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Cardiac ablation: A therapeutic perspective

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CARDIAC ABLATION: A THERAPEUTIC PERSPECTIVE

By

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Abstract

Excitable groups of cells within the human heart can cause premature or abnormal heart beats which can further develop into dangerous, arrhythmias. Cardiac Ablation is a newer therapeutic method developed to treat these various types of arrhythmias. The American Heart Association defines cardiac ablation as, "a therapeutic method used to destroy a small section of heart tissue causing abnormal electrical activity or irregular heartbeat." Ablative therapy has become the preferred method of treatment for several arrhythmias such as AV nodal reentrant tachycardia (AVNRT), atrioventricular reentrant tachycardia (AVRT), focal atria tachycardia, and atrial flutter (AFL). Ablative techniques are also being used and tested for their efficacy in treating more complicated arrhythmias such as atrial fibrillation (AF) and ventricular tachycardia (VT). This study will analyze cardiac ablation techniques and compare its treatment efficacy to traditional or pharmaceutical forms of treatment for these specific arrhythmias.

Introduction

The primary role of the human heart is to pump blood and nutrients throughout the entirety of the body. This is made possible by excitable groups of cells within the heart that control the contraction rate of the four heart chambers: right atrium, left atrium, right ventricle, and left ventricle. These excitable cells make up the conduction system of the heart; they function by transmitting electrical impulses beginning at the sinoatrial node (SA node) throughout the atria to the atrioventricular node (AV node). The AV node holds the impulse for a fraction of a second allowing time for the atria to contract and force blood into ventricles. From there, the impulse travels down the His-Purkinje system and spreads throughout the ventricles inducing a heart contraction also known as a heartbeat. Normal Sinus Rhythm describes the normal heart rate and rhythm of the heart in which the electrical impulse follows the exact path described above resulting in a heart rate between sixty and one hundred beats per minute (60-99 bpm). Any change or variation in the normal sequence/timing of the electrical conduction system is described as an arrhythmia, (American Heart Association [AHA], 2015).

There are many different types of arrhythmias, or abnormal heart beats, with varying levels of severity and persistence. Some can be short-lived (i.e. a premature beat) and have a very small effect on the heart's overall rhythm whereas others may be long-lasting/permanent and result in significant reductions in the volume of blood pumped by the ventricles per minute known as cardiac output (Q). This can be dangerous because when Q is decreased, organs in the body may not receive a sufficient supply of blood which can lead to them to be damaged or shut down entirely. Some common types of arrhythmias include bradycardia (slow heart rate), tachycardia (fast heart rate),

conduction disorders (within the AV junction and bundle branches), premature contractions, and atrial/ventricle dysrhythmias. The type of arrhythmia can often be diagnosed by analyzing abnormalities that take place during an electrocardiogram (ECG). An ECG assesses the electrical conduction system of the heart, (AHA, 2015).

Treatment methods for arrhythmias are also highly variable ranging from drug therapy to invasive surgery depending on the type and severity of the arrhythmia. A relatively newer form of treatment for some arrhythmias is cardiac ablation. The AHA defines cardiac ablation as, "a therapeutic method used to destroy a small section of heart tissue causing abnormal electrical activity or irregular heartbeat," (AHA, n.d.). The ablation technique is a two-step process; first, the site of abnormal activity must be identified using electrode catheters inserted through blood vessels and positioned inside the heart. This step is referred to as cardiac mapping. Second, the abnormal tissue is destroyed via radiofrequency ablation, a form of heat energy, or cyroablation, extremely cold temperatures, delivered through a catheter to the site of abnormal tissue, (Tedrow, Asirvatham, & Stevenson, 2011). This study will analyze cardiac ablation treatment techniques and compare its treatment efficacy to traditional or pharmaceutical forms of treatment.

Literature Review

The first cardiac ablation was performed on humans in 1981 using a high energy direct current (DC) shock to destroy the abnormal tissue. The DC shock created a high voltage form of energy that lacked both precision and control. Radiofrequency (RF) cardiac ablation was developed shortly after. RF cardiac ablation uses a low-voltage form of energy thus enhancing the safety and applicability of the cardiac ablation technique.

Cyroablation was the most recently developed; it destroys the abnormal tissue by delivering temperatures from -60°C to -80°C to the target area. Other methods that utilize acoustic and laser technology to destroy the abnormal tissue are currently under consideration and testing. Both RF cardiac ablation and cyroablation are commonly used today, (Hassett, Swartz, & Bednarek, 2001; Tedrow et al., 2011).

For the ablative therapy to be successful, the arrhythmia must be correctly diagnosed and precisely mapped. When possible, arrhythmias can be correctly diagnosed through ECG monitoring; however, ECG monitoring cannot always capture short-term, non-persistent arrhythmias. In this case, diagnostic electrophysiological studies (EPS) are necessary to ensure accurate diagnosis. During diagnostic EPS, the heart is electrically stimulated to induce the abnormal, symptomatic arrhythmia so that it can be captured and diagnosed. Furthermore, diagnostic EPS can provide conduction information detailing SA nodal, AV nodal, and His-Purkinje functioning. Once diagnosed, the origin of the arrhythmia must be mapped to ensure proper catheter positioning during the ablative procedure, (Tedrow et al., 2011).

For cardiac mapping of an arrhythmia, both fluoroscopy, an internal body imaging technique, and other complex mapping systems are utilized to aid in proper catheter placement. Mapping systems provide real-time three-dimensional images of the cardiac anatomy, in addition to catheter positioning and electrophysiological information about the tissue. In some cases, MRI, CT, and echocardiographic data are also required to assist catheter placement and mapping, (Tedrow et al., 2011). After the catheters have been properly placed, the erratic cells can be destroyed.

According to Bashore, Granger, Jackson, & Patel (2016), cardiac ablation has proven both safe and effective with a rate of procedural complications ranging from one to five percent. The most common risks associated with the procedure are related to the catheterization process leading to damage of the vascular system with occurrences at a rate of two percent. Although there is a very low-risk, other possible complications include pericardial tamponade, cardiac perforation, AV nodal damage, heart valve damage, coronary artery damage, and systemic embolization, (Bashore et al., 2016; Tedrow, et al., 2011).

Cardiac ablation has already become the primary form of treatment for several different arrhythmias, most commonly, various types of supraventricular tachycardias such as AV nodal reentrant tachycardia (AVNRT), atrioventricular reentrant tachycardia (AVRT), focal atria tachycardia, and atrial flutter (AFL). Ablative techniques are also being used and tested for their efficacy in treating more complicated arrhythmias such as atrial fibrillation (AF) and ventricular tachycardia (VT), (Bashore et al., 2016).

