Catheter Ablation for Cardiac Arrhythmias: Clinical Applications, Personnel and Facilities

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The American College of Cardiology (ACC) recognizes the important role that catheter ablation has assumed in the treatment of arrhythmias, as reflected in this review of the background and current applications of ablative procedures. The following position statement evolved from a document by the North American Society of Pacing and Electrophysiology (NASPE) (1) but has been substantially modified and updated.

Catheter ablation for control of cardiac arrhythmias was first introduced more than a decade ago. Since then these procedures have largely supplanted the need for expensive and potentially more dangerous open heart surgical procedures for several types of arrhythmias. Catheter ablative procedures constitute a widely practiced, nonpharmacologic technique for management of patients with supraventricular tachycardia and selected ventricular tachycardias. The current CPT codes for Intracardiac Catheter Ablation (93650, 93651 and 93652) do not compensate for ablative procedures, except by local option. The ACC believes that routine reimbursement for ablative procedures would now seem appropriate in view of the maturation and clinical utility of the technique, as demonstrated by its safety, efficacy and cost-effectiveness.

Definition of Terms and Methods of Procedure

Ablation refers to the intentional destruction of arrhythmogenic myocardial tissue, accessory atrioventricular (AV) connections or parts of the specialized conduction system to cure or control cardiac rhythm disturbances. Ablative procedures may be performed by using surgical or electrode catheter methods or by delivery of pharmacologic substances to the target region.

Catheter ablative procedures at present involve delivery of energy pulses by means of electrode catheters of the standard type used for electrophysiologic studies or as modified with larger surface area tips and other design features. Radiofrequency has largely replaced direct current shock as the energy source. The methods of procedure vary depending on the type of arrhythmia treated and include ablation of the AV junction, modification of the AV node or perinodal areas, ablation of accessory AV pathways and ablation of atrial or ventricular tissue. Ablation of the AV junction to produce complete AV block involves insertion of an electrode catheter in the region of the AV junction with delivery of radiofrequency current to interrupt impulse transmission from atrium to ventricle. Modification of the AV node is used to eliminate AV node reentrant tachycardia while leaving AV node conduction intact. For patients with accessory AV connections, the catheter is placed in close approximation to the accessory pathway to desiccate this tissue by delivery of radiofrequency energy pulses. After appropriate mapping and localization of sites of ectopic impulse formation or location of the right bundle branch in cases of bundle branch reentrant ventricular tachycardia, radiofrequency pulses can be delivered to terminate the tachycardia. A detailed report (2) by the Diagnostic and Therapeutic Technology Assessment panel (DATTA) of the American Medical Association can be reviewed.

Safety and Efficacy of Catheter Ablative Procedures

Catheter ablation was first used clinically in 1981 and initially involved use of high energy direct current shocks for destruction of the AV junction. Ablative procedures have been
used in thousands of patients worldwide. The early results have been well summarized in a monograph (3). The largest single report of high energy direct current ablation comes from the Percutaneous Catheter Mapping and Ablation Registry (PCMAR) (4), which accumulated data on 552 patients followed up for a mean of 23 ± 18 months. These patients were intolerant of or failed to respond to a mean of 3.5 antiarrhythmic medications. Sixty-four percent of patients had atrial fibrillation or flutter; 20% had AV node reentrant tachycardia; and 16% had a variety of supraventricular arrhythmias. Large series (5,6) using radiofrequency ablation are now appearing.

**Efficacy and safety of direct current shocks for AV junctional ablation.** Sixty-four percent of patients who achieved third-degree AV block remain without symptoms or need for antiarrhythmic therapy (4). However, long-term cardiac pacing is required. Eight percent of patients had return of conduction but with arrhythmia control without symptoms and without requiring an antiarrhythmic drug (4). Ablation therapy was considered to have failed in 16% of patients (4).

