KARAZIN UNIVERSITY
CLASSICS AHEAD OF TIME

Radiofrequency catheter Ablation

The Development of Cardiac Arrhythmia Ablation

Assistant Professor
Daiana Pavlova

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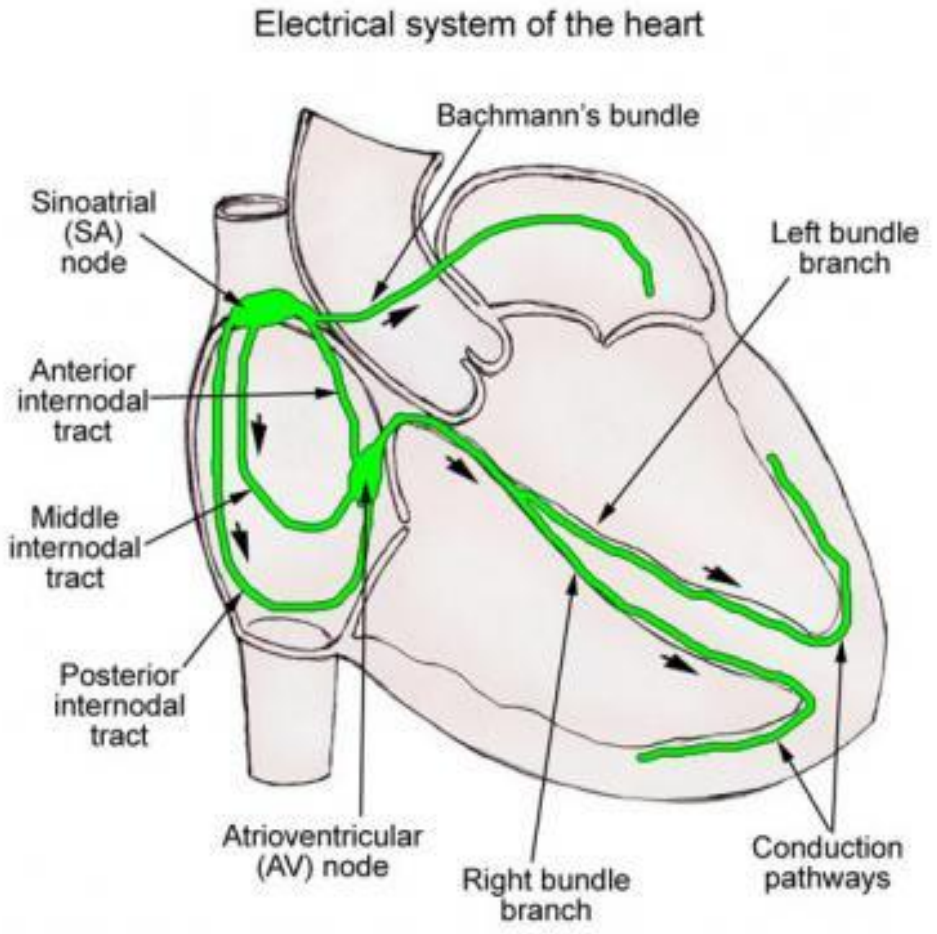
Arrhythmias 1.1

- Arrhythmia is an abnormal rhythm of the heart.
- The only normal rhythm of the heart is a normal sinus rhythm. In this rhythm, an impulse is generated in the sinoatrial (SA) node, which is conducted through and slowed down while passing through the atrioventricular node (AV). It is then conducted through the bundle of His, to the left and right bundle branches, and eventually into the Purkinje fibers.
- Any deviation from this conduction pathway results in an arrhythmia.

https://www.ncbi.nlm.nih.gov/books/NBK558923/#:~:text=Arrhythmia%20is%20an%20abnormal%20rhythm,the%20atrioventricular%20node%20(AV).

Schematic illustration of the cardiac conduction system



https://emedicine.medscape.com/article/1922987-overview#a2

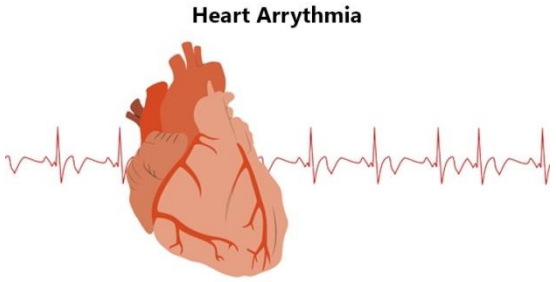
Arrhythmias 1.2

- Arrhythmias can be classified based on various criteria.
- The most common way to categorize them is based on the rate of conduction as bradyarrhythmia with a heart rate of fewer than 60 beats per minute (bpm) and tachyarrhythmia with a heart rate higher than 100 bpm.

https://www.ncbi.nlm.nih.gov/books/NBK558923/#:~:text=Arrhythmia%20is%20an%20abnormal%20rhythm,the%20atrioventricular%20node%20(AV).

Evaluation of Arrhythmia 1.1

- The prevalence of arrhythmias is expected to be 1.5% to 5% in the general population.
- The overall presence of arrhythmia is associated with higher morbidity and mortality.
- In patients suspected of arrhythmias, an electrocardiogram (EKG) is the first step and will usually give the diagnosis.



https://www.ncbi.nlm.nih.gov/books/NBK558923/#:~:text=Arrhythmia%20is%20an%20abnormal%20rhythm,the%20atrioventricular%20node%20(AV).

Evaluation of Arrhythmia 1.2

- The patient presentation can be varied even for the same arrhythmia and can require a different management approach based on the patient's clinical condition and characteristics.
- While clinical history, physical exam and EKG findings may reveal particular kinds of arrhythmia, it can sometimes be challenging to form an appropriate management plan without an expert opinion.
- While an internist is always involved in the care of patients with arrhythmia, it is essential to consult an interprofessional team of specialists, including cardiologists, electrophysiologists, and interventionists.
- Based on the condition, the patient may need further evaluation with electrophysiological or ischemia workup for the cause of arrhythmia, which will eventually be treated by a cardiac catheterization or **ablation procedure**.

https://www.ncbi.nlm.nih.gov/books/NBK558923/#!po=2.38095

MECHANISMS OF CARDIAC ARRHYTHMIAS

- The 3 main mechanisms responsible for cardiac arrhythmias: **automaticity, triggered activity, and reentry**.

- Although identifying the specific mechanism may at times be challenging for the clinician and require invasive electrophysiological study, differentiating and understanding the underlying mechanism may be critical to the development of an appropriate diagnosis and treatment strategy.

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4823581/pdf/main.pdf

Definitions

Automaticity - is defined as spontaneous impulse initiation, the excitation of which is propagated from cell to cell resulting in depolarization across the myocardium;

Triggered activity - is a term used to describe impulse initiation in cardiac fibers that is dependent on afterdepolarizations, abnormal depolarizations of cardiac myocytes that interrupt phase 2, phase 3, or phase 4 of the cardiac action potential in the electrical conduction system of the heart and may lead to cardiac arrhythmias;

Reentry - the action or process of re-entering something.

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3164530/

Supraventricular arrhythmia 1.1

- The term 'SVT' literally indicates tachycardia with [atrial rates >100 beats per minute (b.p.m.) at rest], the mechanism of which involves tissue from the His bundle or above.
- Traditionally, SVT has been used to describe all kinds of tachycardias apart from ventricular tachycardias (VTs).
- Arrhythmia can originate from abnormal impulse initiation in an individual myocyte or, more realistically, in a close cluster of myocytes.
- This can occur in non-pacemaker cells through a mechanism similar to the physiological automaticity of pacemaker cells [sinus node and AV node (AVN)], and is thus named **'abnormal' or 'enhanced automaticity'**.

