Non-invasive recording of His bundle potential in man

Simplified method

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In 6 cases with sinus rhythm and one with atrial fibrillation, the bipolar surface electrocardiograms were taken through band pass filters simultaneously with the intracavitary His bundle electrogram, and averaged using a signal processor. By these relatively simplified procedures 'blips' considered to be derived from His bundle potentials between PR segments could be recorded. It was found that 'blips' originating from the His bundle were recorded most distinctly when a cathode was applied to the posterior mid-line and an anode to the sternum, both at the level of the fourth intercostal space. In some instances it was possible to record 'blips' probably derived from the bundle-branches. To identify the onset of ventricular potentials it was necessary to refer to the surface electrocardiograms taken with a usual time constant. The interval from the onset of 'blip' to the onset of ventricular activity (BV) agreed perfectly with the directly recorded His bundle to ventricle conduction time (HV) in 6 out of 7 cases investigated, and in the remaining case this interval was found to be only 1 ms longer than the HV.

His bundle electrography has so far been considered essential for the diagnosis and study of atrioventricular conduction disorders, but as it requires catheterization it cannot always be so readily employed. For the benefit of patients it is better to use non-invasive approaches as much as possible. Recently, reports have appeared on the recording of potentials during the PR interval in dogs (Berbari *et al.* 1973; Flowers *et al.*, 1974). We report here our recordings of 'blips' considered to represent the His bundle potential using a simpler procedure than those hitherto described.

Subjects and methods

The subjects in this study were 7 patients undergoing cardiac catheterization (4 male and 3 female), 6 with sinus rhythm and 1 with atrial fibrillation. Using the method of Scherlag *et al.* (1969) His bundle electrograms were recorded from the ventricular cavity, and simultaneous bipolar surface electrocardiograms were taken through band pass filters with a high frequency cut-off at 300 Hz and low cut-offs at 80 Hz on a data recorder (Nihon Kohden Co., RMB 5104) by applying a cathode to the midsternal line and an anode to the posterior mid-line at the level of the 4th intercostal space.

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The signals obtained were passed to a signal averager (Nihon Kohden Co., ATAC 201) which was triggered by the P waves amplified from the oesophageal lead, or by QRS complexes when replaying the tape in reverse. The input was fed into the signal averager after amplifying it by a DC-amplifier (Nihon Kohden Co., RB-5). The total amplification was set at about 100,000-fold. 'Blips' thus obtained from PR segmental potentials were compared with the His bundle electrograms recorded by the intracardiac catheter.

Results

Changes in the PR segmental potentials obtained by averaging are shown in Fig. 1. Averages obtained from over 100 cycles satisfactorily demonstrated 'blips'. There were some cases where 500 cycles were required, but on the whole averaging repeated over more than 100 times resulted in only a slight improvement of signal-noise ratio (Fig. 1c and d).

The results of our study on the reproducibility of the 'blips' obtained from PR segmental potentials are shown in Fig. 2. The first half of the taped tracings were averaged by triggering from the P wave and the last half by triggering from the QRS complexes when the tape was played in reverse, and the two averages obtained were compared: the two

FIG. 1 The numbers of cycles averaged to obtain 'blip' on the PR segment. Panel (a) and (b): 10 and 32 cycles averaged, respectively. Panel (c) and (d): 128 and 512 cycles averaged, respectively; no significant change in the configuration of the 'blip' (B₁) on the PR segment results from the greater number of averaged cycles. ASA: Atrial activity in surface averaged electrogram. VSA: Ventricular activity in surface averaged electrogram. TSA: T wave averaged.

configurations coincided well, indicating satisfactory reproducibility.

In averaging surface electrocardiograms through band pass filters as described, the onset of the ventricular potentials often became obscure because of overflow of the amplitude. For this reason, to time the onset of ventricular depolarization, electrocardiograms recorded with a time constant of 2.0 s were averaged simultaneously with those passed through the band-pass filter; the onset of QRS complexes was then clear and served as a reference (Fig. 3).

In Fig. 4a and b are shown the results of simultaneous recordings of the averaged surface potentials and of the intracavitary His bundle potentials from two patients with sinus rhythm. Fig. 4c also gives the results from the patient with

atrial fibrillation. In all of these cases the 'blips' derived from the PR segment potentials by averaging (B₁) coincided with the His bundle potentials recorded directly.

The Table shows the BV and HV intervals from the 7 patients for comparison. While there was 1 patient with difference of 1 ms in the interval, in the other 6 BV and HV intervals were identical. In these cases the duration of B₁ was 7 to 15 ms.