In general, supraventricular tachycardia (SVT) describes several different abnormal heart rhythms in which premature atrial depolarizations arise from an ectopic stimulus somewhere in the atria or atrioventricular nodal tissue. Types of SVT arising in the atria include sinus tachycardia, inappropriate sinus tachycardia, sinus nodal reentrant tachycardia, focal atrial tachycardia, multifocal atrial tachycardia, AFL, and AF. Types of SVT arising in the atrioventricular nodal tissue include AVNRT, AVRT, junctional ectopic tachycardia, and non-paroxysmal junctional tachycardia. Most forms of SVT are triggered by an electrophysiological mechanism known as reentry. In reentry, a propagating impulse continually re-stimulates the heart creating a reentrant circuit. The

exact reentrant path, severity, symptom manifestation, and treatment strategy are widely variable depending on the specific type of arrhythmia, (Gugneja & Kraft, 2015).

The most common type of paroxysmal (sudden onset) SVT is AVNRT with a prevalence of fifty to sixty percent in patients presenting with narrow QRS complexes, (Gugneja & Kraft, 2015). AVNRT is so-named because the reentrant circuit takes place within the AV nodal tissue. As a result, heart rate increases and typically ranges from 140-250 beats per minute (bpm). Despite the increase in speed, the heart rate remains regular and constant. Although typical symptoms associated with AVNRT include angina, shortness of breath, palpitations, and lightheadedness, other cases may present as asymptomatic. Incidences may be short-term, lasting only a few brief seconds or long-term, lasting several hours/days. AVNRT can be identified on an ECG (Figure 1) by the lack of identifiable p-waves which become lost in the preceding beat; QRS complexes will appear at a constant, rapid rate and may present as more narrow than normal. Still, diagnostic EPS are generally essential for an accurate diagnosis, (Bashore et al., 2016).

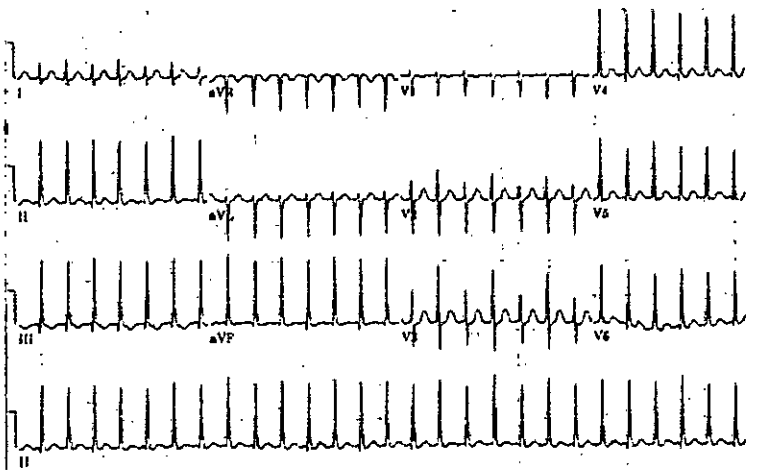

Figure 1. AV Nodal Reentrant Tachycardia (http://www.cardiacedu.com /ecg/avnrt.jpg). The figure above is an example ECG for AVNRT demonstrating a regular, tachycardic rhythm with unidentifiable p-waves.

The mechanism of AVNRT onset (Figure 2) is made possible due to structure of the AV nodal conduction system. In most people, the AV node consists of two pathways connecting the atria to the ventricles, a slow pathway and a fast pathway, (Tedrow et al., 2011). AVNRT is triggered by a premature atrial contraction. When the premature stimulus reaches the AV node, the slow pathway may be ready to conduct but the fast pathway may still be in recovery period from the previous contraction and unable to conduct. If this occurs, the slow pathway will conduct the stimulus like normal in an anterograde fashion during which time the fast pathway is still recovering. By the time the conduction makes it through the slow pathway to the ventricles, the fast pathway may be fully recovered and carry on the conduction in an anterograde fashion, from ventricles to atria. By the time the conduction makes it through the fast pathway to the atria, the slow pathway may be fully recovered and the conduction can reenter the slow pathway creating the tachycardic reentrant circuit, (Gugneja & Kraft, 2015).

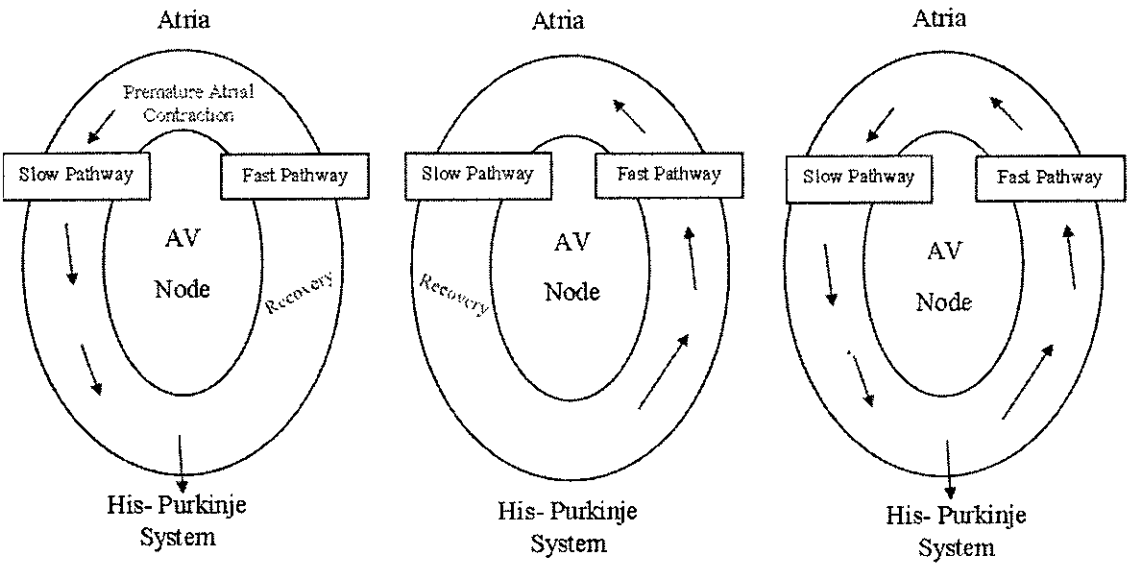

Figure 2. AVNRT Reentry Mechanism. The image on the left represents the premature contractile trigger, with only the slow pathway ready to pass on the anterograde conduction. The middle image represents retrograde conduction through the fast pathway. The image on the right represents the full tachycardic reentrant circuit.

