Clinical SQUID Magnetocardiography at University of Tsukuba Hospital

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April 16, 2017 (STH47, HP124). A 64-channel SQUID magnetocardiography (MCG) system, MC-6400, made by Hitachi High Technologies Ltd. [1], is clinically used at Tsukuba University Hospital since 2007 [2,3]. They are routinely examining about 100 patients per month on the average. In the period between 2008 and 2016, the total number of the patients was more than 10,000. The heart diseases diagnosed in fetuses as well as adults are atrial arrhythmia, abnormal repolarization, ventricular arrhythmia, and fetal arrhythmia. SQUID magnetocardiograms produce functional images of electric behavior of the heart, which cannot be visualized by real-time MRI or X-ray CT that observe morphological changes only. SQUID can directly catch functional abnormality from temporal change of electrical current distribution images at millisecond intervals. The patient numbers clearly show that the SQUID MCG is now one of the indispensable diagnostic instruments at that hospital. Another such SQUID MCG system is also used at the National Cerebral and Cardiovascular Center, Osaka, Japan, and they had a similar success [4,5].

The routine clinical use was stimulated by the fact that the MC-6400 system received Japanese insurance reimbursement approval in 2003. It became the world's first SQUID MCG covered by the insurance (Fig. 1). This approval had significantly improved the patient statistics and accelerated the diagnostic software development.

The SQUID MCG software produces electrical heart current images, so called current arrow maps, from magnetic fields measured by a SQUID array (Fig. 2). The merit of MCG over conventional electrocardiography (ECG) measuring electric signal on the body surface is that MCG is not affected by inhomogeneous body structure surrounding the heart. Moreover, in the fetal MCG the signal from a fetal heart can be separated from mother's signal. Acceptance of MCG by the medical doctors was missing, because they were unable to understand the SQUID data easily, being educated to find abnormalities in ECG waveforms. It seemed that a lot of persevering effort would be required before practical use (not a trial use) in hospitals.

In addition to the insurance reimbursement approval, a breakthrough towards the routine use was made by the development of an algorithm and software to visualize the current arrow map, the current vector, and the magnetic field strength [6,7,8]. Furthermore, needed was the longtime effort to accumulate large-scale data of normal and abnormal hearts, and the introduction of abnormality score such as the "abnormal repolarization-degree." The doctor can

judge the disease level by using the score and, if necessary, investigate more detailed information of arrow maps and other images. The software turns SQUID data into images understandable to the doctors. The database as a knowledge storage is indispensable for reaching the routine use of the method, after the hardware and software development [9]. In general, advanced instruments need 10 or sometime even 20 years before entering routine use.

The two clinical SQUID systems are currently used for pre-operative and prognosis diagnostics. Further widespread use may help patients who cannot be retrieved by ECG. An article on the clinical status at Tsukuba University Hospital was submitted to the IOP SUST special issue "Focus on Low and High-T_c Superconducting Sensors and Detectors", tentatively scheduled to appear in mid-2017.

Fig. 1. SQUID magnetocardiography (MCG) system MC-6400 operating at University of Tsukuba Hospital.

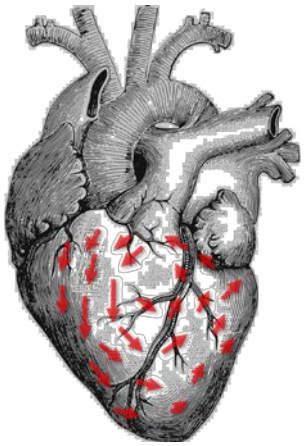

Fig. 2. Illustration of current arrow map visualized by SQUID MCG software. Dynamic change can be acquired at millisecond intervals. Current arrow maps can reveal diseases that are impossible to detect with morphological imaging techniques.

References

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