2019 ESC Guidelines for the management of patients with supraventricular tachycardia

Supraventricular arrhythmia 1.2

- An alternative form of abnormal impulse initiation involves oscillations of membrane potential, named early or delayed 'after-depolarizations'. In such cases, the resulting arrhythmias take the name of 'triggered activity'.
- Arrhythmias resulting from automaticity and triggered activity are defined as 'non-re-entrant'.
- Arrhythmias can also arise when myocardial regions activate the regions, which have already recovered. This results from abnormal propagation of the excitation wavefront. This mechanism, named 're-entry'.
- The SVT may result in palpitations, fatigue, light-headedness, chest discomfort, dyspnoea, and altered consciousness, more likely to present with a clear history, SVT usually produces symptoms.

2019 ESC Guidelines for the management of patients with supraventricular tachycardia

Atrial fibrillation and atrial flutter

- Atrial fibrillation and atrial flutter are the most common of these atrial arrhythmias.
- Atrial fibrillation (AF) is the most prevalent cardiac arrhythmia, affecting 1% to 2% of the general population, is associated with increased morbidity and mortality and is a risk factor for embolic stroke and worsening heart failure.
- It is known that the prevalence of atrial fibrillation generally increases with age. It has been estimated that the number of individuals with atrial fibrillation will double or triple by the year 2050.

https://www.ncbi.nlm.nih.gov/books/NBK540985/#!po=2.17391

Atrial Fibrillation

- The mechanisms underlying Atrial Fibrillation (AF) are classically described as mechanisms responsible for its initiation (triggers).
- In 1998 it was first reported the essential role of the pulmonary veins (PVs) in the initiation and maintenance of AF.
- Ectopic activities originating from the PVs were identified in 94% of patients suffering from frequent AF episodes.
- Compared to the atrial cells, the PVs cardiomyocytes have specific action potential properties that predispose to arrhythmogenesis.
- Ablation targeting the site of origin of the ectopic activities abolished the arrhythmia and prevented its recurrence in 62% of the cases.
- The role of the PVs in triggering AF was confirmed in multiple studies.
- Radiofrequency catheter ablation for atrial fibrillation (AF) has become a frequently used therapy after failure of antiarrhythmic drug.

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6232922/#!po=3.67647

Pulmonary vein isolation by catheter ablation

- Therefore, electrical isolation of these veins by catheter ablation is currently being explored as a treatment modality for patients with paroxysmal and even more permanent types of atrial fibrillation.

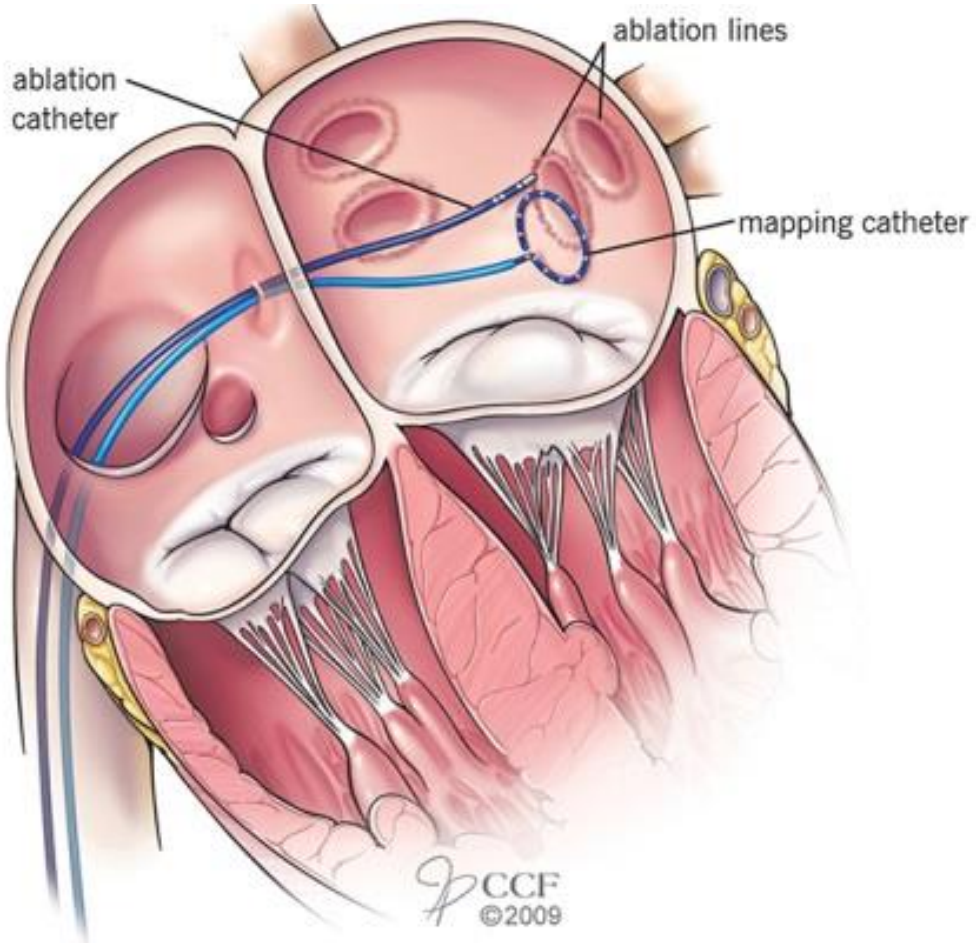
At present, two different techniques are used:

- 1) selective ablation of electrical connections between left atrium and myocardial sleeves inside the PVs;
- 2) lesions around and outside the PV's.

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2499711/

Pulmonary Vein Isolation Ablation: Procedure Details

Energy is delivered through the tip of the catheter to tissue that is targeted for ablation. The energy is applied in a circle around the connection of the left upper and lower pulmonary veins to the left atrium.



https://my.clevelandclinic.org/health/treatments/17401-pulmonary-vein-isolation-ablation/procedure-details

