occurrence of rapid regular palpitations of sudden onset and offset were regarded as symptomatic failures for the purposes of analysis. Most of these palpitations were not documented on an electrocardiogram and may have been due to other arrhythmias, such as sinus tachycardia and atrial flutter.

Statistical Analysis
Sensitivity, specificity, and predictive accuracy were calculated using the results of the 6-month postoperative electrophysiological study as the gold standard for determining surgical success or failure.

Results
Division of 214 accessory pathways was attempted in 174 patients. One hundred twenty-one accessory pathways (57%) were located in the left free wall, 68 (32%) in the posterior septal space, and 25 (11%) in the right free wall. Thirty-nine percent of the 174 patients had a posterior septal pathway. A total of 39 patients had surgery for a combination of either left free wall, right free wall, or posterior septal pathways (one had surgery for accessory pathways in all of these locations). An additional 91 patients had surgery for AV junctional reentrant tachycardia. Another four patients had surgery for both accessory pathway and AV junctional reentrant tachycardia. Indications for surgery in patients with an accessory pathway were failed medical therapy in 71 patients (41%), patient preference in 57 (33%), and potentially lethal rapid antegrade conduction over the accessory pathway in 43 (25%). An additional three patients had division of their accessory pathway as a concurrent procedure to other cardiac surgery. In patients having AV junctional reentrant tachycardia surgery, the major indications were failed medical therapy in 52 (57%) and patient preference in 30 (33%). An additional nine patients had surgery as an adjunctive procedure to other cardiac surgery. The median length of postoperative follow-up was 34 months (range, 5–90 months).
All evaluative procedures were requested in all patients. Table 1 shows the number of tests that were actually performed. Eight patients did not have an early, 1-week postoperative electrophysiological study because of intractable atrial fibrillation. A late 6-month postoperative electrophysiological study was not obtained in 29% of patients with accessory pathways and 14% of patients with AV junctional reentrant tachycardia. Only four patients (2%) were lost to follow-up.

The outcome of surgery as predicted by the various evaluative tests is shown in Table 2. Early tests, either the electrocardiogram, the electrophysiological study, or a combination of both, predicted very low surgical failure rates of only 2% for accessory pathways and 6% for AV junctional reentrant tachycardia in keeping with other published results.1–34 Twelve-lead electrocardiograms done during the first 6 months after surgery also predicted a low surgical failure rate of 4% of accessory pathways and 9% for AV junctional reentrant tachycardia. Long-term surgical failure rates, as detected by the 6-month postoperative electrophysiological study, were much higher: 8% for accessory pathways and 24% for patients with AV junctional reentrant tachycardia. In all but one patient, long-term failures occurred in patients with a posterior septal pathway or AV junctional reentrant tachycardia. Of the 10 accessory pathway failures, six had inducible sustained tachycardia. Potentially lethal rapid antegrade conduction over the accessory pathway was present in one of the four patients without inducible tachycardia. Sustained tachycardia lasting at least 4 seconds was induced in all of the failures with AV junctional reentrant tachycardia; in 15 (79%) patients, it lasted long enough to complete ventricular extrastimulus testing. In addition to these surgical failures, there also were six patients who had an additional arrhythmia circuit detected at a postoperative study that was different than that attempted at initial surgery. In the three mapping failures who had surgery for AV junctional reentrant tachycardia, the undetected circuit was always the posterior type of this tachycardia. The additional circuits in the three other mapping failures who had surgery for an accessory pathway consisted of another accessory pathway in two cases and of anterior AV junctional reentrant tachycardia in one case. Inclusion of these mapping failures in the group of surgical failures did not significantly change the sensitivity, specificity, and accuracy of the examined tests.

Most patients (61%) had experienced palpitations since surgery. For those who had accessory pathway surgery, the palpitations were judged at interview to be ectopic beats in 35 (37%), atrial flutter or fibrillation in 26 (28%), and sinus tachycardia in eight (9%); in 25 patients (27%), the palpitations were suggestive of supraventricular tachycardia (i.e., the palpitations were rapid, regular in nature, and of sudden onset and offset). For those who had surgery for AV junctional tachycardia, the palpitations were judged at interview to be ectopic beats in 14 (21%), atrial flutter or fibrillation in 12 (18%), and sinus tachycardia in nine (13%); in 33 patients (49%), the palpitations were suggestive of supraventricular tachycardia. Most patients (227, or 88%) thought their surgery was successful even if they were symptomatic or had electrophysiological evidence of failure. The patients’ opinions of surgical outcome compared with symptomatic and electrophysiological determined outcomes are shown in Table 3.

