Atrial fibrillation and cardiac arrhythmia

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Introduction

Atrial fibrillation is the most common form of cardiac arrhythmia; it involves the two upper chambers of the heart known as the atria. During atrial fibrillation the normal pulses generated by the sinoatrial node are overcome by the electrical pulses that are generated in the atria and pulmonary veins, which leads to irregular impulses being conducted to the ventricles, and therefore irregular heartbeats are generated.

AF is identified by rapid and oscillatory waves that vary in amplitude, shape and timing instead of regular P-waves. Electrocardiograms are therefore used commonly to diagnose AF in patients.

Arterial Fibrillation can present asymptomatically meaning that it can present in a patient but show no symptoms, it is considered to be non life threatening in many cases although it can result in heart palpitations, fainting, chest pain and in chronic cases congestive heart failure. The risk of stroking is also increased due to the fact that blood may pool and form clots in poorly contracting atria. Patients with AF are usually given blood-thinning medication such as warfarin to stop clots forming. Atrial fibrillation can occur in the absence of structural heart disease, known as lone AF, although this only occurs in approx. 15% of cases. Commonly AF is associated with hypertension, diabetes, obesity, coronary artery disease, pulmonary disease, valvular heart disease and coronary heart failure.

Basic Pathophysiology of Atrial Fibrillation

Atrial fibrillation usually begins with increased premature atrial contractions (ectopic beats) progressing to brief runs of atrial fibrillation usually that are

usually self-terminating, over time these episodes can increase in duration and sometimes become persistent. During this progression structural changes in the atria occur as well as biochemical changes in the atrial myocytes. Pathophysiological adaptation of the atria to fibrillation has been broadly termed remodeling. More specifically, the changes primarily affecting the excitability and electrical activity of the atrial myocytes have been termed electrophysiological remodeling.

The primary change in the structure of the atria is fibrosis, which is usually considered to be due to the atrial dilation, although in some cases genetic influences and inflammation can also be a cause. In 1990 Sanfilippo stated that atrial dilation was not a consequence of AF although more recently in 2005 Osranek stated that atrial dilation was not a consequence of AF.

Dilation is due to almost any structural abnormality of the heart, such as hypertension, valvular heart disease and congestive heart failure; this structural abnormality causes a rise in intra-cardiac pressures. Demonstrating the strong relationship between atrial fibrillation and structural heart disease. Once dilation does occur it begins sequences of events that lead to the activation of the rein aldosterone angiotensin system and a subsequent increase in matrix metaloproteinases and disintegrin, leading to remodeling of the atria and fibrosis. Fibrosis is not limited to muscle mass of the atria, it can occur in sinus node and atroventricular node also, relating to sinus node dysfunction (sick sinus syndrome).

During normal electrical conduction of the heart the SA node generates a pulse that propagates to and stimulates the muscle of the heart

(myocardium), when stimulated the myocardium contracts. The order of stimulation is what causes correct contraction of the heart, allowing the heart to function correctly. During atrial fibrillation the impulse produced by the SA node is overcome by rapid electrical discharges produced in the atria and adjacent parts of the pulmonary veins. When AF progresses from paroxysmal to persistent the sources of these conflictions increase and localise in the atria.

Principles of Catheterization and Ablation

The fundamental aim of catheter ablation is to eliminate ectopic beats that arise most often in the pulmonary veins and less often in the superior vena cova and coronary sinus. This is accomplished through catheter insertion into blood veins in order to reach the heart, isolation of abnormal heart tissue and ablation of this abnormal heart tissue through the use of radiofrequency, cryoblation or high intensity focused ultrasound.

Rate Control and Rhythm Control

Despite ablative techniques and antiarrhythmic drugs available, management of common rhythm disturbance remains a problem. Rate control is the preferred treatment for permanent atrial fibrillation and for some patients with persistent atrial fibrillation, if they are either over 65 years of age or have coronary heart disease. Rate control is usually done through the use of pharmaceutical drugs (usually beta blockers or rate limiting calcium channel blockers) in order to slow ventricular heart rate and stop the atria from fibrillating. Rhythm control is most commonly used for the treatment of paroxysmal atrial fibrillation and in some cases of persistent atrial fibrillation if the patient is either less than 65 years of age, has lone

atrial fibrillation or congestive heart failure. Rhythm control is usually achieved through the use of either a cardioversion (electrically or pharmacological) or the use of pharmaceutical drugs (usually beta blockers) in order to maintain sinus rhythm. This treatment is needed for a longer time in order to stop reoccurrence of atrial fibrillation. [http://www. cks. nhs. uk/atrial_fibrillation/management/detailed_answers/first_or_new_presentation_of_af/rate_or_rhythm_control#-391784). Atrial fibrillation is treated most commonly pharmaceutically although if the drugs cannot control the AF or if the patient is having a bad reaction to the medication, catheter ablation therapy allows for greater control of heart rate and rhythm than drug therapy although it does present more risk to the patient.

