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# Introduction to cardiac electrophysiology and assessment of sinus node and atrio-ventricular conduction

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## Abstract

**Background:** Interest in cardiac electrophysiology is increasing in sub-Saharan Africa, but the interpretation of results is poorly understood. Cardiac electrophysiology is the study of electrical activity of the heart by virtue of catheters that are positioned in the heart, as opposed to leads placed on the chest surface. It is useful in identifying sites of origin of various cardiac arrhythmias, diagnosing conduction abnormalities and treating various arrhythmias
**Material and method:** This study is a review of cardiac electrophysiology methods. It aims to help physicians understand and interpret cardiac electrophysiology reports.

Keywords: Electrophysiology, intracardiac catheters, leads, sino-atrial node, atrio-ventricular node, conduction

## Introduction
A cardiac electrophysiology study (EPS) is an invasive percutaneous cardiac procedure. It is used in management of various serious arrhythmias. The study also accesses the conduction systems, unravels the underlying mechanism and location of initiation of arrhythmia, helps determine risk and the type of (and need for) treatment. Interest in cardiac electrophysiology is increasing in sub-Saharan Africa, but the interpretation of results is poorly understood. It is helpful that the physiology should be appreciated even before undergoing training. This article presents an overview including physiology, indications, basic procedure and summary evaluation of sinus node and atrio-ventricular-nodal conduction.

## Basic physiology
The EPS starts with placing catheters in the heart to acquire intracardiac electrical signals, displayed as intracardiac electrograms (IEGs). Since a negative deflection is always inscribed when an electrical pulse is moving away from the recording electrode, a sharp negative unipolar signal denotes the point of origin of the impulse, which then spreads away to the rest of the myocardial tissue. In a baseline EPS, the EGMs are usually obtained from catheters located in the following anatomical structures: the high right atrium near the sinus node (HRA), the His-bundle (His), the Coronary sinus (CS) and the apex of the right ventricle (RV).

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Figure 1: Cardiac electrophysiology graph

The most common displayed format (Figure 1) follows the sequence of the normal impulse during sinus rhythm and includes from top to bottom: two or three ECG leads (usually I, III and V1), HRA, His distal, His proximal, CS 1-10 and RV.[1] The graphs were observed at a program which has been previously reported.[2]

**Indications for cardiac electrophysiology**

An EPS precedes each catheter ablation and serves to[3] 1) Characterize the baseline His-Purkinje conduction system; 2) Determine the presence of an arrhythmia substrate such as abnormal AV connections (accessory pathways)/dual AV nodal physiology, zones of conduction block (such as an atrial scar in congenital heart disease (CHD) or post-surgery); 3) Initiate tachycardia for determining its underlying mechanism, with or without pharmacological provocation (isoprenaline, atropine, and adrenaline; 4) Apply electrophysiological maneuverers for the differential diagnosis; and 5) Establish the correct diagnosis. Electrophysiological manoeuvres are also made after ablation to confirm success, assess the integrity of the His-Purkinje conduction system, and check for additional tachycardia substrates.

**Catheter placement and electrocardiogram definitions**

The multipolar catheters are introduced mostly through the femoral veins. The electrodes at the distal end help monitor electrical activity. The proximal end of each electrode is connected to a system for recording intracardiac electrograms. Most commonly, the two distal electrodes on the high right atrial (HRA) catheter and the right ventricular (RV) catheter are used for pacing. The remaining electrodes are used for recording purposes. Catheters (Figure 2) are placed as below:[4,5]

1. High right atrium: lateral wall of the right atrium at right atrium—superior vena cava junction.
2. Coronary sinus: runs transversely in the left atrioventricular groove on the posterior side of the heart.
3. His bundle: the high septal part of the right ventricle.
4. Right ventricular apex: apical right ventricle.

**Baseline analysis**

The baseline analysis of intracardiac recordings starts with the measurement of the time intervals between consecutive signals.[4] Since the sinus node is located high in the right atrium, the first atrial bipolar EGM is recorded form the HRA catheter, followed by the atrial signals in the His catheter and the proximal poles of the CS catheter. The most delayed atrial signal is normally inscribed from the distal pole of the CS catheter (CS 1, 2), which is located at the lateral wall of the left atrium. The atrial signals are followed from the His signal and after that from the RV signal. The baseline time intervals (Figure 3) measured are:

PA Interval: from the onset of the P wave (synchronous to P wave on surface ECG) to the onset of the low atrial signal in the His EGM, showing intra-atrial conduction time (25 to 55 ms.

AH Interval: from the beginning of A wave (synchronous to P wave on surface ECG) to the sharp His signal (55 to 125 msec).

HV Interval: from the beginning of the His deflection to the earliest identified ventricular

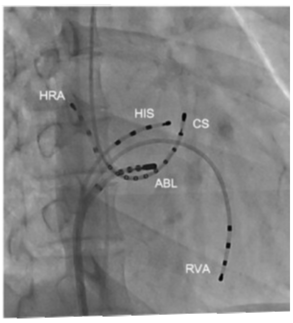


Figure 2: Fluoroscopic views in the right anterior oblique projection showing the catheter position[6]

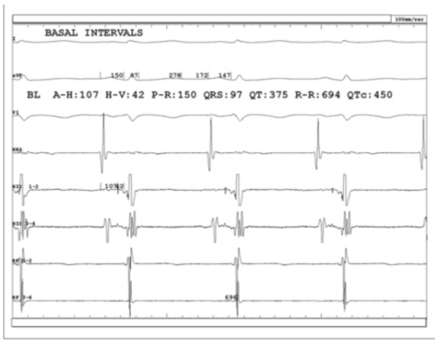


Figure 3: Measurement of basal intervals

activity on the surface ECG (35 to 55 msec).