Acute major complications of high energy direct current ablation are rare but include induction of ventricular arrhythmias, myocardial perforation, venous thrombosis and myocardial depression. The most serious in-hospital complication is polymorphous ventricular tachycardia and occurs in ~4% of patients. The most serious reported complication is a 1.8% incidence of sudden cardiac death, which may occur from 3 days to 6 months after ablation (4). The causal relation of the ablative procedure itself and sudden death is unclear. Long-term outcomes, including proarrhythmia assessment, have been described (7,8). Notably, direct current shocks for ablative procedures have now been largely supplanted by radiofrequency technology. Direct current shocks may still be useful in some instances, especially if radiofrequency fails (9,10), and some developmental work in direct current ablation continues (11).

**Results of radiofrequency ablation of the AV junction.** The reported efficacy of radiofrequency ablation for the AV junction varies from 70% to 95% (5,6,9,10,12,13). Data compiled for 260 consecutive patients who underwent radiofrequency ablation of the AV junction were supplied to NASPE from five centers in the United States. Morady et al. (9) concluded that radiofrequency ablation was more efficacious and safer than direct current ablation. The procedure was successful, as defined by induction of complete AV block, in 86% to 99% of patients. Serious complications included late sudden death, electromechanical dissociation and death and acute myocardial infarction within 1 week after the procedure (9). Olgin and Scheinman (10) found that radiofrequency ablation was comparable in efficacy and perhaps safer than direct current shock. The 1992 NASPE survey (6) reported an experience of 1,600 AV junctional ablations, with 95% success and 1.3% complication rates. There were two procedure-related deaths (0.125%). In summary, the radiofrequency technique appears to be safer and is as effective as direct current shock. Late sudden cardiac death has been reported after radiofrequency ablation (for accessory pathways) (5); the overall incidence is unlikely to exceed that observed after direct current shock ablation (4,14) and may in fact be the expected rate in the patient population studied. Use of radiofrequency energy obviates the need for general anesthesia during the ablative procedure.

**Results of catheter ablation of accessory AV connections.** The worldwide experience using direct current ablation or destruction of accessory AV connections has been summarized (2,4). The largest reported series using direct current ablation was reported by Warin et al. (15), who reported a 96% success rate in 246 consecutive patients. Significant complications included a 2% incidence of cardiac tamponade and a 2% incidence of sudden death; four patients required permanent cardiac pacemakers (15).

Radiofrequency energy has largely supplanted high energy direct current shocks for ablation of accessory AV connections (1,2,5,6,16-20). Of 787 patients (1,2) who underwent attempted radiofrequency ablation of accessory AV connections, the reported success rate (defined as ablation of pathway function and tachycardia control without medications) ranged from 88% to 99%. Significant acute complications included coronary artery spasm in three patients, with myocardial infarction in one. Two patients had aortic valve damage, and three had cardiac tamponade requiring pericardiocentesis. Three instances of AV block were reported in attempted ablation of septal accessory pathways. Clots in either the right or left atrium appear to be very infrequent, and only one systemic and one pulmonary embolus has been reported. The incidence of emboli appears to be relatively low whether or not postprocedural anticoagulants are used. For left-sided pathways, retrograde and transseptal approaches appear to be comparable and complementary (20). The 1992 NASPE survey (6) reports success rates of 91% in 2,527 left free wall pathways, 87% in 1,279 septal pathways and 82% in 715 right free wall pathways; overall complication and death rates were 2.1% and 0.2%, respectively. Radiofrequency ablation of accessory pathways has also proved cost-effective (21).

