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Autor: Schuilenburg, R.M.

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Department of Cardiology and Clinical Physiology
Wilhelmina-Gasthuis, University of Amsterdam

His bundle electrography

R. M. Schuilenburg

His bundle electrography is a simple method which provides a substantial aid in the analysis of disturbances of conduction and rhythm.

The recording of the His potential makes a functional evaluation of three parts of the A-V conduction system possible, that is of the A-V node, of the His bundle itself and of the bundle branch-Purkinje system. The assessment of the conduction times from atrium to His bundle, through His bundle and from His bundle to ventricles will give, in the presence of abnormal A-V conduction, important information concerning the localization of the defect. Moreover the site of impulse formation in ectopic rhythms can be defined. The three parts of the A-V conduction system can be stressed and thereby tested with regard to their function by intracardiac stimulation procedures. These procedures may also be used in the analysis of the different kinds of re-entrant arrhythmias.

In our studies we use as a routine four bipolar or tripolar electrode catheters introduced in both femoral veins with a modified Seldinger technique, one positioned across the tricuspid valve for the recording of the His potential, another for the recording of a high right atrial potential, and two for stimulation purposes, in the right ventricular apex and against the atrial septum.

We use Elema equipment for the recording of the intra- and extracardiac electrocardiograms: the EMT 12 general amplifier for the amplification of the bipolar His bundle signal and an 8 or 16 channel direct writing ink-jet recorder. For our stimulation studies we use a stimulator which has been developed after long years of animal experimentation and built according to our specifications by the laboratory of Medical Physics of the University of Amsterdam.

This stimulator meets the standards of safety and reliability, which are required for use in the human heart. The time intervals of the stimuli of the basic driven rhythm and of the 3 or 4 test pulses, which may be applied, can be adjusted with an accuracy of 1 msec.

The His bundle potential, usually a biphasic or triphasic deflection of 15 to 25 msec duration, splits the P-R interval in an A-H interval, representing the conduction time through atrium and A-V node and an H-V interval, representing the conduction time through the His bundle and bundle branch-Purkinje system.

Our normal values are: A-H 117±36 msec and H-V 43±14 msec (mean ±2 S.D., n = 28). The longest A-H interval observed in normal subjects was 150 msec. The longest H-V interval 55 msec.

The A-V conduction may be stressed by *atrial pacing tests* in two ways, the first by *stepwise increases of atrial driving rate*, and the second by the application of *atrial test stimuli* during regular driving. During rate increases the A-H interval gradually increases as rate goes up, until at a critical driving rate a Wenckebach phenomenon occurs in the A-V node. The H-V interval remains constant. Thus, in normal conditions the A-V node is the weakest link in this test. A-V conduction is thought to be abnormal, if an A-H Wenckebach occurs at a lower rate than 140 per minute or when conduction disturbances at a lower level than the A-V node are observed.

The other way to stress A-V conduction is the application of atrial premature beats during regular atrial pacing. Gradual shortening of the coupling interval of the premature beat results in gradual shortening of the corresponding intervals of the His potentials. Usually a minimum coupling interval of the His bundle potentials can be found, which is defined as the functional refractory period of the A-V node (FRP_{AVN}). Further shortening of the atrial coupling interval results in widening of the corresponding His activation interval due to progressive delay in the A-V node, until at a critical atrial coupling interval the impulse is blocked completely within the A-V node. This last atrial coupling interval is termed the effective refractory period of the A-V node (ERP_{AVN}). The functional and effective refractory periods of the A-V node measured in this way can be used as parameters of A-V nodal function.

Our normal values assessed at an atrial driving rate just above the sinus rate are FRP_{AVN} 390±110 msec, ERP_{AVN} 290±80 msec (mean ±2 S.D.). In some patients (25%) the ERP_{AVN} can not be measured because A-H conduction remains present until the refractory period of the atrium is reached. In normal conditions the A-V node is shown to be the weakest link also with this test.

In pathological conditions and sometimes in normal individuals block of early premature atrial beats may occur in the His bundle or in the bundle branch system and the refractory period of these structures can be measured.

In the following discussion I would like to focus upon one application of His bundle electrography, that is its use in analysis of disturbances of atrioventricular conduction, to start with the most pronounced degree of conduction abnormality the *complete A-V block*.