The detection of long-term electrophysiological failures by the various tests is shown in Table 4. Early tests were poor indicators of long-term outcome, detecting only 20% of accessory pathway and 16% AV junctional reentrant tachycardia failures. Similarly, the late electrocardiogram detected only 50% of accessory pathway failures and 26% of AV junctional reentrant tachycardia failures. Rapid regular palpitations were present in only 59% of long-term electrophysiological failures. Patients were also poor judges of surgical outcome (as determined by the 6-month postoperative electrophysiological study). Only 20% of accessory pathway failures and 26% of AV junctional reentrant tachycardia failures thought their surgery was a failure, irrespective of whether they experienced postoperative palpitations.
The sensitivity, specificity, and predictive accuracies of the electrocardiogram, early electrophysiological study, and symptomatic review when the late electrophysiological study was used as the gold standard are shown in Table 5. None of the examined tests had a sensitivity of more than 0.74, and most had a sensitivity of approximately 0.3 for detecting long-term outcome as determined by the 6-month postoperative electrophysiological study.

Patients were also asked whether they derived any benefit from having a late postoperative electrophysiological study and whether they would, with hindsight, still have had the study if given a choice. Eighty-one percent of the accessory pathway patients and 65% of the AV junctional reentrant tachycardia patients who had a late electrophysiological study felt that the test had been helpful by providing clarification or reassurance about their surgical outcome. Many of the patients who did not have a late electrophysiological study (21 of 50, or 42%, accessory pathway patients and seven of 13, or 54%, AV junctional reentrant tachycardia patients) also felt that an electrophysiological study would have been helpful to provide some reassurance or clarification of their surgical outcome. With the benefit of hindsight, only 18 of the 172 accessory pathway patients (10%) and 11 of the 89 AV junctional reentrant tachycardia patients (12%) contacted would have preferred to avoid a late electrophysiological study. All of the remaining patients (except six patients who were uncertain and four who were lost to follow-up) would still have had a late electrophysiological study, either for their own benefit or for research purposes.

**Discussion**

Several different surgical techniques are used for curing accessory pathways and AV junctional reentrant tachycardia: endocardial versus epicardial approaches, cryoablation, and perinodal dissections of different types. Extraordinarily high success rates are claimed by some groups for their particular approaches. Comparisons of the efficacy of the various techniques are hindered by variations in methods of determining late outcome of the surgery. The adequacy of the postoperative testing is likely to be a major determinant of the reported success rates. Electrophysiological testing just before hospital discharge is a major determinant of the reported success rates. Electrophysiological testing just before hospital discharge is a major determinant of the reported success rates.
charge is appealing but does not detect transient abolition of accessory pathway function. This may last several weeks. In addition, most patients dislike detailed, four-catheter electrophysiological studies only 1 week after major open-heart surgery. Hence, limited electrophysiological studies are usually performed at that time using only percutaneous epicardial wires or a reduced number of endocardial electrodes without a coronary sinus catheter. These minimize patient discomfort but are incomplete electrophysiological studies. Inducing the patient to return to the hospital for a comprehensive electrophysiological study several months after surgery also has inherent problems. Often patients have travelled long distances to referral centers and do not want to return, may be unwilling to take additional time off work, may not want to incur further expense, or may find the thought of yet another electrophysiological study distressing. Some cardiologists and surgeons argue that postoperative symptoms are the gold standard and that routine late invasive electrophysiological testing is expensive, dangerous, and irrelevant. We disagree. Symptoms may be misleading, are often absent in surgical failures, and are often present in objective surgical successes. Placebo-type responses occur with surgery at least as often as with any other form of treatment. In our experience, most asymptomatic patients with evidence of persistent accessory pathway function or inducible tachycardia at late electrophysiological study will develop symptoms if followed long enough. In addition, it is important for the surgeon to know if the target tissues were successfully divided so that individual performances can be improved and the results from different institutions can be compared objectively. This quality control aspect is essential when arrhythmia surgery programs are begun, surgeons are in training, or new surgeons join the staff.