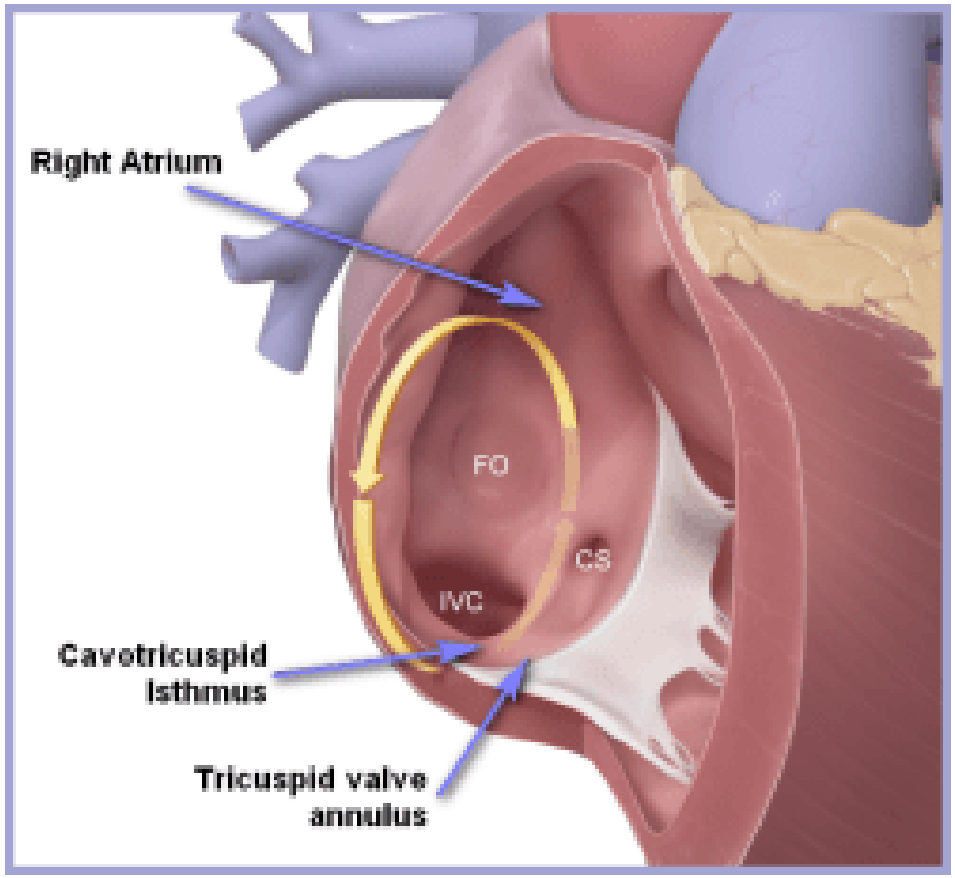
Atrial flutter

Atrial flutter is a macro-reentrant tachycardia and depending on the site of origin can be typical or atypical atrial flutter.

- Electrical axis of the flutter waves can help to determine the origin of the atrial flutter;
- Typical or cavotricuspid isthmus (CTI) dependent is the most common type of atrial flutter; this rhythm originates in the right atrium at the level of the tricuspid valve annulus;
- The atypical atrial flutter is independent of the CTI, and can be in the right atrium or the left atrium.

https://www.ncbi.nlm.nih.gov/books/NBK540985/#!po=2.17391

Cavotricuspid isthmus



Cavotricuspid isthmus (CTI) is part of the right atrium located between the inferior vena cava (IVC) ostium and the tricuspid valve.

Typical Atrial Flutter comes from the right atrium and is usually terminated by what is called a Cavo-Tricuspid Isthmus (CTI) lesion ablation line which blocks the Flutter.

https://a-fib.com/2020-af-symposium-abstract-pfacti-lesions-terminates-flutter-in-a-small-study/

Radiofrequency ablation of cardiac arrhythmias: past, present and future

- The treatment of cardiac arrhythmias has been revolutionized by the ability to definitively treat many patients with radiofrequency catheter ablation (RFA), rather than requiring lifelong medication.
- Radiofrequency ablation has revolutionized treatment for tachyarrhythmias and has become first-line therapy for many tachycardias.
- Non-pharmacological management of refractory cardiac arrhythmias has progressed over the last 60 years from arrhythmia surgery to high-voltage direct current catheter ablation from a standard external defibrillator, only to be superseded by radiofrequency ablation over the last 20 years.

https://academic.oup.com/qjmed/article/105/4/303/1553881

The main RFA purpose

- In general, all ablative-type therapies for cardiac arrhythmias consist of the delivery of some source of energy within the heart at such a magnitude that it caused local myocardial destruction of anatomic regions critical for abnormal impulse generation and/or propagation.
- The aim of these destructive lesions is either silencing the foci responsible for abnormal automaticity or interruption of the reentry circuits responsible for arrhythmia genesis or continuation.
- Now the most commonly used types of ablations are **radiofrequency and cryothermal**.

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6023703/pdf/medi-97-e11044.pdf

Catheter ablation – History 1.1

- The use of catheter ablation was first introduced in the late 1960s; it was designed first for recording, where the surgical treatment of the cardiac arrhythmia was the main concept.
- In 1967, the concept of induction of cardiac arrhythmia was first introduced through programmed electrical stimulation.
- In 1981, the concept of the transvenous catheter was first defined when a patient that was undergoing an electrophysiological recording following defibrillation, where a high-voltage discharge was emitted when the defibrillator electrode hit the catheter electrode at His. This energy caused damage to underlying tissue.

https://pubmed.ncbi.nlm.nih.gov/29262168/

Catheter ablation – History 1.2

- In the 1990s, radiofrequency ablation replaced the direct current.
- RF energy is an alternating current generated with a frequency of 350 kHz to 700 kHz (usually 500 kHz on commercially available RF generators) delivered in a continuous, unmodulated sinusoidal manner to create thermal injury.
- The current is delivered in a unipolar fashion from the tip of the catheter electrode to a large surface (100 cm2 to 250 cm2). A patch is placed against the skin where the electric energy is delivered and converted to thermal injury when it passes through the tissue (resistive heating).
- Large patches are placed on the patient back as a ground to avoid skin burns.

https://pubmed.ncbi.nlm.nih.gov/29262168/

Catheter ablation - current

- Current ablation equipment allows temperature monitoring and temperature control, which is a valuable tool during radiofrequency ablation procedures as it provides important information regarding the adequacy of tissue heating, minimizes the development of coagulum and lesion size.
- Newer technical modifications, including a larger distal electrode and saline cooling, have helped to minimize impedance rise and allow the creation of larger and deeper lesions.

https://pubmed.ncbi.nlm.nih.gov/29262168/

Catheter ablation procedures

- Catheter ablation procedures are performed in an electrophysiology laboratory (a cardiac catheter laboratory with specific equipment for the electrophysiology work), with both diagnosis and ablation usually achieved together.

Figure 1. The setup of the operating room.

https://academic.oup.com/qjmed/article/105/4/303/1553881

Indications for radiofrequency catheter ablation

There are three main indications for catheter ablation:

- Definitive treatment of symptomatic supraventricular tachycardia (SVT) due to atrioventricular re-entrant tachycardia (AVRT), atrioventricular nodal re-entrant tachycardia (AVNRT), unifocal atrial tachycardia, or atrial flutter;
- AF with lifestyle-impairing symptoms and failure of antiarrhythmic agents.
- Symptomatic idiopathic ventricular tachycardia (VT).

https://www.ncbi.nlm.nih.gov/books/NBK470203/

Preparation

- Counseling of patients and explanation of the procedure is the main step of preparation.
- Complete blood count, renal function, and liver functions should be checked, especially in patients who are on antiarrhythmic drugs.
- Coagulation profile is checked, especially for patients on anticoagulation.
- No eating and drinking for 6-8 hours before the start of the procedure. If necessary, a few small sips of water to take the medicine (in case of arterial hypertension, diabetes, etc.).
- 2-3 days before the operation, the patient should stop taking antiarrhythmic drugs (in agreement with the doctor);