Treatment of AVNRT requires interruption of the AV nodal reentrant circuit. Current available treatments that aim to end the AVNRT episode include mechanical maneuvers, drug therapy, and cardioversion. Because of their low risk, mechanical maneuvers are usually the first treatment method attempted. Mechanical maneuvers aim to increase vagal tone thereby ending the tachycardic episode. Both the Valsalva maneuver and carotid sinus massage are commonly used, (Bashore et al., 2016).

The Valsalva maneuver is an action in which the patient attempts forced expiration with a closed glottis; as a result, intrathoracic pressure rises. At the onset of straining, blood pressure increases due to the added intrathoracic pressure; however, continued straining results in compression of the veins, decreased blood pressure, decreased cardiac output, and inhibition of baroreceptors. Then, once the glottis is reopened, both intrathoracic pressure and cardiac output return to normal levels, but the

blood vessels remain constricted due to the previously inhibited baroreceptors. The constricted vessels cause an increase in blood pressure which in turn stimulates the baroreceptors to lower the heart rate and blood pressure ending the tachycardic rhythm, (Barrett, Barman, Boitano, & Brooks, 2016). Carotid massage is usually performed by a physician while the patient's blood pressure and EKG are being closely monitored. The technique involves rubbing of the one of the carotid arteries, located on both sides of the neck, for 5 to 10 seconds where it divides into two main branches, the internal and external carotid artery. Like the Valsalva maneuver, this increases blood pressure which then stimulates the arterial baroreceptors to lower heart rate and blood pressure ending the tachycardic rhythm, (carotid sinus massage, n.d.).

If mechanical attempts are unsuccessful, drug therapy is the next mode of treatment. The class of drug chosen for treatment is highly dependable on patient history and symptom information; however, adenosine, calcium channel blockers, and beta blockers are all commonly prescribed. Verapamil and diltiazem are calcium channel blockers utilized to block conduction through the AV node thus ending the AVNRT episode. Adenosine also functions to block conduction through the AV node. In contrast, beta blockers antagonize the effects of sympathetic nerve stimulation and prolong AV conduction thereby decreasing heart rate and ending the AVNRT episode. Although drug therapy can be highly effective, it can also be unpredictable and have proarrhythmic effects. In cases where drug therapy is unwarranted, cardioversion is a highly successful and viable treatment option. Although all three of these strategies may be successful in ending the AVNRT episode, only drug therapy and ablation are permanent, preventative measures, (Bashore et al., 2016).

Due to the side-effects of anti-arrhythmic drugs and high risk associated with long-term drug therapy, cardiac ablation has been established as the preferential method of treatment. Furthermore, the anatomy and dual conductive capacity of the AV node make the ablative technique highly successful, (Gugneja & Kraft, 2015). The AV node is made up of a dense center that connects the atria to the bundle of HIS and two or three other lobes that project outward to spread the conduction. One of the lobes, extending from the os of the coronary sinus to part of the tricuspid valve, forms the slow conduction pathway. As described above, the slow conduction pathway is the location of reentry triggering AVNRT. It is positioned so that it can be ablated without damaging all transmission through the AV node leaving normal heart functioning in-tact once the erratic tissue is destroyed, (Tedrow et al., 2011).

The largest risk associated with the procedure is complete blockage of the AV conduction system leaving the heart unable to function on its own and requiring pacemaker implantation. Hindricks (1996) assessed this risk level and concluded there was a 5 percent risk of complete AV block during a RF ablative procedure for AVNRT. Another study, (Hanninen et al., 2013) found cyroablation to be an extremely successful method of AVNRT treatment. Their results indicated 0% of the patients treated with cyroablation to have permanent AV block compared to the 0.8% treated with RF ablation (n=1066) making it especially beneficially in the case of children and young adults where risk of complete AV block is particularly large. However, additional results concluded there is a larger prevalence of reoccurrence with cyroablation when compared to RF ablation ($P = 0.0002$). Comparing the efficacy of drug therapy to ablative therapy,

ablation is the preferred method of treatment for AVNRT with a success rate greater than 95 percent, (Tedrow et al., 2011; Gugneja & Kraft, 2015).

AVRT, the second most common paroxysmal SVT, has an incidence rate of 0.1 – 0.3 percent and male-to-female ratio of 2:1, (Gugneja & Kraft, 2015). Like AVNRT, AVRT is made possible due to the nature of the duel conduction system; however, unlike AVNRT, only one conducting pathway follows the typical route through the AV node. The other pathway bypasses the AV node forming a secondary, accessory pathway from the atria to the ventricles indicative of Wolff-Parkinson-White Syndrome. By bypassing the AV node, anterograde conduction through the accessory pathway doesn't "pause" while the ventricles fill with blood. Therefore, the portion of the ventricles stimulated by the accessory pathway contracts before the rest of the ventricles. The presence of accessory pathways as seen in Wolff-Parkinson-White Syndrome is detectable on an ECG by the presence of a short PR interval and delta waves (Figure 3). The delta waves are indicative of the premature partial ventricular stimulation. If the accessory pathway conducts in a retrograde fashion, it cannot be detected on an ECG during normal sinus rhythm; these pathways are called concealed accessory pathways, (Gugneja & Kraft, 2015; Tedrow et al., 2011).

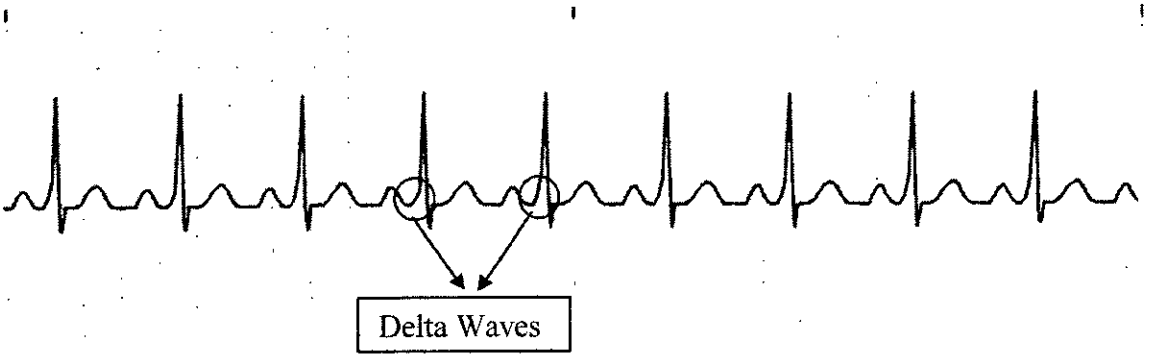

Figure 3. Wolff-Parkinson-White-Syndrome (2014). The ECG above exhibits a shortened PR interval with the presence of delta waves as a result of the premature ventricular contraction triggered by the accessory pathway.

