Noninvasive Recording of His Potential Using Magnetocardiograms

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The present study investigated whether magnetocardiograms (MCGs) could noninvasively detect the His potential. In 22 patients, the His–ventricular (HV) intervals in MCGs (64-channel system, 2-min signal averaging, filter: 0.1–100 Hz, and band-eliminating filter of 50 Hz) were compared with those recorded in an electrophysiologic study (EPS, filter: 30–400 Hz). In 14 of the patients (64%), the His potential was recorded in the MCGs. There was a correlation between the HV intervals in the MCGs and those in the EPS (R=0.81, p<0.01). This study indicates that MCGs can be used to investigate the specialized conduction systems for which EPS is currently used. (Circ J 2003; 67: 622–624)

Key Words: His potential; Magnetocardiograms; Signal averaging

An invasive procedure, such as an electrophysiologic study (EPS), is required to diagnose the origin of an atrioventricular (AV) conduction block. Both magnetocardiograms (MCGs) and electrocardiograms (ECGs) are body surface mapping techniques: MCGs record the cardiac magnetic fields using a superconducting quantum interference device (SQUID) sensors, whereas ECGs record the electrical currents using electrodes. We have reported that MCGs are more sensitive to weak electrophysiological phenomena than are ECGs and the aim of the present study was to use MCGs to noninvasively detect the His potential and measure the His–ventricular (HV) interval.

Methods

Twenty-two patients (9 manifest Wolff-Parkinson-White (WPW) syndrome, 4 AV nodal reentrant tachycardia, 4 paroxysmal atrial flutter, 3 ventricular tachycardia, 1 concealed WPW syndrome and 1 sick sinus syndrome) were examined by ECGs, EPS, and 64-channel MCG (a first-order gradiometer, sensors with an interval of 2.5 cm in an 8×8 matrix (Fig 1A), Hitachi Ltd, Japan). All patients were diagnosed from the EPS as having 1:1 AV conduction. Exclusion criteria were irregular AV conduction, rate-dependent HV prolongation or a permanent pacemaker.

His Potentials in EPS and MCGs

His potential recording in the EPS and on the MCGs was carried out after successful catheter ablation in the 9 patients with manifest WPW syndrome and before ablation in the other 13 patients.

EPS The His potential was recorded using a quadripolar catheter (6Fr, 2–5–2 mm; filter: 30–400 Hz, paper speed: 100 mm/s). It was defined as a biphasic or triphasic deflection between the atrial and ventricular potentials, and the HV interval was defined as the interval from the beginning of the His bundle deflection to the earliest onset of ventricular activation in either the ECG leads or the His bundle recordings.

MCG A 64-channel MCG system was placed in a magnetically shielded room (magnetic detection limit <20 femto tesla/√Hz) at the University of Tsukuba, Tsukuba, Japan. Cardiac magnetic fields were recorded in the anterior chest for 2 min (1-ms interval). The distance between the chest wall and the SQUID sensor was approximately 4.5 cm. ECG lead II was simultaneously recorded. Using ECG triggering (R wave), we signal-averaged the sampling data during sinus rhythm without pre-excitation (101±36 beats). The signals were filtered below 0.1, above 100 Hz, and a band-eliminating filter of 50 Hz and recorded at a paper speed of 100 mm/s. Two cardiologists, unaware of the patients’ information, judged whether or not the His potential had been recorded. On the MCGs, a His potential was defined as: (1) a high-frequency component between the atrial and ventricular potentials, (2) a potential greater than 0.08 pico tesla, and (3) a potential with starting and ending points that were clearly distinguishable from the baseline. The HV interval was defined as the interval from the beginning of the His potential to the earliest onset of the ventricular component in the 64 channels of the MCGs. We compared the His potential recorded by the MCGs and during the EPS.

Data are presented as the mean±standard deviation. The significance of associations was tested with the Student’s t-test, the paired t-test, the Pearson’s correlation coefficient, or the Bland and Altman analysis. A p<0.05 was considered to be significant.

This study was approved by the ethical committee of the Tsukuba University Hospital. All patients gave written informed consent before the study.