If a third degree block is localized in the *A-V node*, this will be evident from the complete dissociation between atrial and ventricular activations and the constant temporal relation of the His potential with the ventricular activation. The focus activating the ventricles is located within the distal part of the A-V node or in the proximal part of the His bundle. Usually the QRS complexes are narrow, although bundle branch block may co-exist. In this type of block the ventricular rate may rise considerably after the administration of atropin.

Complete block in the A-V node may be transient if caused by an acute inferior myocardial infarction or by digitalis intoxication. We estimate that in about one quarter of patients with chronic third degree A-V block the block is localized in the A-V node.

Recently we have been able to demonstrate that a complete block may also be located *within the His bundle*. Characteristically the bipolar His bundle recording shows that the His potential is split in two components, of which one (H) bears a constant time relation with the atrial activation, while the other (H') precedes each ventricular complex. This is thought to result from overriding of the zone of block in the His bundle by the two electrodes, which have a distance of 10 mm. Usually the QRS complexes are normal. If there is a co-existent bundle branch block, it is difficult to predict from the conventional ECG that the A-V block is located at a higher level than the bundle branches.

With the forementioned atrial stimulation procedures it can be shown that in most cases A-V nodal conduction is normal. If carefully sought for, complete His bundle block appears to be a relatively frequent abnormality. We estimate it to be present in 15 to 20% of cases with complete A-V block. The most frequent type of complete A-V block, however, is the *complete bilateral bundle branch block*, caused by a primary degenerative process as described by Lenègre, by sclerosis of the cardiac skeleton as described by Lew or by ischemic heart disease.

In these patients the His bundle potential is related to the atrial activation. The ventricles are activated by a focus in the distal bundle branch-Purkinje system, giving rise to a slow ventricular rhythm with broad QRS complexes. Atrial stimulation procedures demonstrate that the conduction through the A-V node is normal in most cases.

His bundle recordings are also helpful in localizing the conduction defect in *second degree A-V block*. Its manifestation in the A-V node is a Wenckebach or a 2:1 relation between atrial activations and His bundle potentials. A Mobitz II type of block, in which one atrial beat is blocked without gradual lengthening of the conduction time in the preceding beats, like in the case of the Wenckebach phenomenon, is not observed in the A-V node. On the other hand, in the His bundle the Mobitz type II block is a relatively frequent form of second degree block. An electrocardiogram showing a Mobitz type II block with normal narrow QRS complexes must raise the suspicion of a conduction disturbance in the His bundle. A Wenckebach type of block, however, may also occur in the His bundle. This Wenckebach type of block is not, as previously was thought, confined to the A-V node, but may be found in all parts of the A-V conduction system. Thus, it may be observed also in the bundle branch system, especially in patients with partial bilateral bundle branch block.

Here the H-V interval shows a beat-to-beat increase (sometimes to values as great as 280 msec) until finally one beat is blocked below the His bundle.

More common in the bundle branch system is the Mobitz type II block. In this type of block there is sudden block of the H-V conduction of one atrial beat, without lengthening of the H-V intervals of the preceding beats. Like the Wenckebach block, the Mobitz II block occurring at the bundle branch level is a manifestation of partial bilateral bundle branch block.

Now we come to the less pronounced form of conduction disturbance: *the first degree block*. A first degree block within the *A-V node* usually presents a prolonged P-R interval in the conventional ECG. His bundle recordings will reveal that this R-P prolongation is due to a prolonged A-H interval. As a rule the atrial stimulation tests will demonstrate a depressed A-V nodal function. The rate at which an A-W Wenckebach occurs will be well below 140 per minute and the refractory periods of the A-V node will be prolonged.

On the other hand a first degree block in the *His bundle* may go unrecognized in the surface ECG. The P-R interval and the QRS configuration may be completely normal. His bundle electrography gives the diagnostic clue in this treacherous conduction disturbance, which may show an unexpected and transient progression into a second or even third degree block, by the demonstration of a splitting of the His potential in two components of which the interval may amount to 55 msec. Increases of the atrial driving rate will result in second degree block in the His bundle of the Wenckebach or Mobitz II type. Atrial premature beats with a critical coupling interval will be blocked within the His bundle, thus allowing the assessment of the effective refractory period of the His bundle, which value will be in most cases considerably longer than the functional refractory period of the A-V node.