Similar to the mechanism of AVNRT, a premature atrial contraction can create a reentrant circuit through the accessory pathway triggering an episode of AVRT. In orthodromic AVRT, the reentrant circuit consists of anterograde conduction through the AV node and retrograde conduction through the accessory pathway. In this case, ECG readings demonstrate narrow QRS complexes often without any detectable p waves or inverted p waves (Figure 4). Less common is antidromic AVRT in which the reentrant circuit consists of retrograde conduction through the AV node and anterograde conduction through the accessory pathway producing wide, bizarre QRS complexes on an ECG (Figure 5). (Gugneja & Kraft, 2015).

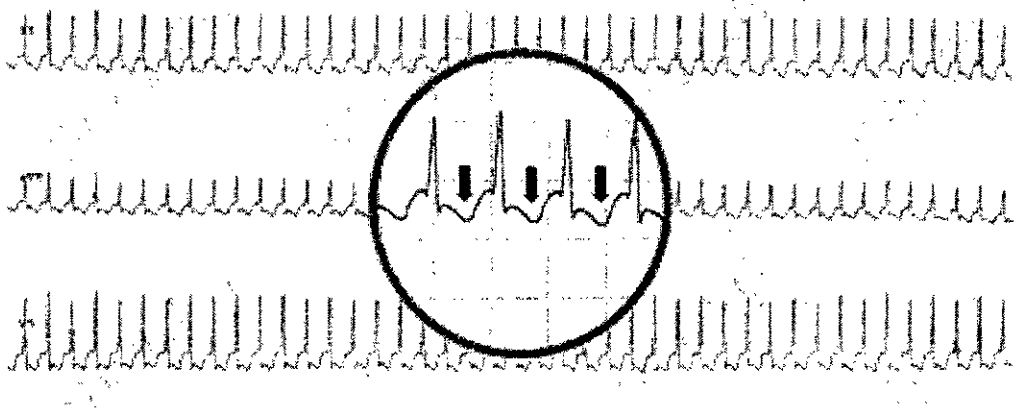

Figure 4. Orthodromic AVRT (http://en.my-ekg.com/arrhythmias/supraventricular-tachycardias.html). The above ECG represents a tachycardic arrhythmia with inverted p waves (arrows) and narrow QRS complexes indicative of orthodromic AVRT.

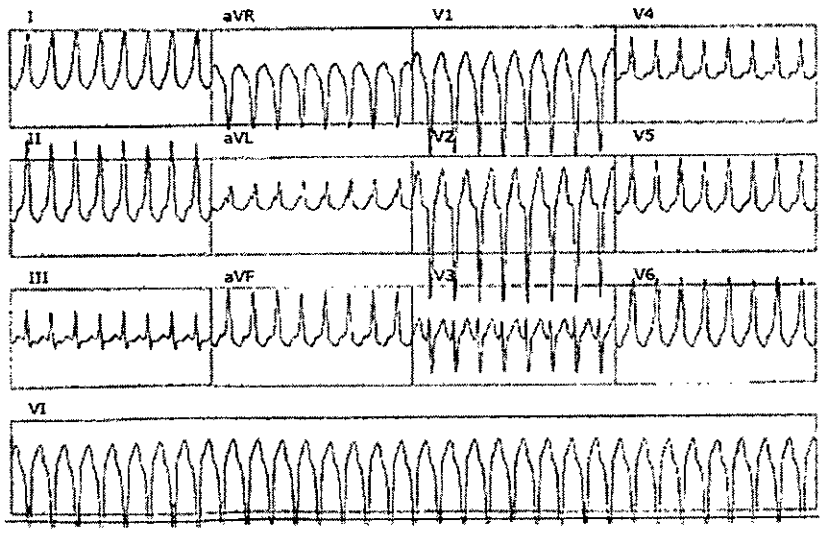

Figure 5. Antidromic AVRT (2011). The above ECG represents a tachycardic arrhythmia with no visible p waves and abnormal, misshapen QRS complexes indicative of antidromic AVRT.

Common symptoms of AVRT include lightheadedness, syncope, and palpitations. Because of the extremely fast rate the accessory pathway is able to conduct a stimulus, patients with AVRT are at a high risk for entering atrial flutter or atrial fibrillation which can further develop into ventricular fibrillation or sudden death, (Gugneja & Kraft, 2015).

Risk factors for AVRT include male gender, age < 30, and history of AF or congenital heart disease (CHD). Unless there is reason to believe there is poor conduction through the accessory pathway, in which case drug therapy may be a plausible from of treatment, patients with AVRT are at a high risk of unpredictable cardiac death and must undergo ablative therapy. For cases in which drug therapy is warranted, the goal is to slow conduction through the accessory path and AV node. To slow conduction through the accessory path, common medications prescribed include class I agents, or sodium channel blockers. Class Ia drugs, i.e. quinidine, slow the rate during the depolarization phase of conduction whereas class Ic drugs, i.e. flecainide, slow the rate during the repolarization phase of conduction. To slow conduction through the AV node, prescription is similar to that of AVNRT including, class II agents, or beta blockers, and class IV agents, or calcium channel blockers, (Bashore et al., 2016).

Ablative therapy of AVRT targets the accessory pathway. Diagnostic EPS are often required to both confirm the direction of conduction and determine the precise location of the accessory pathway. Most commonly, accessory pathways are found traversing through the tricuspid valve, mitral valve, or septum. The success rate of the procedure is approximately 95 percent. A common complication of the procedure is reappearance of conduction through the accessory pathway due to healing of the ablated tissue occurring at a rate of 3 – 10 percent. Other possible rare complications include AV block, cardiac tamponade, and hematoma formation, (Tedrow et al., 2011). In most cases, ablation is a superior treatment strategy compared to drug therapy and the preferred method of treatment for AVRT.