**Results of AV node modification in patients with AV node reentrant tachycardia.** Initial reports described the use of high energy direct current discharges in patients with AV node reentry (22,23). Efficacy in terms of tachycardia cure was ~85%, but the procedure was associated with a 5% to 10% incidence of AV block in the initial reports. Selective ablation of the slow AV node pathway appears to reduce the risk of complete AV block to ≤2% to 3% (6). More recently, other groups have described using radiofrequency energy for AV node modification (5,24-31). Jackman et al. (24) demonstrated successful ablation of the slow pathway in 78 of 80 patients with symptomatic AV node reentrant tachycardia guided by identification of a slow pathway electrogram potential. Wathen et al. (25) were successful in another 25 patients using an anatomically guided approach with radiofrequency ablation in the corridor of the perinodal region between the tricuspid annulus and the orifice of the coronary sinus. Successful modification was defined as completed ablation or modification of either fast or slow AV node conduction.
resulting in tachycardia cure without producing third-degree AV block. The procedure was found to be successful in 85% to 99% of patients. The chief complication reported was induction of complete AV block which, as in other series (28), occurred much more frequently in those patients who underwent attempted fast pathway ablation. The 1992 NASPE survey (6) included 3,052 patients undergoing slow pathway ablation, with success in 96% and successful fast pathway ablation in 96% of 255 patients. Overall complications were 0.96%, and no procedure-related deaths were reported.

**Atrial tachycardia and flutter.** In the NASPE survey (6) the success rate was 75% in 371 patients with atrial tachycardia and flutter. The majority of the successes were due to elimination of these arrhythmias, and the remainder included control of the ventricular rate by AV node modification or ablation. There was a 0.81% complication rate and no reported deaths.

Chronic atrial tachycardia frequently leading to cardiomyopathy has been successfully and permanently eradicated by radiofrequency catheter ablation in 12 young patients (32). Successes are being reported in ablations for atrial (5,33,34) and sinus node tachycardias (5,34) in adults.

Radiofrequency catheter ablation has successfully terminated and prevented arrhythmia reinduction in the presence of type I atrial flutter in humans (5,35). In these subjects an area of slow conduction in the low posteroseptal right atrium was directly ablated. In some patients, activation mapping of atrial flutter revealed a counterclockwise reentrant wavefront originating just inferior or posterior to the coronary sinus ostium, proceeding superiorly in the atrial septum to the right atrial free wall, inferiorly toward the tricuspid annulus and, finally, medially between the inferior vena cava and tricuspid annulus. The ablation sites were located just inferior or posterior to the coronary sinus ostium and were characterized by discrete electrograms before the P wave (35).

**Ventricular tachycardia.** Several reports (6,36-41) have described the success of radiofrequency current catheter ablation in patients with sustained ventricular tachycardia. In addition to coronary artery disease-related ventricular tachycardia, this technique has been used in patients with sustained ventricular tachycardia in the presence of bundle branch reentrant tachycardia (37,38) right ventricular outflow tract tachycardia (39) and other idiopathic ventricular tachycardias (40,41).

In the NASPE survey (6) there were 429 patients with ventricular tachycardia with a successful ablation rate of 71% overall; 85% in 224 with structurally normal hearts; 54% in 115 with ischemic disease; and 61% with idiopathic cardiomyopathy. Complications occurred in 3%, with no reported deaths.

**Clinical Applications**

Catheter ablation of the AV junction is currently considered the procedure of choice for patients with drug-resistant atrial fibrillation and poorly controlled ventricular rates, unless primary ablation of the tachycardia focus is possible. Similarly, catheter ablation of the accessory AV connection is the procedure of choice for patients with drug-resistant accessory pathway-mediated tachycardias. The remarkable efficacy and safety of the latter procedure allowed extension of its use for patients with symptomatic tachycardias (involving an accessory connection) who refuse long-term dependence on drug therapy or have drug intolerance. Catheter modification of the AV node is the procedure of choice for patients intolerant to drugs or with drug-resistant AV node reentrant tachycardia and may be used in preference to long-term dependence on drug therapy for symptomatic patients with AV node reentry. This procedure is clearly preferable to surgery in terms of risk, expense, pain and other discomfort. With the further refinements in catheter mapping, radiofrequency ablation for atrial and ventricular tachyarrhythmias is now possible.