A few remarks on the effect of the atrial stimulation tests in patients with bundle branch block and 1:1 A-V conduction. In about one quarter of these patients second degree block in the still conducting part of the bundle branch system may be observed on increasing atrial driving rate. This amounts to one third of the patients who have a prolonged H-V interval during the spontaneous rhythm. Atrial premature beats may be blocked in the conducting part of the bundle branches in one third of the patients. In these patients atrial stimulation tests may therefore demonstrate coexistent conduction abnormalities in the non-blocked parts of the bundle branch-Purkinje system.

In our material 65% of the patients who had a history of intermittent cerebral ischemia (Adams-Stokes attacks, syncopes or repeated attacks of dizziness) showed a prolonged H-V interval during the spontaneous rhythm, and atrial premature beats were blocked in the bundle branch system in 45%.

The available time does not allow to give a detailed analysis of the many different combinations of conduction disturbances, nor to discuss interesting and clinically relevant phenomena like supernormal conduction, gap phenomena and reentry, as they may be studied with the previously described stimulation techniques.

To summarize, His bundle electrography provides a useful mean to locate atrioventricular conduction defects, especially if combined with atrial stimulation. The method is simple and can be applied by anyone who has the facilities to record a high fidelity electrocardiogram and to introduce a catheter into the heart.

Summary

In this presentation the use of His bundle electrography in the diagnostic localization of atrioventricular conduction defects is discussed. The recording of the His potential allows an identification of conduction disturbances at a level above, in, or below the His bundle.

Atrioventricular conduction can be stressed and latent conduction abnormalities thereby unmasked by atrial stimulation tests, such as the gradual increasing of the atrial driving rate, or the application of single atrial premature beats of which the coupling interval is gradually shortened. These stimulation methods make a quantitative characterization of the impulse conduction in the different parts of the A-V conduction system possible.

Zusammenfassung

In dieser Arbeit wird die Anwendung der His-Bündelelektrokardiographie zur Lokalisationsdiagnose von AV-Leitungsstörungen diskutiert. Die Aufzeichnung des His-Potentials erlaubt die Identifikation der Leitungsstörungen auf einem Niveau über, im oder unter dem His-Bündel.

Die AV-Leitung kann forciert werden und dadurch können latente Leitungsabnormitäten mittels Vorhofstimulationstests aufgedeckt werden, so etwa durch stufenweises Steigern der Vorhoffrequenz oder durch die Anwendung einzelner vorzeitiger Vorhofschläge, deren Kupplungsintervall stufenweise verkürzt wird.

Diese Stimulationsmethoden ermöglichen ein quantitatives Erfassen der Impulsleitung in den verschiedenen Anteilen des AV-Leitungssystems.

Résumé

Dans cet article l'auteur discute des possibilités offertes par l'ECG du faisceau de His pour localiser les troubles de conduction du système atrioventriculaire. L'enregistrement des potentiels du faisceau de His permet d'identifier les troubles de conduction situés au-dessus, dans ou en-dessous du faisceau de His.

Il est possible de surcharger la conduction atrio-ventriculaire dans le but de mettre en évidence des anomalies latentes de conduction par stimulation des oreillettes, par exemple en augmentant graduellement la fréquence auriculaire, ou en provoquant quelques pulsations auriculaires précoces, dont l'intervalle de de transmission est progressivement raccourci.

Ces méthodes de stimulation permettent une appréciation quantitative de la transmission de l'influx nerveux dans les différentes parties du système atrio-ventriculaire.

Riassunto

In questo lavoro viene discusso l'uso dell'elettrocardiografia del fascio di His nella localizzazione diagnostica dei disturbi della conduzione atrio-ventricolare. La registrazione del potenziale di His permette l'identificazione dei disturbi della conduzione a diversi livelli, prima, nel e dopo il fascio di His. La conduzione atrio-ventricolare può venir sollecitata oltre un livello critico, così da smascherare anomalie latenti della conduzione, ad esempio grazie all'elettrostimolazione atriale con aumento graduale della frequenza, oppure suscitando extrasistoli atriali con intervalli di accoppiamento progressivamente ridotti. Questi metodi di stimolazione rendono possibile una valutazione quantitativa della conduzione dell'impulso elettrico nelle diverse sezioni del sistema di conduzione atrio-ventricolare.

Address of author: Dr. R. M. Schuilenburg, Cardiologische kliniek, Academisch Ziekenhuis, Eerste Helmersstraat 104, Amsterdam-Oud west, The Netherlands