Focal atrial tachycardia (AT) describes an abnormal arrhythmia beginning within the atrial musculature creating a rapid heart rate between 150-250 bpm. Incidence rates are approximately 2 percent in healthy, young adults and as high as 13 percent in the elderly, (Prystowsky, Padanilam, & Waldo, 2011). Cases of focal AT may be spontaneous, short episodes or persistent, chronic episodes. Three possible mechanisms that trigger the tachycardic episode include abnormal automaticity, externally triggered activity, or localized reentry. Pharmacological therapy is a possible treatment strategy, but not always effective; it is generally only used for infrequent, short-term cases, (Prystowsky et al., 2011).

Ablation has become the standard form of treatment for focal AT with a success rate greater than 80 percent, recurrence rate of 8 percent, and a complication rate of 1 to 2 percent. There is a wide range of possible origination locations including the tricuspid or mitral region, coronary sinus musculature, atrial appendages, and pulmonary veins. As a result, the appearance of focal AT on an ECG can be highly variable; therefore, the tachycardia must be present or provocable for accurate mapping and catheter placement to be possible (Tedrow et al., 2011).

Atrial flutter (AFL) is an abnormal rhythm of the heart where the atria (upper chambers) fire at rapid rate (240-340 beats per minute). The atria are essentially "twitching", and many of the impulses don't reach the AV node resulting in an irregular ventricular heart rate. Most commonly, conduction from the atria continues through the AV node 50 percent of the time resulting in a ventricular rate around 150 bpm. AFL can be identified on an ECG (Figure 6) by the presence of flutter waves which appear saw-toothed and jagged (Gugneja & Kraft, 2015).

Figure 6. Atrial Flutter (2013). The ECG above contains flutter waves separated by consistent, rapid QRS complexes characteristic of AFL.

Common symptoms of AFL include a tachycardia, angina, dyspnea, dizziness, lightheadedness, syncope, and heart palpitations (AHA, 2014). AFL generally presents with other cardiac abnormalities such as hypertension, coronary artery disease, and sick sinus syndrome. Both acute and permanent cases of AFL can result in decreased blood pressure and myocardial ischemia; however, cardiomyopathy becomes a threat for more persistent cases of AFL. In addition, AFL may present as a transitional arrhythmia leading to atrial fibrillation or ventricular tachycardia, (Wellens, 2002).

There are two main types of AFL: Type I AFL and reverse typical flutter. Type I AFL is the most common. Like most supraventricular tachycardia arrhythmias, AFL is triggered by a reentry circuit. In type I AFL, the large reentrant circuit occurs in the right atrium conducting in a counterclockwise direction whereas in reverse typical flutter, the conduction follows the same path, but moves in a clockwise direction. Both types include the right atrial isthmus, the bridge between the tricuspid valve and the region around the inferior vena cava/coronary sinus, in the electrical circuit; this is a key component of the reentrant circuit. Other less common types of AFL include left atrial flutter, double wave reentry atrial flutter, lower loop reentry right AFL, and upper loop reentry right AFL, (Prystowsky et al., 2011).

Treatment strategies for AFL include drug therapy, cardioversion, and ablation. When an episode of AFL occurs, the first step is to terminate the tachycardic rhythm. For temporary termination of AFL, class III drugs such as ibutilide, dofetilide, azimilide, and sotalol are most frequently used. In addition, cardioversion has proven safe and successful at terminating AFL in over 90% of incidents; however, it doesn't prevent reoccurrences. To prevent further reoccurrences of AFL by inhibiting premature atrial beats, Amiodarone and Class I drugs are the most efficacious. Due to the possible side-effects associated with pharmacological therapy, including pro-arrhythmic effects and abnormal cardiac and kidney functioning, ablation is preferred method of long-term treatment, (Wellens, 2002).

Both RF ablation and cyroablation have been proven safe and effective forms of treatment for AFL. Currently, RF ablation is the most typical treatment for AFL; the standard treatment uses endocardial activation mapping to localize the circuit. The ablative technique attempts to create a bi-directional block of the improper circuit thereby terminating the arrhythmia, (Spitzer, Karolyi, Rammler, & Otto, 2002; Wellens, 2002). When incorporated in the circuit, the right atrial isthmus is the most common ablated site due to its 95 percent success rate making it significantly more effective than drug therapy (Tedrow et al., 2011). In a study by Manusama et al. (2004), the RF ablation technique was compared to cyroablation technique for success in treating common AFL. Their results also concluded cyroablation to be equally effective as RF ablation for both short-term and long-term treatment of AFL; furthermore, cyroablation is perceived to be less painful than the standard RF ablation technique. By demonstrating high success with low complication rates, cardiac ablation has become the standard method of AFL treatment.

Discussion

Ablative therapy has become the preferred method of treatment for several arrhythmias discussed above, but its uses are still being tested and developed for more complicated arrhythmias. Atrial fibrillation (AF) is one such arrhythmia. AF describes an arrhythmia in which, like AFL, the atria are essentially twitching at a rapid rate of 300 to 600 bpm. As a result, the ventricular rate is also rapid, 150-300 bpm, and irregular. The appearance of the ECG reflects these abnormalities (Figure 7); the baseline appears wavy and irregular representing the rapid atrial electrical activity with QRS complexes intermittent and very erratic.

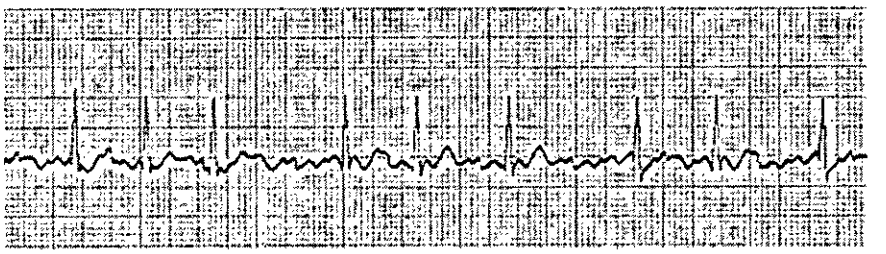

Figure 7. Atrial Fibrillation (2013). The above ECG exhibits a wavy, irregular baseline with intermittent QRS complexes indicative of AF.