**Frequently Used Methods of Surgical Assessment**

Most series have used operative mapping, electrocardiograms done during the first week after surgery, and an electrophysiological study performed via epicardial wires at 1 week after the operation to evaluate surgery.1–29,33,34 Using these tests, high success rates, approaching 100%, have been claimed for both accessory pathway operations and those done for AV junctional reentrant tachycardia.1–29,33,34 This was also the case in our experience when the results of early tests were used as the determinant of surgical success (Table 2). However, late electrophysiological study in our patients has demonstrated these early studies to be poor predictors of long-term outcome, detecting only 20% of accessory pathway and 16% of AV junctional reentrant tachycardia failures.

As expected, late evaluation with the electrocardiogram is an inaccurate method of surgical assessment. Only accessory pathways with a visible delta wave in sinus rhythm or supraventricular tachycardia documented on an electrocardiogram will be detected. In our study, a late electrocardiogram detected only 50% of the long-term electrophysiological accessory pathway failures and 26% of the AV junctional reentrant tachycardia failures (Table 4).

More frequent Holter monitoring may have documented supraventricular tachycardia during symptoms. However, prolonged monitoring over weeks to months would have been required in most cases. In some of our patients, the first symptomatic episode of tachycardia did not occur for as long as 6 months after surgery. As a rule, patients do not like prolonged electrocardiographic monitoring. Furthermore, both symptomatic and asymptomatic patients would need to be studied. Therefore, prolonged late electrocardiographic monitoring is an expensive and unrealistic option.

**Assessment of Operative Outcome by Late Electrophysiological Study**

The late electrophysiological study 6 months after surgery was the most accurate and sensitive method of assessing surgical outcome. This was not unexpected as late assessment should detect surgical failures who were missed by early postoperative tests because of transient impairment of their accessory pathway or arrhythmia circuit. The electrophysiological study will also detect arrhythmia circuits due to AV junctional reentrant tachycardia and accessory ventriculoatrial pathways. These will be missed by the electrocardiogram or Holter monitor unless the patient has supraventricular tachycardia (which may be infrequent) at the time of the test. The electrophysiological study also has the advantage over other methods of assessment of being able to accurately characterize any residual arrhythmia circuit and thus give the surgeon and electrophysiologist an accurate reason as to why surgery failed. This is important if mapping and surgical techniques are to be improved in the future. The late electrophysiological study may be inaccurate if the accessory pathway or arrhythmia circuit is traumatized during catheter insertion transiently preventing pathway detection or if the stimulation protocol used is not aggressive enough to induce tachycardia. This is an uncommon phenomenon in our experience. Only two patients (1%) have had documented tachycardia after having had a “normal” 6-month postoperative electrophysiological study representing a failure rate of 1% (sensitivity, 0.94; specificity, 0.99; and accuracy, 0.99). Inclusion of these two patients in the analysis as surgical failures does not change the conclusion that the 6-month postoperative electrophysiological study is the most accurate and sensitive method of detecting surgical success or failure.

**Symptomatic Assessment of Surgical Outcome**

The relief of symptoms is one of the major aims of surgery; therefore, ideally, the abolition of significant symptoms should be one of the gold standards used for evaluating surgery. However, palpitations of some sort are experienced by most patients after surgery. In our study, 61% of patients had experienced some palpitation since surgery. Fischell and colleagues3
found that 49% of their 45 patients had experienced some palpitation after surgery. Postoperative palpitations may be due to a variety of arrhythmias such as ectopic beats, atrial fibrillation, atrial flutter, and sinus tachycardia in addition to reentrant supraventricular arrhythmias. Therefore, decisions as to the significance of undocumented palpitations require clinical judgment and would not be expected to be very accurate. If the definition of "palpitations" is made more restrictive and more likely to represent supraventricular tachycardia (e.g., the presence of sustained rapid regular palpitations of sudden onset and offset similar to the preoperative symptoms), the history becomes a more reliable indicator of surgical failure but still lacks sensitivity and specificity (Table 5). In our study, symptoms suggestive of supraventricular tachycardia were present in 17 of the 29 surgical failures (59%) at late electrophysiological study and 25 of the 171 electrophysiologically proven cures (13%). Fischell et al\(^3\) also showed the low specificity of palpitations suggestive of supraventricular tachycardia. One of their two symptomatic "failures" had sinus tachycardia recorded on Holter monitor during the palpitation. The higher incidence of symptoms suggestive of supraventricular tachycardia in our study compared with that of Fischell et al's study\(^3\) (5%) may be due to the type of follow-up. All of our reported symptomatic follow-up was obtained by direct questioning of patients by interviewers experienced in the follow-up of arrhythmia patients. Fischell and colleagues obtained their data by telephone interview with the patient in only 29 of the 44 patients that they studied, the remainder of their data being obtained from questionnaires, the local physician, and patient charts. In our experience, these lack the accuracy of direct patient interview. Symptoms are also insensitive because not all surgical failures will necessarily be symptomatic at the current length of follow-up. In our study, 12 of the 29 surgical failures (41%) at late electrophysiological study had not experienced palpitations suggestive of supraventricular tachycardia at a median follow-up of 34 months. The patients' own assessments of surgical outcome are also an inaccurate yardstick of true surgical outcome. Often, patients do not want to disappoint themselves or their physicians by admitting that their surgery may have been a failure. In our study, 21 of the 29 failures (72%) detected at electrophysiological study considered their surgery to have been successful even if they had experienced palpitations suggestive of supraventricular tachycardia.