Radiofrequency Catheter Ablation

Electrically isolating arhythmogenic thoracic veins is the most important aspect of this procedure. The application of radiofrequency energy to an endocardial surface is used to cause cellular electrical destruction with the loss of cellular electrical properties, essentially the destruction of abnormal electrical activity [39, 40]. This technique can be enhanced through the use of larger ablation electrodes, [41-46] allowing the creation of deeper lesions. During the procedure a physician will map the area to locate abnormal electrical activity, this is facilitated through the use of electroanatomic mapping system (fig 2) allowing for better navigation when the catheter is inserted into the artery. Reported success of radiofrequency ablation is dependent on the severity of the condition and ranges from 65% to 85% and patients presenting with complications is 5%.[cryostat]

Cryoblation

The most used format of cryoblation is the cryoballoon approach. This involves a deflectable a deflectable over-the-wire catheter with an inner and outer balloon inserted, allowing for anatomical variance this balloon is available in two sizes (23mm and 28mm). The guidewire is positioned in the distal part of the pulmonary vein, the deflated balloon is then progressed to the pulmonary vein ostium. Using the central balloon marker the balloon position is then estimated before inflation, once the desired position is found the balloon is inflated; pressurized N20 is then delivered to the tip of the catheter via an ultrafine injection tube down a central lumen in the inner balloon, working like an expansion chamber. Sudden expansion of the liquid gas causes evaporation and absorption of heat from tissue and low temperatures are then achieved (Approx -80dc). An occlusion angiogram is then performed in the central lumen of the catheter to ensure good balloon pulmonary vein contact. Cryoblation is then started for at least five minutes under the condition that optimum pulmonary venous occlusion is achieved. The most important issue when using this technique is to establish optimum contact between the pulmonary vein antrum and the balloon.

High Intensity Focused Ultrasound (HIFU)

High intensity ultrasound is used in percutaneous ablation of atrial fibrillation through the use of a steerable balloon catheter. The high intensity focused ultrasound balloon is positioned at the ostium of the pulmonary veins and forms a sonicating ring to ablate pulmonary vein antrum when high intensity focused ultrasound is delivered. An arrhythmia-free rate of 59%-75% was

achieved by HIFU balloon in several studies investigating its effectiveness in atrial fibrillation ablation. 15-17

Commercially Available Devices and Systems

Medtronic GENius Multichannel RF Generator

This generator is used for the creation of endocardial lesions during cardiac ablation procedures for the treatment of supraventricular arrhythmias. The generator delivers temperature-controlled radiofrequency energy, utilizing five radiofrequency energy mode selections: bipolar only, unipolar only, and combination energy mode selections of 4: 1, 2: 1, and 1: 1. This system must be used with a catheter that is single use and sold separately to the device. The generator automatically recognizes the attached Cardiac Ablation Catheter and loads preset default temperature, time, and energy mode setting parameters. Ablation parameters such as ablation duration, energy mode, target temperature and channels can also be manually selected.

Medtronic Cardiac CryoAblation Device

The CryoConsole contains both electrical and mechanical components as well as exclusive software for controlling and recording a cryotherapy procedure. This system requires catheters that are purchased separately such as Medtronics Artic front cryoablation catheter (Fig. 3). This system stores and controls the delivery of the liquid refrigerant through the coaxial umbilical to the catheter, recovers the refrigerant vapor from the catheter under constant vacuum, and disposes of the refrigerant through the hospital scavenging system. Multiple features are built into both the CryoConsole system and catheters to ensure safety.

Epicor™ Cardiac Ablation System Price

The Epicor™ LP Cardiac Ablation System delivers High Intensity Focused Ultrasound using algorithms designed to precisely deliver energy up to 10mm. Unlike the other treatments high intensity focused ultrasound has the ability to create lesions from the inside out, depositing energy at the endocardium first and then building the lesion back up to the surface. The ability to focus HIFU cardiac ablation energy helps reduce the risk of tissue disruption, charring and collateral damage as well as overcome procedural limitations that have historically been associated with other ablation technologies.

Conclusion

In terms of ablation the umbrella terminology of Atrial Fibrillation does not take into account the complex nature of the disease. If a patient presents with paroxysmal atrial fibrillation they may only require a single catheter to be used, however if this condition becomes more continuous/chronic the patient may require multiple catheters and 3D navigational software. The three techniques described in this report appear to be similar in terms of their success rate, radiofrequency and cryoablation have a success rate of approx. 65-85% while High intensity focused ultrasound has a success rate of approx. 59-75%, this perhaps indicates that high intensity focused ultrasound may not be as effective in treating atrial fibrillation as radiofrequency and cryoablation although it is worth noting that these figures are taken from different research studies at different times and involve different patients that could be presenting greater or lesser a severity of atrial fibrillation.