AF is the most common chronic arrhythmia effecting 2.2 million to 5 million Americans with a prevalence of 0.4 percent in the general population and as high as 8.8 percent in the elderly (greater than 80 years old), (Prystowsky et al., 2011). Although AF can develop in an otherwise healthy heart, "it is commonly associated with rheumatic heart disease, hypertension, ischemic heart disease, pericarditis, thyrotoxicosis, alcohol intoxication, disorders of the mitral valve, and digitalis toxicity," (Gugneja & Kraft, 2015). AF alone is rarely fatal; however, due to the atrial inactivity, patients with AF are at a higher risk of embolism formation leading to a stroke then the general population. In addition to AF, the presence of five other risk factors help predict risk of stroke:

congestive heart disease, hypertension, age over 75, diabetes, and previous stroke history. According to Bashore et al. (2016), patients with AF in addition to multiple other stroke risk factors have a substantial 20 percent risk of stroke development compared to a 2 percent chance in patients with no other risk factors. Other possible consequences of AF include hypotension, increased dementia risk, decreased cardiac output, hemodynamic collapse, myocardial ischemia, and tachycardia-induced myocardial dysfunction, (Bashore et al., 2016; Michaud & Stevenson, 2015).

Despite some discrepancy, cases of AF are usually classified into one of three broad categories: paroxysmal, persistent, or permanent. Paroxysmal AF describes cases where AF episodes abruptly start and stop lasting for less than 7 days, though most cases end within the first 24 hours. Paroxysmal AF is typically triggered by rapidly firing ectopic cells or reentrant circuits located in the atrial musculature or pulmonary veins. High alcohol consumption or alcohol withdrawal are also known to trigger paroxysmal AF. In cases where AF lasts for longer than 7 days, it is categorized as persistent; persistent AF generally requires electrical or pharmacological cardioversion. When AF persists for over a year despite treatment attempts, it is categorized as permanent AF. The longevity of both persistent and permanent AF is most often due to single or multiple reentry circuits in addition to changes in the structure and anatomy of the atria to further support reentry and sporadic, random contraction. Loss of myofibrils, the contractile component of cardiac muscle, build-up of glycogen granules, and lack of cell-to-cell communication/regulation at gap junctions are all common atrial structural changes opposing return to sinus rhythm. Other terms used to classify AF include first-detected AF when only one episode has occurred, recurrent AF when two or more episodes have

occurred, and lone AF when episodes occur in a patient with no other cardiac disorder. Cases of AF may present as asymptomatic or symptomatic; palpitations, fatigue, anxiety, dyspnea, angina, and dizziness are all common symptoms, (Prystowsky et al., 2011; Michaud & Stevenson, 2015).

The initial strategy for AF treatment requires management of symptoms and lowering the risk of stroke or further complications associated with the arrhythmia. The next step is involves choosing a permanent rate or rhythm control strategy. Because of the variability in symptom manifestation, the form of symptom management is determined on a case to case basis. More often than not, strategies applied for controlling cardiac rate or rhythm are also effective in terminating AF symptoms. Anticoagulants are generally required for managing stroke risk. Warfarin, a vitamin K antagonist, is the typical drug of choice; it has been shown to decrease stoke risk by 60 to 80 percent in comparison to a placebo, (Prystowsky et al., 2011). Newer anticoagulation drugs with similar success to warfarin include dabigatran, rivaroxaban, and apixaban. The newer drugs are associated with less negative drug/food interactions, therefore tend to have a higher patient compliance than seen in patients prescribed warfarin. Despite the necessary, positive effects of anticoagulation therapy, long-term usage increases risk of hemorrhage and bleeding, (Prystowsky et al., 2011).

As stated above, either a rate or rhythm control strategy is required for long-term AF management. Several studies have shown no difference in success or mortality rates when comparing rate versus rhythm control strategies; therefore, the method of treatment is determined on a case to case basis. The goal of rate control is to decrease the ventricular rate to less than 100 bpm thus increasing cardiac output and alleviating

symptoms. Rate control strategies exist in two stages, acute and chronic. In the acute stage, either beta blockers or calcium channel blockers may be administered to decrease automaticity and prolong AV conduction. Depending on treatment urgency, the medications may be delivered orally or intravenously. In cases where beta blockers or calcium channel blockers alone are not sufficient in rate control, digitoxin may also be prescribed, (Prystowsky et al., 2011; Michaud & Stevenson, 2015).

When AF and associated symptoms persist regardless of drug therapy attempts, chronic rate control is essential. AV- nodal ablation resulting in complete heart block followed by permanent pacemaker implantation is the typical form of chronic rate control. Several studies (Kay et al., 1998; Brignole et al., 1997) found improved quality of life and ventricular functioning with the ablative-pacemaker method; however, the procedure is not without limitations. Because this method doesn't terminate the rapid firing of the atria, the procedure does not replace the need for anticoagulation therapy, and embolism formation still poses a major threat. In addition, this procedure is less appealing for younger patients due to the likelihood of life-long pacing dependency (Prystowsky et al., 2011; Michaud & Stevenson, 2015; Tedrow et al., 2011).

Rhythm control strategies, as the name suggests, aim to maintain sinus rhythm. This can be achieved through antiarrhythmic drugs, pharmacological cardioversion, direct current cardioversion, or cardiac ablation each method with its own risks and benefits. The method of therapy is chosen on a case to case basis depending on the symptoms, risks, and needs of the individual. Antiarrhythmic drug therapy can be successful, but also yields a high-risk for many side-effects; more than 20 percent of patient receiving long-term drug therapy develop toxicities, (Michaud & Stevenson,

2015). Therefore, drug therapy is not recommended in all cases, and the specific antiarrhythmic is chosen based on side effect risk for a particular patient profile.

Class Ic antiarrhythmic agents, such as sodium channel blockers, effect the purkinje fiber action potential by slowing repolarization. They have been shown to prevent AF episodes, but increase the risk of AFL development; therefore, they are avoided in patients with CHD or heart failure where AFL presents too high of a risk. In patients without other heart disease, they can be used in combination with beta-blockers or calcium channel blockers, but patients must still be highly ECG monitored. Class III agents, such as dronedarone, sotalol, dofetilide, block potassium channels thereby prolonging repolarization and slowing conduction. They can be useful for patients with other heart conditions; however, long QT syndrome, an over-elongation of the QT interval poses a threat requiring periodic ECG monitoring, (Prystowsky et al., 2011; Michaud & Stevenson, 2015; Bashore et al., 2016). The most successful antiarrhythmic drug in rhythm control is amiodarone, a class III agent. Two thirds of patients administered amiodarone maintain sinus rhythm compared to only 30 to 50 percent of patients who benefit from receiving the other antiarrhythmic agents, (Michaud & Stevenson, 2015).