**Evaluation of the sinus node**

Sinus node function is evaluated in patients who present with syncope or presyncope and we need to demonstrate the causal relationship between the two so that a permanent pacemaker can be advised. The sinus node recovery time (SNRT) is determined by pacing the right atrium at cycle lengths between 600 and 350 msec for 30 to 60 seconds.[7] The SNRT is defined as the interval between the last paced atrial depolarization and the first spontaneous atrial depolarization resulting from activation of the sinus node (Figure 4). The SNRT is corrected for the underlying sinus cycle length (SCL) and is expressed as the corrected SNRT (CSNRT = SNRT − SCL). A corrected SNRT greater than 525 msec is generally considered abnormal.

**Evaluation of atrioventricular conduction abnormalities**

A prolongation of the AV interval in the His EGM denotes a block within the AV node. Longer duration or splitting of the His EGM in two reflects a conduction delay within the His bundle, while a significant prolongation of the HV time (more than 100 ms) indicates a block below the AV node in the His-Purkinje system. These indicate pacemaker implantation since they can progress to a complete AV block.[8,9]

If the duration of His EGM is normal, the AV conduction is assessed by atrial extra-stimuli pacing or by incremental atrial pacing. A gradual prolongation of the AH interval is a normal response of the AV node called "decremental conduction". This conduction delay of incoming impulses prevents potentially dangerous ventricular tachycardia.

In a block at the AV node, an atrial signal without following His and ventricular signals is recorded in His bundle EGM. In a block distal to the AV node the atrial signal is followed by a His deflection without a ventricular signal (Figure 5). This warrants pacemaker implantation.[10]

Determining the Wenckebach point is important in the assessment. A train of pacing stimuli are delivered, beginning with the patient's cycle length, and gradually reducing the cycle length after about four beats. When a beat is dropped, the responsible cycle length is called the AV or VA Wenckebach (Figure 5). It is normally between 350–450 ms or 150-200/min. The absence of V-A time prolongation at higher pacing rates suggests conduction using an accessory pathway (AP). Severely impaired AV conduction is associated with a Wenckebach point less than 100 bpm. A common method of supraventricular tachycardia (SVT) induction with a pacing train (S1) just above Wenckebach rate. This causes delay in the AV node, which allows retrograde pathway recovery, and re-entry.[11]

Extra-stimulus testing is when an extra-stimulus


Figure 4: Measurement of the sinus node recovery time

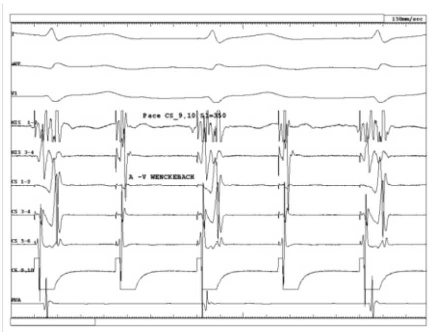


Figure 6: Determining the Wenckeback point on incremental pacing.

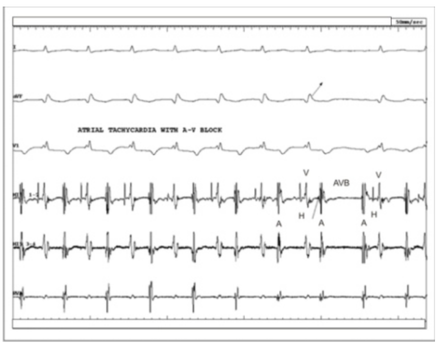


Figure 5: A supra His AVB: Atrial electrogram without His and ventricular electrogram

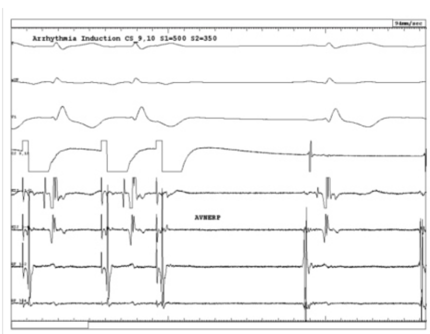

Figure 7: Extra-stimulus pacing to determine the effective refractory period.

follows a train of eight stimuli. The fixed train help establish a reproducible conduction velocity, so the effect of the varying S2 can be observed. At shorter coupling intervals the extra stimulus is delayed at the AV node, until it blocks, described as the effective refractory period (ERP) of the AV node (Figure 7). Normal AVN ERP is 250–400 ms. The ERP can also be determined for the atria, retrograde AVN conduction, ventriculo-atrial conduction and the ventricle

The refractory period ensures that contraction and most of relaxation are complete before another action potential is initiated. It prevents repeated stimulation. A short refractory period at any point can cause a tachycardia, and that pathway should be ablated. Before block occurs, if enough delay is induced, the retrograde limb of a tachycardia may recover, and a re-entrant arrhythmia is induced. The extra-stimulus is a physiological method of inducing an arrhythmia as it mimics an ectopic, which triggers arrhythmias in most patients.[12]

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