https://www.ncbi.nlm.nih.gov/books/NBK470203/

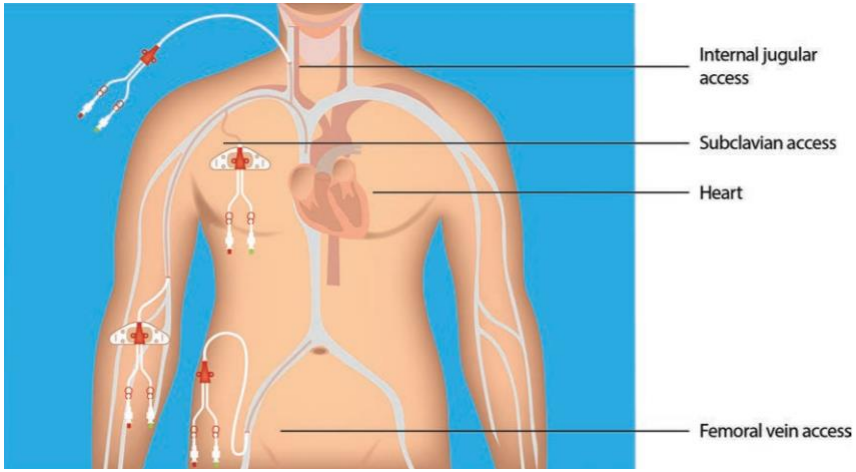
The procedure

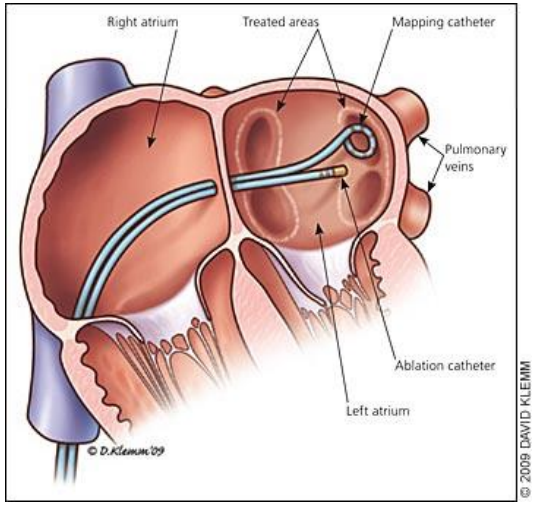
- The patient is draped and the site of vascular access is cleaned with antiseptic agents similar to other cardiac catheterization procedures.
- Local and intravenous anesthesia is the choice.
- During the procedure, special long flexible electrodes are used, which can both record the electrical activity of the heart and stimulate the heart during an electrophysiological study (EPI). They are performed in the heart under fluoroscopic guidance.
- The procedure may take several hours or even longer.
- The patient may feel slight discomfort during the ablation.
- Patients require long-term follow-up if the arrhythmia has been cured.

https://www.ncbi.nlm.nih.gov/books/NBK305758/?report=reader

Access

- The venous system approaches mostly right and left femoral veins.
- The internal jugular or subclavian vein approach may be used.
- Diagnostic catheters are inserted to allow pacing, stimulation, and signal recording at the high right atrium, right ventricle, His bundle and the coronary sinus.
- The left side can be accessed through an antegrade transeptal puncture from the right atrium into the left atrium or a retrograde aortic approach.





https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3270925/

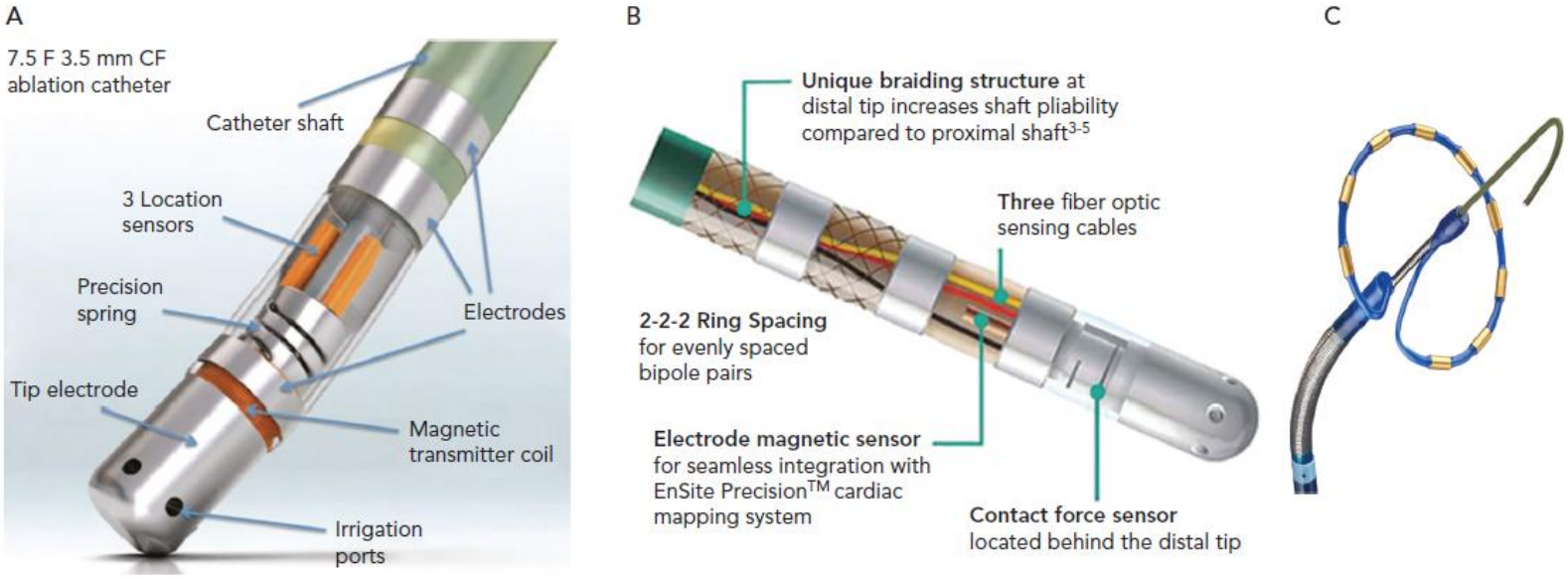
Operation room

Operation room – Navigation – Control

Equipment 1.1

- Catheters - A variety of catheters is available with at least two ring electrodes that can be used for bipolar stimulation and recording.
- Deflectable catheters to facilitate positioning for mapping and delivering ablative energy.
- Catheters with multiple poles (8 to 64) that allow simultaneous acquisition of activation points.

Figure 1: Radiofrequency Ablation Devices with CF and Multi-electrode Ablation Catheters



(A) Thermocool Smarttouch, from Lin et al.[164] (B) Tacticath Catheter, from Abbott (www.sjmglobal.com). (C) PVAC Gold – the non-irrigated multi-electrode catheter, reproduced with permission of Medtronic, Inc.

https://www.ncbi.nlm.nih.gov/books/NBK470203/

Equipment 1.2

- Junction Box - is a rectangular box that receives the intracardiac signals from the catheters and provides the interface to the physiologic recorder.
- Recording Apparatus - the physiologic recorder records, displays, and stores intracardiac and surface recordings. It consists of filters, amplifiers, display screens, and recording software.
- From the junction box, the physiologic signals are introduced into the recorder.

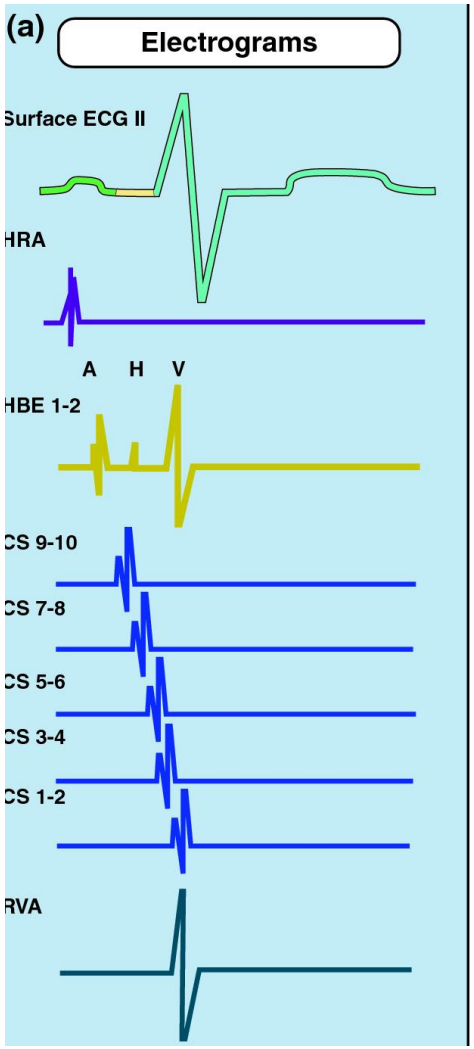
https://www.ncbi.nlm.nih.gov/books/NBK470203/