Results

In all 22 patients, the His potential was recorded during the EPS. The HV interval was 43±6 ms (37–58 ms). Fig 1B

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His Potential in Magnetocardiograms

His Potential in Magnetocardiograms shows the MCG signals in 3 cases: A spike potential was recorded in cases 1 and 2, but not in 3, and we defined this spike potential as the His potential on the MCGs. The HV intervals on the MCGs and those recorded in the EPS were, respectively, 45 and 58 ms in case 1, and 42 and 45 ms in case 2. In case 1, the potential was recorded on channel 22, but was not detected on the 8 channels surrounding 22 (Fig 1C). The clearest recording occurred with filtering of the signals below 0.1 Hz, above 100 Hz, and the band-eliminating filter of 50 Hz (Fig 1D).

In 14 of the patients (64%), the potential was recorded on a single channel in 10 and on 2 channels in 4. The clearest His potentials were recorded on channel 12 (1 patient), channel 14 (5 patients), channel 20 (1 patient), channel 21 (2 patients), channel 22 (1 patient), channel 23 (1 patient), channel 28 (2 patients), and channel 30 (1 patient). The potentials were distributed over an area of the left side of the chest surrounded by the sternum, the midclavicular line, and by the 2nd and 4th ribs. The HV interval of 14 cases was 41±5 ms (34–50 ms). In 6 of the 14 patients, the His potential was recorded twice, before and after EPS, and the HV interval did not differ between the 2 measurements. In 8 patients, the potential was recorded once only, because of delta waves (6 patients) or paroxysmal atrial fibrillation (2 patients) before or after EPS. Between patients with and without a His potential on MCGs, there were no differences in heart rate, averaging times, and the AV and HV intervals recorded during the EPS.

We found a linear correlation between the HV intervals on the MCGs and those recorded in the EPS (R=0.81, p=0.005, Fig 2A). The HV interval on the MCGs was significantly smaller than those recorded in the EPS (MCGs 41±5 ms, EPS 43±6 ms, p=0.003). The difference in HV intervals (EPS – MCGs) was 4±4 ms. The limits of agreement were –4 ms and 11 ms (Fig 2B). Heart rate and PQ interval did not differ between the MCGs and the EPS.

Discussion

An invasive procedure, the EPS, is necessary for precise diagnosis of the foci and mechanisms of arrhythmias and conductivities of the specialized cardiac conduction system. The purpose of the EPS is diagnosis and treatment of patients with arrhythmias, but it is only diagnostic in patients with an abnormal specialized conduction system. Noninvasive techniques are more ideal and practical than invasive ones and therefore it is advantageous if the His
potential can be recorded by ECGs and MCGs. However, the noninvasive recording of the His potential is somewhat controversial because of the need to differentiate ‘noise’ from physiological signals originating from the heart. Several methods, such as using signal averaging, lead positions, filters, type of calculation and a magnetically shielded room have been reported for ECG. Signal averaging limits the clinical indication for recording the His potential to patients with regular HV conduction because signal averaging and specific filtering may distort physiological signals. Therefore, there might be a difference between EPS and body surface mappings in the signal properties.

In the present study, we investigated the recording of His potentials on the body surface using 3 methods: signal averaging, a magnetically shielded room, and SQUID sensors. We consider that the spike potential in the MCGs corresponds to the His potential recorded in the EPS. First, the potential was recorded in the left side of the chest using bipolar leads between the esophagus and the anterior chest. Second, there was a significant correlation between the HV intervals in the MCGs and those recorded in the EPS. Statistical significant correlation between the HV intervals recorded on the body surface and those from an EPS has not been previously demonstrated.

Study Limitations
It is possible that the spike potential in the MCGs was an artifact, not a His potential. Second, the detection rate (64%) and the correlation coefficient (R = 0.81) have room for improvement. Further studies on averaging times, recording positions, and filters are required to improve the sensitivity, specificity, and reproducibility of the His potential on MCGs.

Conclusion
Signal averaging with MCG enabled us to record His potentials on the body surface, which indicates that MCG can be used to diagnose the specialized conduction system for which an EPS is currently performed.

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