Discussion

Since, in the electrocardiogram from the body surface, the potentials of the atrioventricular conduction system, especially those of the His bundle, are only a few microvolts at best, they do not appear at all on routine tracings. When the signals are amplified, they become lost in noise so as to be unrecognizable. When the recordings are analysed from a fixed triggering point and are averaged over tens to hundreds of cycles by a signal processor, however, random noise is averaged out whereas signals located at a fixed distance from the trigger become amplified. By applying this principle, we obtained 'blips' from the surface electrocardiogram by averaging PR-segmental potentials using P waves or QRS complexes as a trigger and compared these with a directly recorded intracavitary His bundle electrogram. We found that the onset of both deflections coincided perfectly. In every case, the duration of the 'blips' was 7 to 15 ms, which is similar to the values for the His bundle electrogram so far reported (Narula *et al.*, 1971). A particular advantage of our method lies in the technique of playing the recorded tape backwards (T, QRS, and P in that order), so that we were able to obtain the averages between QRS complexes and P waves without using a large computer with a signal processor. Taking into account the anatomical position of the His bundle, we tried various sites for the surface electrodes, such as in the midline posteriorly at the height of V₄ for the cathode and in the midsternal line or anterior axillary line at the level of the fourth intercostal space or in normal electrocardiographic V₄ position for the anode. It was found that the recordings could be clearly made in every case on the sternum at the 4th intercostal space. None the less, in patients with extreme cardiac enlargement or axis rotation, the above positions may not necessarily be found to be the best; further studies would be required in this respect.

We have selected the posterior midline as an anode and the sternum as a cathode for the time being, but the polarity may be either way, and it can be expressed by an upward deflection or by a

downward deflection simply by changing the polarity of the signal processor. Consequently, irrespective of the polarity of the deflection a sharp one should be taken as the 'blip' derived from the His bundle.

We have encountered some cases (Fig. 4b) where initial 'blips' (B₁) were followed by other 'blips' from the bundle-branch (B₂). Using the method applied here, however, the latter was not always

recordable in every case, and it seems necessary to consider a different lead system to obtain these in all cases. BV and HV were identical in 6 out of 7 cases including the patient with atrial fibrillation and in the remaining one differed by only 1 ms. It may not be wrong, therefore, to say that 'blip' (B₁) on the surface-averaged electrocardiogram represents the His bundle potential itself.

FIG. 2 Panels (a) and (b) show two examples of averaged tracings. Upper row: A tracing averaged by P wave triggering. Lower: A tracing averaged by triggering from the QRS complex (see the text). BV: Interval between onset of 'blip' and onset of ventricular activation.

FIG. 3 Simultaneous recording of the surface averaged electrocardiogram (Panel (b)) through the band pass filters of 80-300 Hz, and the standard electrocardiogram (Panel (a)) averaged in several cycles. The latter was used as a reference to indicate the onset of ventricular activation. BV: Interval between the onset of 'blip' and the onset of ventricular activation.

Flowers *et al.* (1974) have pointed out that the onset of the ventricular potential in the surface-averaged electrocardiogram begins somewhat earlier than the ventricular potential of the intracavitary lead, and that the BV interval is occasionally shorter than the HV interval. This may be explained by the fact that in the electrocardiogram obtained through the band pass filter the potentials of the conduction system immediately before the excitation of the ven-

tricle are increased greatly by averaging, thus causing an overflow of amplitude which masks the onset of the QRS complex. Therefore, we referred to the averaged potentials of the electrocardiogram as recorded with the usual time constant, in order to mark the onset of ventricular excitation in the averaged surface potentials. By this means we have found that the onset of ventricular excitation agreed well with that of the His bundle electrogram.

FIG. 4 (a) A 60-year-old man with arteriosclerotic heart disease; (b) A 32-year-old man with idiopathic cardiomyopathy. (c) A 35-year-old woman with atrial fibrillation and mitral regurgitation.

In every case, the 'blip' (B_1) shown in the PR segment corresponds to the His bundle potential directly recorded. HBE: His bundle electrogram. SAE: Surface averaged electrogram. HV: His bundle potential to ventricle conduction time. BV: 'Blip' to ventricle conduction time.

TABLE

Case No.	Age (yr)	Sex	Diagnosis	Rhythm	HV (ms)	BV (ms)
1	60	M	ASHD	NSR	32	32
2	32	M	ICM	NSR	34	34
3	56	M	ASHD	NSR	46	46
4	39	M	RHD, MR	NSR	40	41
5	35	F	RHD, MR	AF	26	26
6	29	F	RHD, MS	NSR	43	43
7	30	F	RHD, MS, MR	NSR	36	36

Notes: ASHD=arteriosclerotic heart disease, ICM=idiopathic cardiomyopathy, RHD=rheumatic heart disease, MS=mitral stenosis, MR=mitral regurgitation, NSR=normal sinus rhythm, AF=atrial fibrillation.

As described, the recording of His bundle potentials by a non-invasive and simplified method from the body surface has been shown to be clinically applicable. It seems possible that by further studies recordings of the potentials of the bundle-branch may be obtained more distinctly.

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