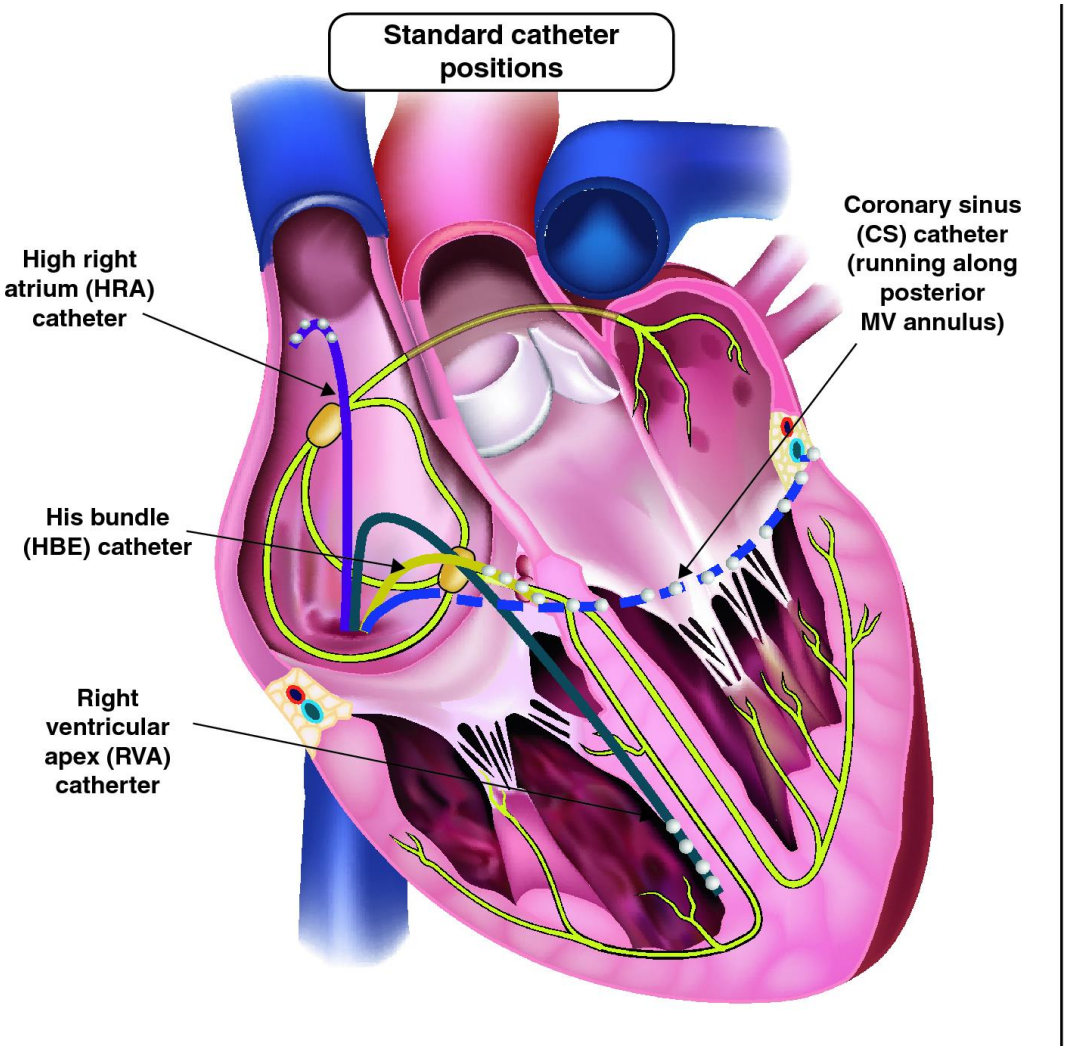
Intracardiac Electrograms and Electrophysiology Studies 1.1

- Electrophysiological studies are performed to record and analyze intracardiac electrograms (EGMs).
- Different catheter types are inserted via venous access and placed at distinctive locations in the heart. For spatial mapping, circular mapping catheters are often inserted into the atria. There are interesting parameters that can be quantitatively determined from cardiac mapping data, especially the local wave direction and conduction velocity (CV).
- These parameters can aid in the understanding of the arrhythmia pattern and possible substrate changes.
- Furthermore, intracardiac EGMs were simulated by modeling measurement catheters in realistic atrial geometries.

https://www.ibt.kit.edu/3043.php

Intracardiac Electrograms and Electrophysiology Studies 1.2





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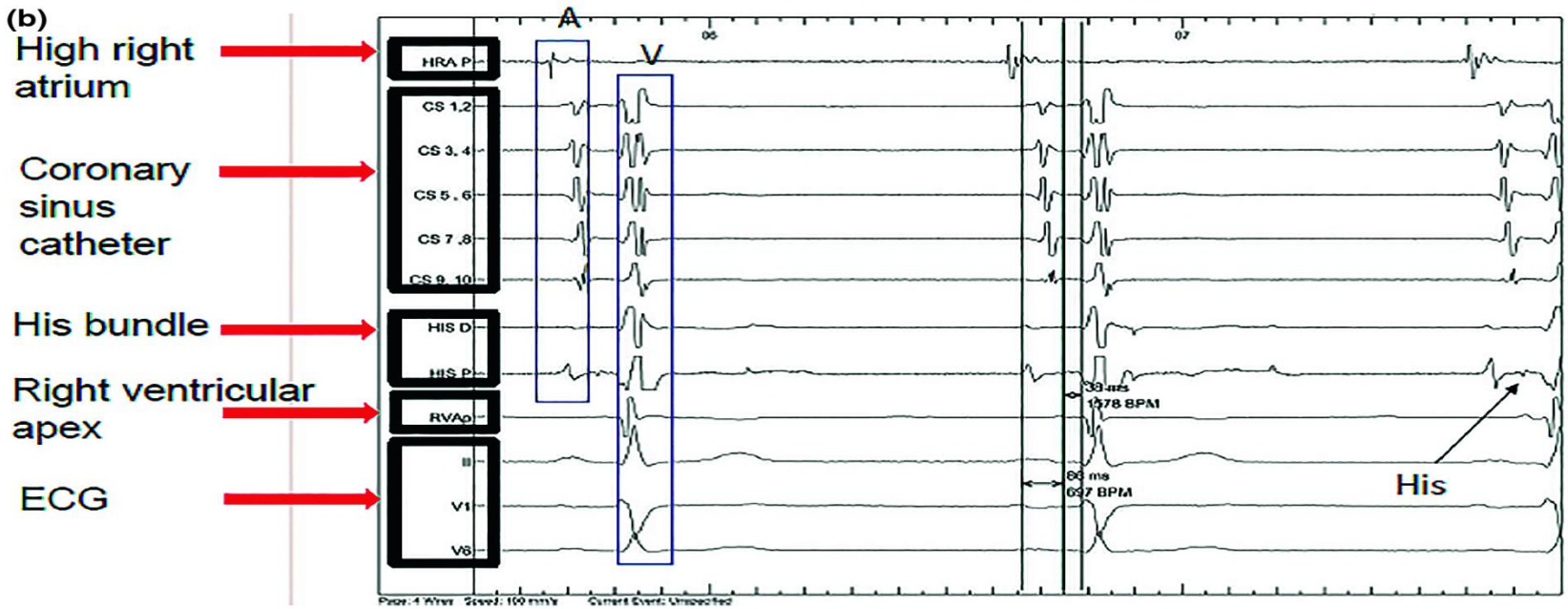
Intracardiac Electrograms and Electrophysiology Studies 1.3



The combination of simulation and analysis of intracardiac EGMs helps to determine parameters for personalized simulations, develop new analysis techniques that support the physicians during electrophysiological studies, improve catheter design, and to gain better understanding of atrial arrhythmias.