Two forms of cardioversion have been used for rhythm control in AF patients, pharmacological and direct current. In both forms of treatment, the need for anticoagulation therapy needs to be addressed before the procedure. During the 48 hours after first-detected AF onset, risk of stroke is usually low and cardioversion is a plausible treatment technique. Because of the lowered risk of embolism formation during the first 48 hours, anticoagulation therapy is not usually needed preceding cardioversion except in

extreme high-risk cases. In contrast, cases where timing of AF onset is unknown or exceeds 48 hours, the risk of thromboembolism is higher. For cardioversion to be applicable, echocardiographic data must obtained to ensure no thrombus presence. Anticoagulation therapy may be necessary before or following cardioversion for weeks or longer depending on patient's stroke risk (Prystowsky et al., 2011; Michaud & Stevenson, 2015).

The final strategy for rhythm control is cardiac ablation. Ablative techniques aim to destroy the foci causing the rapid, erratic contractions; typical targets include both electrical triggers such as pulmonary vein foci and atrial muscular foci, and atrial substrate triggers such as fibrosis, hypertrophy, mutations of ion or gap junctions, and electromechanical remodeling, (Lubitz, Fischer, & Fuster, 2008). Since 1998 when ablative therapy was first attempted in treating AF, the technique has advanced from linear ablation, pulmonary vein isolation, and left atrial linear ablation to ganglionic plexus ablation, ablation of complex fragmented atrial electrocardiograms (CFAEs) and most recently, box isolation, (Kumagai, 2011). As stated above, the pulmonary veins have been identified as a common location for abnormal automaticity triggering AF making them a primary target for ablative therapy. Furthermore, the pulmonary vein – left atrium junction has been identified as a common location of reentry providing a system to maintain the arrhythmia. The autonomic tone of the ganglionated plexi that innervate the pulmonary veins and left atrium serves as a source of AF genesis thus the ganglionic plexi have also become a target for ablation, (Kumagai, 2011). Box isolation aims to terminate AF by isolating both the posterior left atrium and pulmonary veins; the posterior left atrium has been found to contain electrical triggers, reentry circuits,

ganglionated plexi, and other abnormal substrates. Not all cases of AF require the same ablative technique; ablation producing pulmonary vein isolation may be a suitable form of treatment for paroxysmal AF whereas permanent AF may require extensive ablation as seen in ablation of CFAEs, (Kumagai, 2011).

Ablation has been most successful in treating paroxysmal AF with success rates as high as 70 to 80 percent in patients without other structural heart complications (Tedrow et al., 2011). The most common ablative techniques for treating paroxysmal AF include pulmonary vein isolation and box isolation (Kumagai, 2011).The effectiveness of ablation therapy was compared to drug therapy in treating paroxysmal AF in a five trial meta-analysis study (Piccini et al., 2009). They found 77 percent of the patients treated with catheter ablation returned to sinus rhythm within one year of the procedure with 17 percent requiring multiple ablative procedures and 2.6 percent enduring major complications. In comparison, only 29 percent of the patients that received drug therapy returned to sinus rhythm after the one year period. Another meta-analysis study, (Calkins et al., 2009) found similar results. The ablative procedure was successful in 57 percent of patients who received one treatment, 71 percent of patients who received multiple treatments, and 77 percent in patients who received multiple treatments in combination with drug therapy. The success rate of drug therapy alone was lower than all three ablative therapy groups at 52 percent. Five percent of the ablation patients observed major complications compared to 30 percent of the drug therapy patients; however, the complications due to drug therapy were much less severe than the complications due to ablative therapy.

Cardiac ablation has been less successful in treating persistent and permanent cases of AF, but new techniques and strategies are still being developed. To treat these long-term AF cases, more extensive ablation techniques are required. Typical techniques include ablation via multiple linear lesions or ablation of CFAEs. CFAEs are defined as, "fractionated electrocardiograms composed of 2 or more deflections with a mean cycle length ≤120 ms," (Kumagai, 2011). They have been identified as a key location for vagal innervation, slow conduction, reentry and AF maintenance. One study demonstrated CFAE ablation to be successful in 93 percent of paroxysmal AF cases, 87 percent for persistent AF, and 78 percent for permanent AF; however, a similar study had much less success with only 12 percent of patients receiving CFAE ablation returning to sinus rhythm. Due to the difficulty in identifying the problem CFAE from the many other bystanders, more study and testing needs to be done affirming the success of this ablative technique (Kumagai, 2011). Overall, many studies have demonstrated the superiority of catheter ablation over drug therapy for termination of AF; however, data is still lacking on the overall mortality and morbidity rates comparing the two different forms of treatment.

Cardiac ablation is also being developed for its use in treating ventricular tachycardia (VT). VT is another rapid arrhythmia defined as three or more premature, consecutive beats that arise in the ventricles. As a result, the ventricular rate typically rises to 160 to 240 bpm whereas the atria are unable to contract at all. Premature ventricular contractions (PVCs) are identifiable on an ECG appearing as widened, deformed QRS complexes often lacking a preceding p wave (Figure 8). The typical

mechanism for consecutive reoccurrence of PVCs leading to VT is reentry, (John & Stevenson, 2015; Badhwar, 2014).

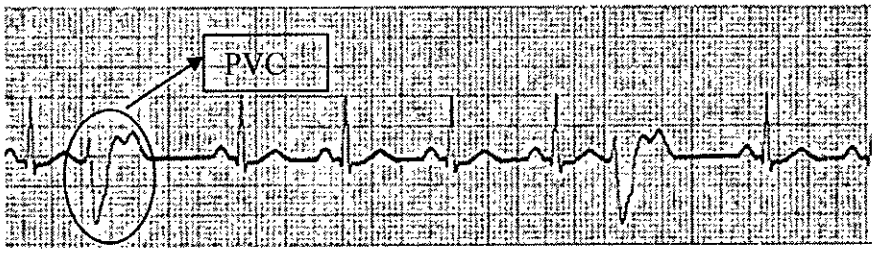

Figure 8. Premature Ventricular Contraction (2013). In the above ECG, normal sinus rhythm is interrupted by the presence of PVCs appearing as widened, premature QRS complexes.