These recommendations are supported by a recent state of the art statement by the Subcommittee on Electrocardiography and Electrophysiology of the American Heart Association (42), a NASPE policy statement of which this is an update (1), peer-reviewed published reports (43,44 [and many others, see References]), extensive survey data (6) and major textbooks of cardiology (45-47).

**Comparison With Other Techniques or Procedures**

Alternative therapy includes use of drugs for tachycardia control, antitachycardia pacing, implantable cardioverter-defibrillators and direct cardiac surgical ablation. Heretofore, cardiac surgery has been considered the treatment of choice for patients with drug-resistant supraventricular arrhythmias (48,49). Cardiac surgery is very effective but requires an open heart procedure, a hospital stay of 5 to 8 days and prolonged convalescence until complete recovery is achieved. Catheter ablation is preferable to surgery in patients with drug-resistant arrhythmias arising from atrial tissue because it is associated with lower immediate morbidity and mortality and costs much less than surgery. Catheter ablation in patients with accessory pathway-mediated tachycardia or AV node reentrant arrhythmia is curative and thus obviates long-term need for drug therapy. The catheter approach involves a short hospital stay, after which the patient resumes normal activities. The hospital stay can be ≤ 1 day in ideal cases, although this is not yet typical because newly diagnosed and complex cases and those that require monitoring during drug washout or next-day confirmation electrophysiologic studies all may require a longer hospital stay.

Drug therapy in patients with resistant arrhythmias who require multiple drugs may be expensive, especially when factor over the projected life of younger patients, and are often associated with adverse effects. Many of the available drugs are not suitable for pregnant women because of the potential for teratogenic effects. Drugs often require meticulous attention to proper timing and dosage because missing or
altering a single dose may place the patient at risk for recurrent arrhythmias, and many patients are averse to long-term dependence on drug therapy. Antitachycardia pacing is seldom used today for treatment of supraventricular tachycardias because 1) it does not eliminate the arrhythmia, and patients remain symptomatic from their arrhythmias or during pacing-induced termination; 2) it tends to become ineffective during long-term follow-up (50); and 3) application of antitachycardia pacing puts the patient at risk for induction of atrial fibrillation or atrial flutter, which may result in life-threatening arrhythmias for patients with Wolff-Parkinson-White syndrome.

Cost Considerations

Catheter ablation is cost-effective (21,25). Most supraventricular tachycardias involve a brief hospital stay in a unit with electrocardiographic monitoring facilities. Initial diagnostic and, in some patients, follow-up studies to document successful ablation are also required and may be performed at a referring institution. The total cost of the ablative procedure itself, including the physician fee, ranges from $12,000 to $18,000. This is approximately one-third the total cost of surgical treatment (51).

The length of the ablative procedure, including electrophysiologic assessment, averages 3 to 6 h but can take >12 h. Considering the training, expertise and time required for catheter ablation, the physician compensation is substantially less than current rates for comparable interventional techniques, such as coronary balloon angioplasty. It should be further emphasized that there is a >90% rate of permanent cure with the most commonly used catheter ablative procedures (AV junctional modification and accessory pathway ablation).

Unanswered Questions and Future Research

Future research will involve development of better mapping techniques and catheters with better electrode configurations and improved steerability to allow easier access to sites of accessory AV connections. In addition, future clinical and research efforts will focus on refinement of radiofrequency energy; additional energy sources; more effective ablation of arrhythmias, such as ventricular tachycardia, to improve the safety and efficacy of these procedures; and extension to other arrhythmias, including atrial fibrillation. The potential long-term risks of radiation exposure sometimes required for lengthy procedures need to be more fully assessed (52,53).

There is need for long-term surveillance of efficacy and safety of patients undergoing catheter ablation, just as there is for other forms of therapy, including drugs, surgery and devices.