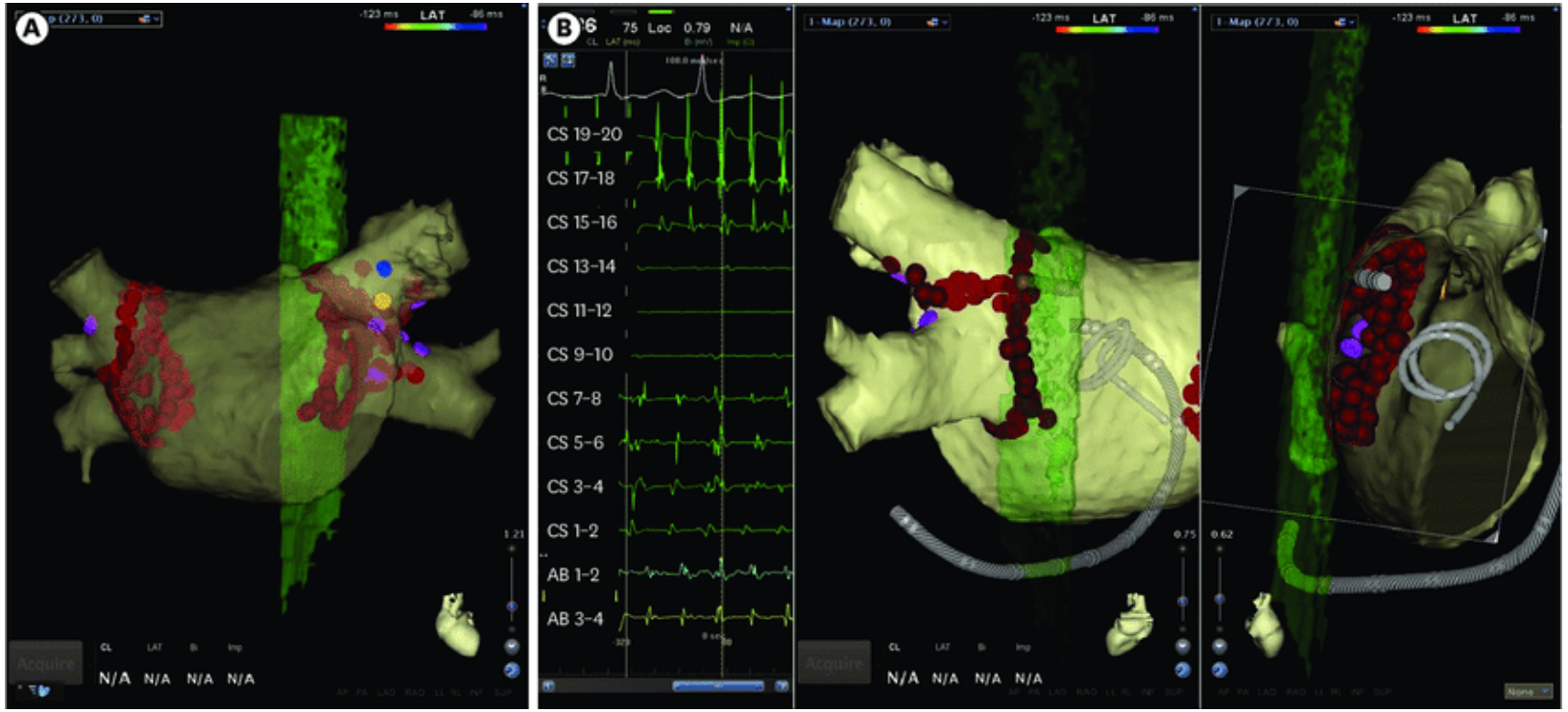
https://www.ibt.kit.edu/3043.php

Mapping System

- Cardiac mapping is the process by which arrhythmias are characterized and localized. Conventional mapping involves acquiring electrogram data from fixed and moving catheters.
- Three-dimensional anatomic localization of the catheter assists in mapping and ablation.
- The most widely used electroanatomic mapping system localizes the mapping and ablation catheter through a magnetic field.
- Another technology offers electroanatomic mapping by creating electrical fields between opposing pairs of patch electrodes located on the patient's chest. Patches are placed on the body to create three axes with the heart located centrally. A transthoracic electrical field is created through each pair of opposing patch electrodes, and the mapping catheter.

https://www.ncbi.nlm.nih.gov/books/NBK470203/

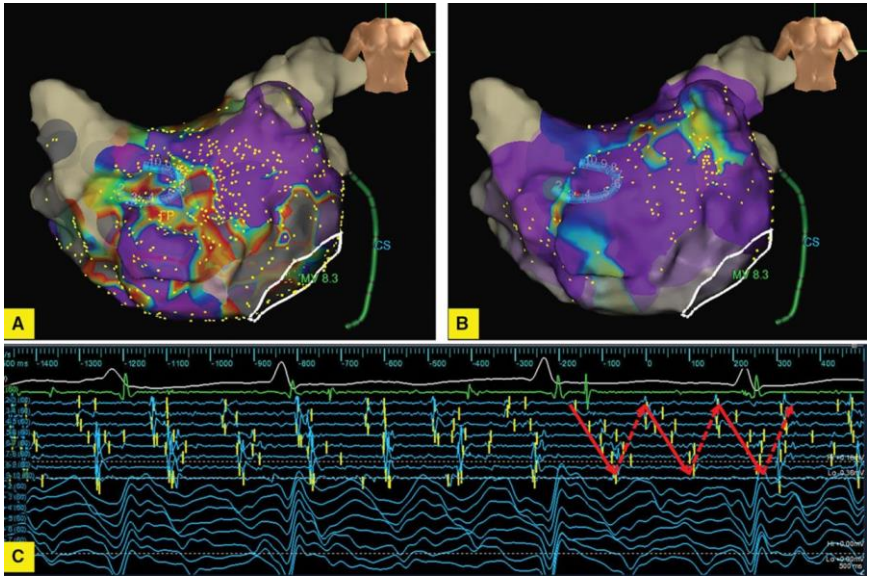
Mapping System – Visualization 1.1

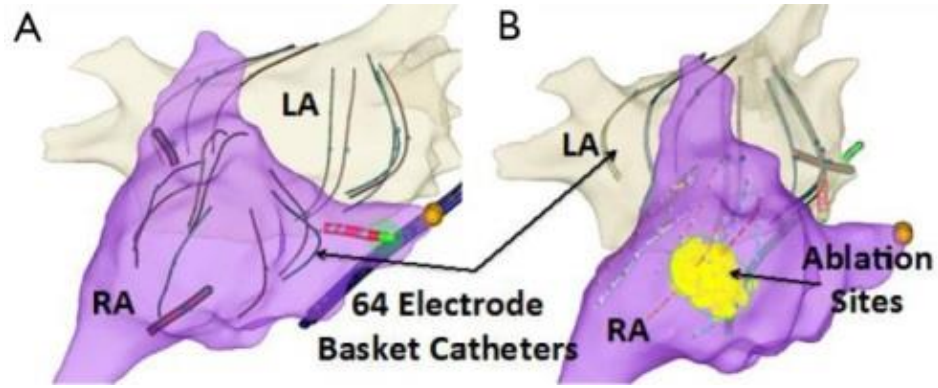


Electroanatomic mapping images of the left atrium acquired by the CARTO 3 Navigation System show that linear ablation at the posterior wall was performed during left-side ablation.

https://www.researchgate.net/figure/Radiofrequency-ablation-findings-A-B-Electroanatomic-mapping-images-of-the-left_fig1_319674109

Mapping System – Visualization 1.2





Maps from the right (RA) and left (LA) atrium. In both atrial are mapping catheters used for guided ablation of a rotor found in the right atrium.