There are two common ways to classify VT. The first is classification based on duration; non-sustained VT describes a case in which the VT episode lasts less than thirty seconds whereas sustained VT episodes last longer than thirty seconds. Sustained VT requires intervention for termination. The second classification is based on the number of ectopic sources triggering the arrhythmia. In monomorphic VT, each premature beats arises from the same, single source. This is distinguished by a consistent QRS morphology beat-to-beat (Figure 9). In contrast, polymorphic VT describes a case in which several ventricular foci initiate premature beats distinguished by variation in QRS morphology (Figure 10), (John & Stevenson, 2015; Badhwar, 2014).

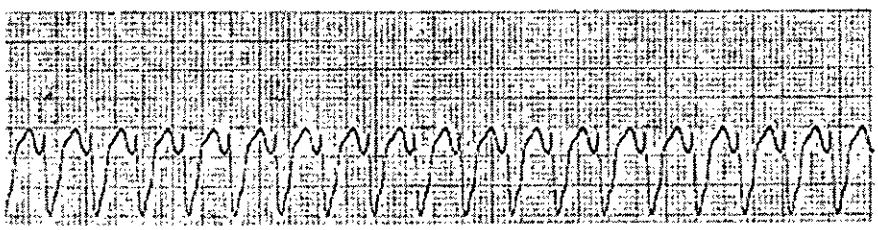

Figure 9. Monomorphic VT (2013). The above ECG exhibits numerous wide, deformed QRS complexes characteristic of VT. The consistent QRS morphology suggests the VT episode is monomorphic.

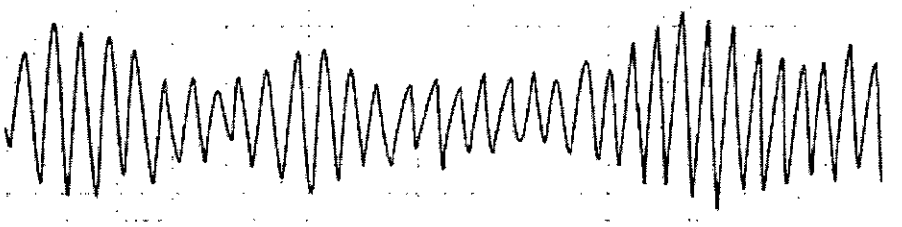

Figure 10. Polymorphic VT (http://www.medicine-on-line.com/html/ecg/e0001en_files /08.htm). The above ECG exhibits numerous wide, deformed QRS complexes characteristic of VT. The inconsistent QRS morphology suggests the VT episode is polymorphic.

VT may present as asymptomatic or may result in several of the following symptoms: palpitations, dizziness, exercise intolerance, episodes of lightheadedness, syncope, or sudden death. In some cases, symptom evaluation can influence the treatment strategy by providing information about the severity of VT and risk of sudden death, (John & Stevenson, 2015). Another important distinction for VT treatment describes whether or not the arrhythmia occurs in conjunction with a structural heart disease or by itself; VT is associated with a form of structural heart disease in 15 to 20 percent of cases, (Badhwar, 2014). The most common disease associated with VT is chronic coronary artery disease; however, cardiomyopathy, myocardial infarction history, and congenital heart disease have led to VT episodes as well. Idiopathic VT, VT without the presence of a structural heart disease, can present as monomorphic or polymorphic; it is often caused by a discrete focal point or reentry circuits identifiable thorough electrophysiological studies.

Idiopathic VT can be terminated with carotid massage, antiarrhythmic drugs, or cardioversion, and treated with carotid massage, antiarrhythmic drugs, implanted cardio defibrillators (ICDs), or ablation depending on the severity, duration, and symptom manifestation. Typically, adenosine and beta blockers are prescribed for VT originating

at a discrete focal point whereas verapamil, a calcium channel blocker, is prescribed for reentrant idiopathic VT. Ablative therapy involves identifying the precise location of the focal point or reentrant circuit. Idiopathic focal VT often originates near the right ventricle outflow tract; in contrast, idiopathic reentrant VT often originates from reentry in the fascicles of the left ventricle. In either case, ablation targets the area with the earliest ventricular activation. Ablative therapy for treatment monomorphic, idiopathic VT has a success rate greater than 80 percent (Tedrow et al., 2011). However, ablation for polymorphic, idiopathic VT has been much less successful and in most cases, antiarrhythmic drugs are the preferred method of therapy.

The typical cause of VT in the presence of a structural heart disease is reentry through areas of myocardial scarring. Treatment strategies include pharmacological therapy, ICDs, and ablation. The mortality rate for VT with an associated heart disease is much greater than idiopathic VT; as such, an ICD or ablative procedure is often necessary. ICD is the standard treatment method for sustained VT in the presence of structural heart disease. Although an ICD can be successful at ending the VT episode, the defibrillator shocks have been associated with a higher risk of death and hospitalization. Ablative therapy is often used in conjunction with an ICD to decrease the frequency of shocking. Ablative therapy for monomorphic VT with associated structural diseases and scarring has a success rate of approximately 70 percent with a 3 percent mortality rate. Complications of the procedure include stroke, femoral hematomas, heart block which can all lead to death. Furthermore, VT recurrence following ablation occurs in approximately half of all patients, (Badhwar, 2014; Tedrow et al., 2011).

Although many of the studies discussed above didn't demonstrate or report statistical significance, the results often demonstrated clinical significance. Statistical significance only assesses the significance of the difference between the two groups being evaluated, i.e. the group being treated versus the group receiving a placebo or two groups receiving different treatments. Though this information can be highly valuable, it doesn't indicate the meaningfulness of the outcome. This information is described by a studies clinical significance which provides information about the effectiveness and efficacy of the treatment strategy.

Conclusion

Cardiac ablation is a rapidly developing form of therapy that has already become an effective treatment for many tachycardic arrhythmias. Ablative therapy has shown superiority over pharmaceutical therapy in most cases of AV nodal reentrant tachycardia (AVNRT), atrioventricular reentrant tachycardia (AVRT), focal atria tachycardia, and atrial flutter (AFL). Despite its proven success, its necessity is usually assessed on a case to case basis to ensure every patient receives the safest and most effective treatment method.

Ablation has also become an option for atrial fibrillation (AF) and ventricular tachycardia (VT). Ablation has shown promise for the treatment of A-fib, although research is still being done for long-term efficacy and effectiveness in certain complicated cases. Ablation has become a common therapy for idiopathic monomorphic VT treatment; however an ICD or pharmacological therapy is still more common for polymorphic VT and VT occurring in the presence of identifiable heart disease. As more

research is done in these areas, the overall cardiac ablation efficacy and practice will continue to expand and save lives.

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