The high incidence of palpitations consistent with supraventricular tachycardia but not based on surgical failure indicates another role for a late electrophysiological study—patient reassurance. Of our patients, 151 (75%) felt that the 6-month postoperative electrophysiological study had been worthwhile for clarifying their outcome and providing a high degree of reassurance that their arrhythmias would not return. Such information is also useful for life insurance, job applications, and military personnel and those wishing to obtain or renew commercial or military aviation licenses.

**Natural History of Early Surgical Failures**

Of additional concern is the possibility that patients predicted to be failures at early testing will be "cures" at later study because of the effects of maturation of scar tissue on the arrhythmia circuit. This would make the results of early studies less specific. In our study, this was rare. Only two of the early failures were found to be normal at late electrophysiological study. Therefore, our data support treating early failures as true long-term failures with early reoperation.

**Clinical but Not Electrophysiological Success**

Some may argue that our definition of surgical failure is unnecessarily stringent. In our study, four of the 10 accessory pathway failures did not have supraventricular tachycardia induced at the late electrophysiological study. However, in one of these, the accessory pathway was still capable of dangerously rapid conduction. In the patients who failed surgery for AV junctional reentrant tachycardia, four of the 19 had induced tachycardias that lasted only a few seconds. Longer episodes were not inducible, even after isoproterenol and atropine. It may be argued that surgery had modified the arrhythmia circuit in these patients without ablating it, thereby resulting in a symptomatic cure. Although these are clinically useful results, they still indicate failure of the surgery to ablate the intended circuit and demonstrate room for improvement of surgical technique.

**Role of Preoperative Electrophysiological Assessment in the Long-term Outcome of Surgery**

Our data also highlight another of the major problems with arrhythmia surgery—the need for accurate and detailed localization of the circuits involved. The results of surgery can only be as good as the accuracy of the electrophysiological assessments before surgical dissection. In our study, six of a total of 35 unsuccessful operations (17%) were the consequence of additional pathways or circuits that became evident only after the original circuit was ablated at surgery. This occurred despite great pains to detect and localize additional pathways and circuits at the preoperative and operative electrophysiological studies. These failures are due to the inherent problems of mapping techniques as well as the phenomenon of preferred arrhythmia circuits, usually with shorter conduction times, which tend to hide other arrhythmia circuits or pathways with longer conduction times. The mapping failures in patients with AV junctional reentrant tachycardia in our study illustrate this. In all of these cases, the undetected circuit was always the slower conducting posterior type rather than the faster conducting anterior type. Failed mapping may also be a conse-
quence of trauma to the additional pathways. This may transiently inhibit their function and prevent their detection.

Conclusions

A late postoperative electrophysiological study provides the most accurate method of assessing surgery for supraventricular tachycardia. It is likely that a similar late electrophysiological study will be the best method for determining the success rates of other methods of ablation such as percutaneous catheter electrical, laser, or radiofrequency ablation. Other measures such as the electrocardiogram and 1-week postoperative epicardial wire electrophysiological study can be used as a rough guide but miss as much as 40% of accessory pathway and 68% of AV junctional reentrant tachycardia failures. Symptoms are poor guides to outcome. Palpitations are common after surgery and usually represent arrhythmias other than supraventricular tachycardia. Patients are also poor judges of surgical success or failure, detecting only 24% of documented long-term surgical failures. The 6-month postoperative electrophysiological study is readily obtainable in the majority of patients and provides valuable reassurance, even in the patients who have been surgically cured. Accurate feedback to surgeons of their long-term results should lead to improved success rates and objective comparison of surgical techniques and results.

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References


**KEY WORDS** • supraventricular tachycardia • surgery • atrioventricular node
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