Pulmonary vein ablation procedure: Energy is delivered through the tip of the catheter to tissue that is targeted for ablation. The energy is applied in a circle around the connection of the left upper and lower pulmonary veins to the left atrium

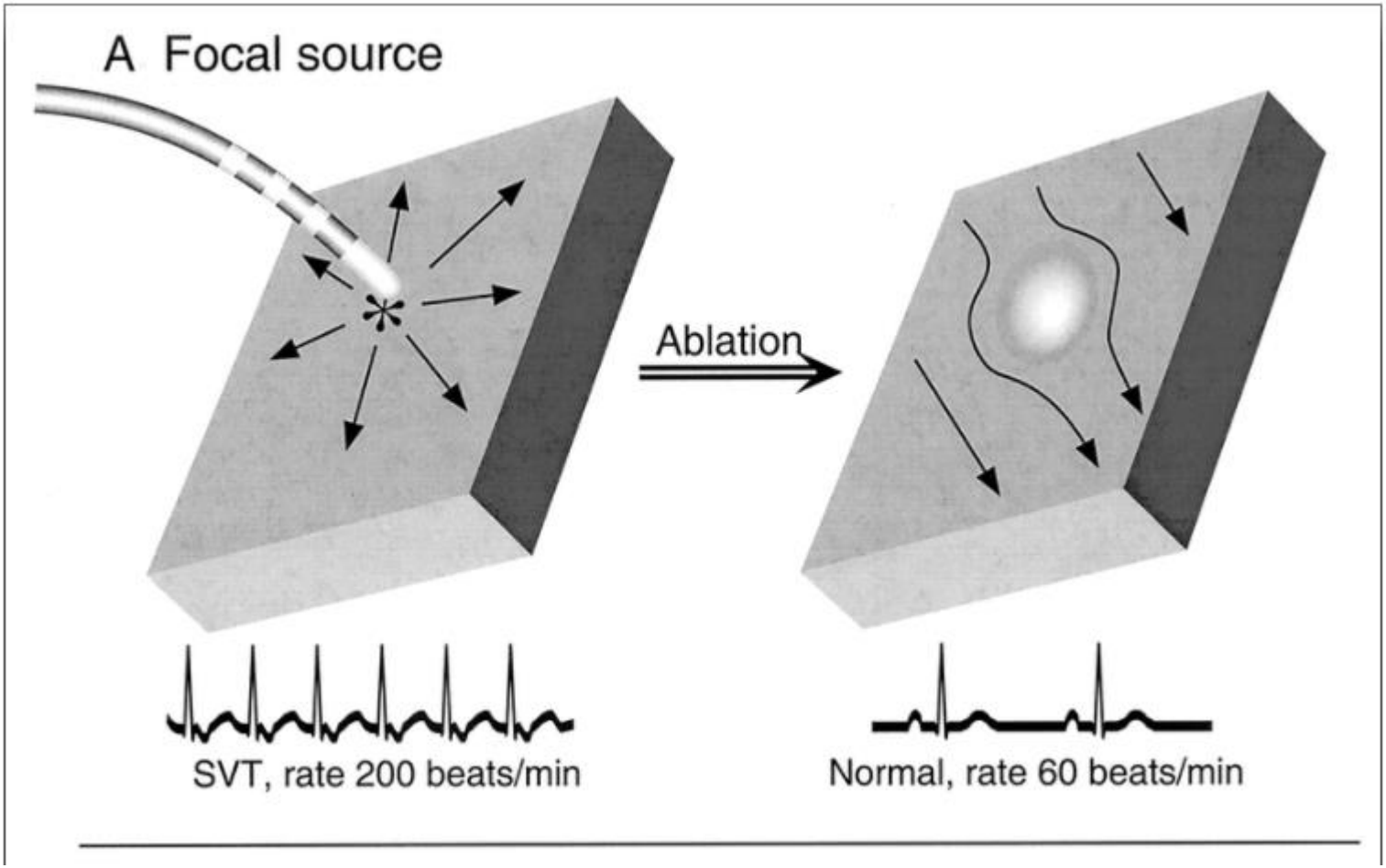
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1767151/

RFA technique

- Using the RFA technique, the electrophysiologist can determine the exact location of the abnormal heart muscle and eliminate (ablate) it.
- The procedure is applicable to a wide variety of tachycardias, has an extremely high success rate for many of these, and has a low complication and rate of tachycardia recurrence.
- RFA works by delivering energy through an electrode at the end of a catheter that has been threaded through a vein or artery to the heart.
- The most common type of energy used is radiofrequency (RF), which coagulates the abnormal tissue that is in immediate contact with the electrode.
- A small scar develops at this site, and the effect is usually permanent.

https://www.ahajournals.org/doi/10.1161/01.CIR.0000046082.16495.8F

Catheter Ablation of Arrhythmias – visualization 1.1



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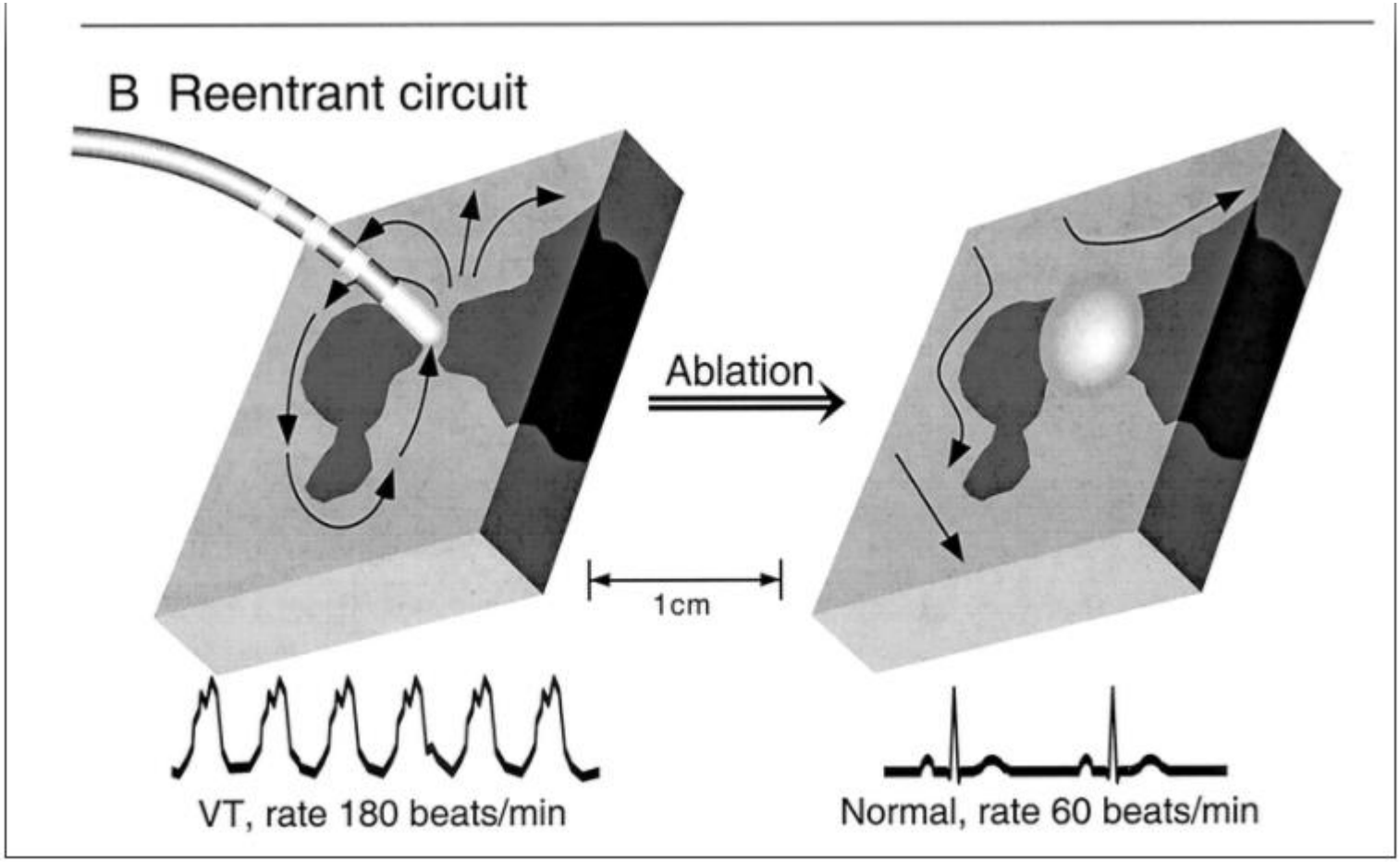
Catheter Ablation of Arrhythmias – visualization 1.2