Personnel

Physicians. The minimal requirements for physician performance of catheter ablation procedures include completion

of training for electrophysiology board eligibility. Extrapolating from published guidelines for general training in clinical electrophysiology (54) and the NASPE and ACC committees were in accord that the physician should have been the primary operator for a minimum of 30 catheter ablation procedures, including at least 15 accessory AV connection ablations.

It was considered desirable that two physicians be involved in complex catheter ablation procedures, particularly those involving ablation of accessory pathways or ventricular tachycardia. The second physician need not be a trained electrophysiologist but should be adept in catheter manipulation and treatment of cardiac emergencies. A cardiologist or electrophysiologist postdoctoral fellow or specially trained registered nurse or physician assistant could fill this role.

To ensure good quality and continued competence, 1) the committees considered that the physician should perform ≥20 ablative procedures/year, an impression backed by data from the NASPE survey (6) showing a significantly higher complication rate in centers performing <20 ablations/year. Anticipated success rates should be at least 80% for AV junctional ablation, AV node modification for AV node reentry and accessory pathway ablation. The success rate for ventricular tachycardia should be at least 30% but is highly dependent on patient selection.

Laboratory personnel. Laboratory personnel should include two nurses (or technicians). One nurse (or physician assistant) is required to administer sedation and carefully monitor vital signs throughout the procedure. The NASPE and ACC committees considered that ablation procedures should only be performed in centers with ready availability of cardiac surgical support and percutaneous transluminal coronary angioplasty teams. It was considered that a cardiac surgeon or anesthesiologist need not be present but should be available for emergencies. It is not necessary to perform these procedures in the operating room.

Facilities and equipment. Ablative procedures should be performed in a facility set up for invasive electrophysiologic studies. The minimal standards for X-ray equipment should constitute a rotatable C arm or table with good quality X-ray image. A video recording system for fluoroscopic images is recommended. Biplane X-ray equipment is considered to be desirable but not absolutely necessary. State of the art roentgenographic equipment is favored to minimize radiation exposure, and duration of radiation should be carefully logged for all procedures. It was considered that the laboratory should establish guidelines for total radiation exposure for these procedures (52,53). A recent study showed that the highest exposure of radiation was to the posterior ninth thoracic vertebral body, which received an average of ~19 rads (52). Radiation experts consider that this degree of exposure would be associated with a lifetime excess risk of fatal malignancy of ~1/1,000 of dying of a malignancy during their lifetime. It should be noted that the background risk of dying of a malignancy is 200/1,000 for a 35-year old person. This level of risk was thought to be lower than the risk of alternative medical or surgical treatment (52). The laboratory should be
equipped to care for patients with acute coronary complications (e.g., thrombus, coronary artery spasm, cardiac tamponade, coronary dissection). In addition, facilities for both temporary and permanent pacemaker insertion should be available.

It is recommended that the devices used for such ablation procedures be utilized in a manner conforming to hospital, local and national regulations governing their application.

**Recommendations**

1. Catheter ablation of the AV junction is recommended as the procedure of choice in patients with drug-intolerant or drug-resistant symptomatic atrial tachyarrhythmias and uncontrolled ventricular rates, when complete AV block is the therapy of choice.

2. Catheter ablation of accessory pathway or pathways is the treatment of choice in patients with drug-intolerant or drug-resistant AV node reentrant tachycardia.

3. Catheter modification of the AV junction, particularly using the slow pathway approach, is the treatment of choice in patients with drug-intolerant or drug-resistant AV node reentrant tachycardia.

4. These procedures are also recommended as alternative therapy in patients with symptomatic drug-intolerant or drug-resistant atrial, sinoatrial and ventricular tachyarrhythmias.

In all four categories, ablation is recommended as therapy in patients who desire avoidance of long-term drug therapy. As these procedures continue to evolve they may become a treatment of choice for initial therapy or an alternative early treatment choice for many patients with these arrhythmias.

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**References**