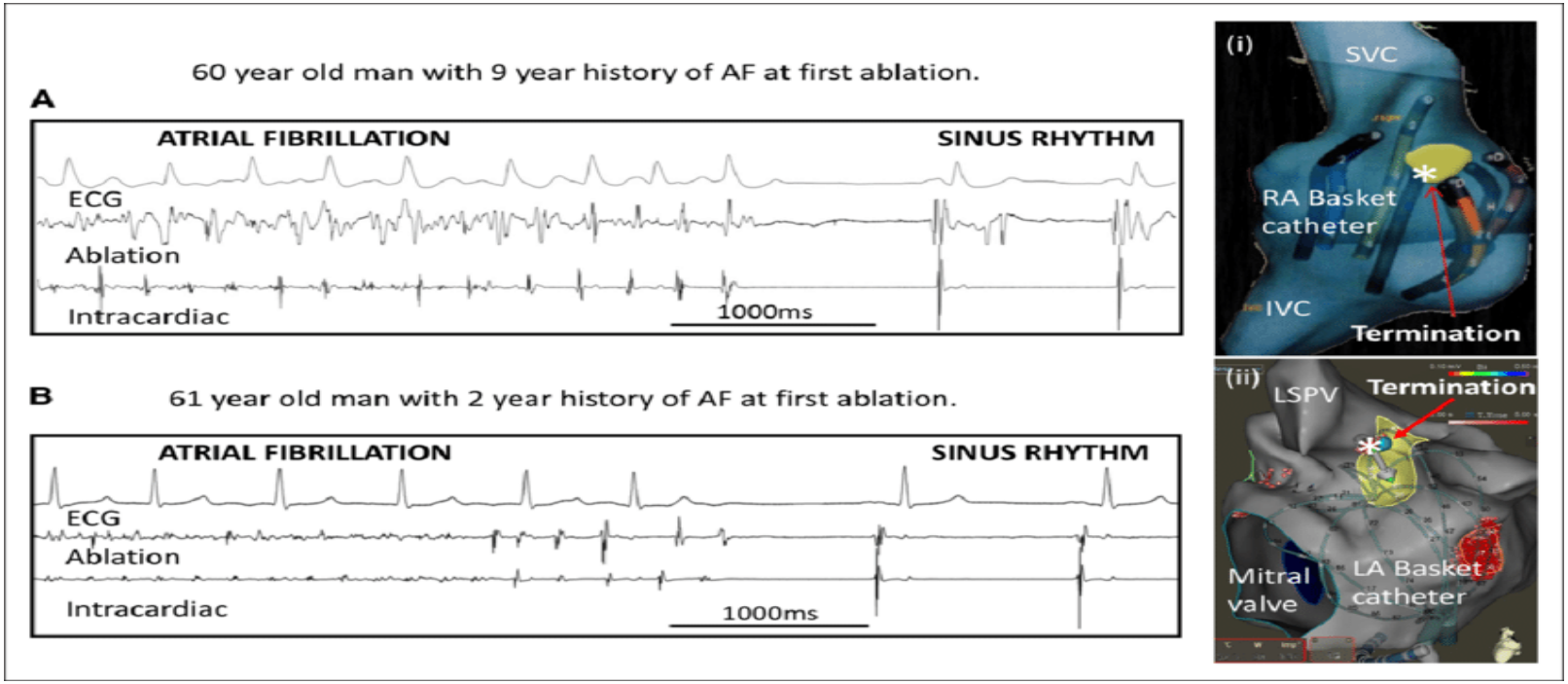
https://www.ahajournals.org/doi/epub/10.1161/01.CIR.0000046082.16495.8F

Catheter Ablation of Arrhythmias –visualization 1.3

Ablation of an SVT. Two electrocardiographic recordings (ECG) and a recording from a catheter in the atrium are shown during an episode of SVT at 230 beats/min. Radiofrequency (RF) energy is delivered at a spot chosen by mapping. Tachycardia stops suddenly and normal rhythm resumes after 2 seconds of ablation energy.

https://www.ahajournals.org/doi/epub/10.1161/01.CIR.0000046082.16495.8F

Catheter Ablation of Arrhythmias – visualization 1.4



Acute termination in patients with persistent atrial fibrillation by first ablation.

IVC indicates inferior vena cava; LA indicates left atrium; LSPV, left superior pulmonary vein; RA, right atrium; and SVC, superior vena cava.

https://www.researchgate.net/figure/Acute-termination-in-patients-with-persistent-atrial-fibrillation-AF-by-first-ablation_fig1_322468428

Complications associated with catheter ablation

- Complications are rarely seen with catheter ablation, but they can include cardiac perforation, pericardial effusion, cardiac tamponade, vascular access complications (bleeding, pseudoaneurysms), pulmonary vein stenosis, thromboembolism, atrioesophageal fistula, left atrial flutter/tachycardia, and phrenic nerve injury (which is more common with cryoballoon ablation).
- Death, myocardial infarction or stroke (0.05% to 0.01%) .
- Heart block, which requires a permanent pacemaker (0.5%) and is mainly dependent on the proximity of the ablation lesion to the atrioventricular node.
- Thromboembolic complications including systemic and venous embolism (pulmonary embolism) are more common 5%.
- Vascular accesses complications, including arteriovenous fistula, aneurysm, and other complication are far more common 2% to 4%.

https://europepmc.org/article/med/29262168

Enhancing Healthcare Team Outcomes

- Catheter ablation is now the mainstay treatment of most arrhythmia, it can offer a better choice for those suffering recurrent arrhythmias, and is a permanent treatment with greater than 90% success rate of Ablation.
- While catheter ablation is usually done by a cardiologist, the monitoring and follow up of the patients is done by the primary care provider, internist and nurse practitioner.
- Even though the success of catheter ablation is high for many atrial arrhythmias, the procedure is also associated with a fair number of serious complications that include death, pulmonary vein stenosis, esophageal perforation, heart block requiring a pacemaker, stroke, phrenic nerve injury, and vascular access complications.
- It is important to educate the patient on the potential complications before the procedure.

https://www.ncbi.nlm.nih.gov/books/NBK470203/

Thank you for attention!