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Research Letter

Detection of Fetal Arrhythmia by Using Optically Pumped Magnetometers

Fetal magnetocardiography (fMCG) is an emerging technology that has provided invaluable insight into the mechanisms of fetal arrhythmia. Its efficacy for diagnosis and management of serious fetal arrhythmia has been acknowledged in the recent American Heart Association Statement on Diagnosis and Treatment of Fetal Cardiac Disease (1).

fMCG is based on the principle that bioelectric currents generate surface magnetic fields, as well as surface potentials, which are proportional to the net current. The main technical requirement for fMCG sensors is a magnetic field resolution of $\leq$10 fT/(Hz)$^{1/2}$ (fT= femtotesla) over a bandwidth of 0 to 100 Hz. The number of sensors needed depends on the desired coverage of the maternal surface and the level of interference suppression required of the signal processing.

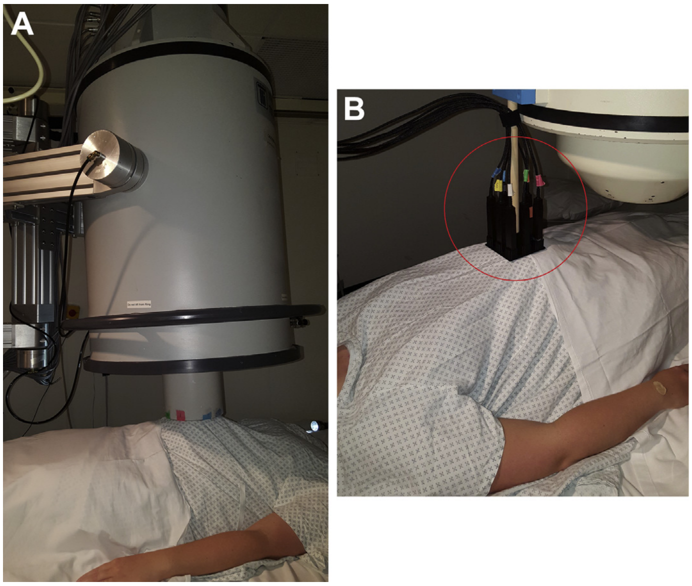
Using a 2-shell, magnetically shielded room in a typical hospital environment, a minimum of 5 to 10 sensors is required.

A major barrier to clinical adoption of fMCG is the high cost and complexity of superconducting quantum interference device (SQUID) technology (2). Recently, however, a cheaper, more practical type of magnetometer, known as an optically pumped magnetometer (OPM) (3), has become available. In this study, we compared the quality of fMCG recordings made using SQUID with those made with the OPM system.

The subjects were 15 healthy women, 8 with uncomplicated pregnancies and 7 with pregnancies complicated by fetal arrhythmia or a high risk of fetal arrhythmia.

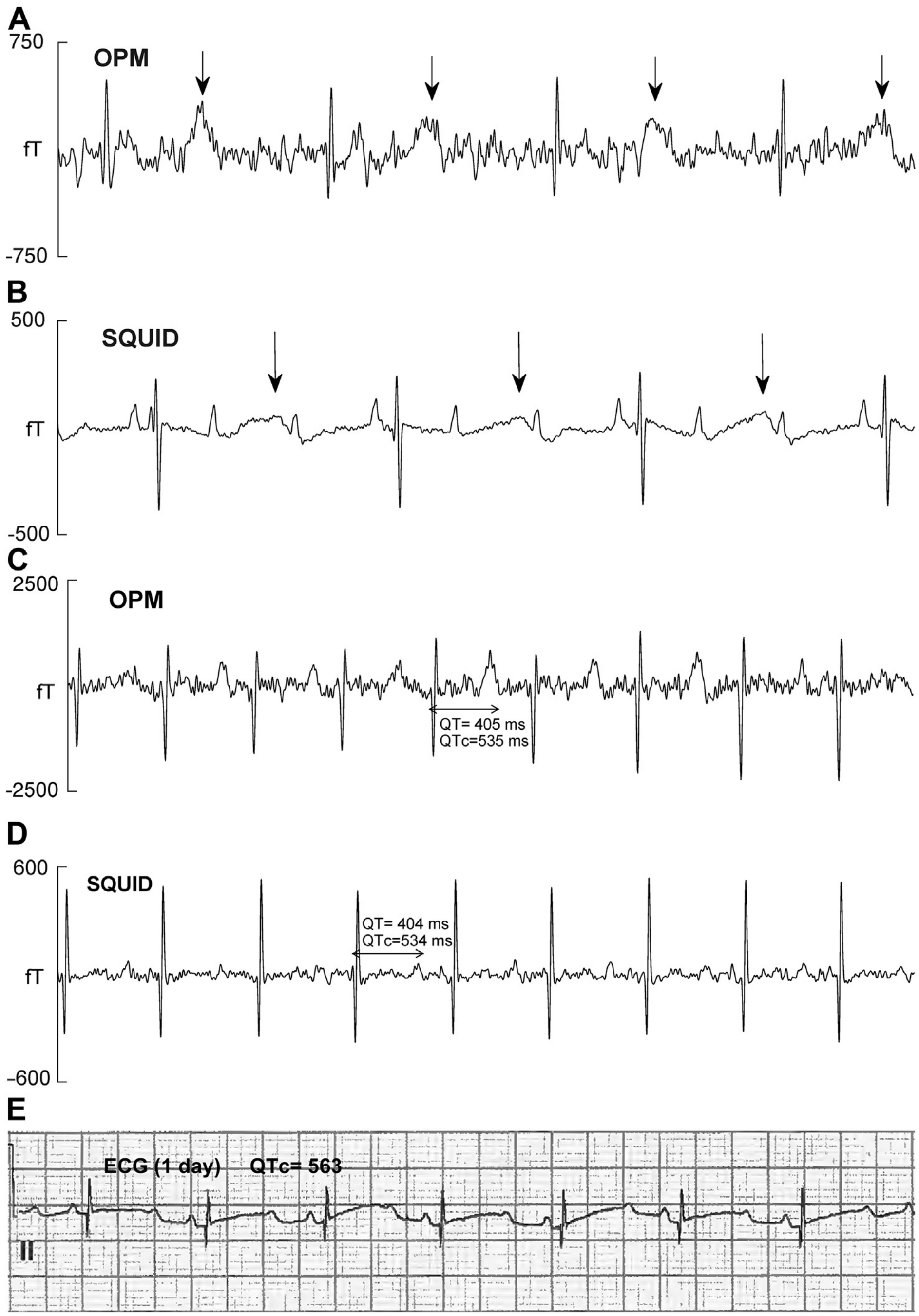
The fMCG recordings were acquired within a 2-shell, magnetically shielded room, using a U.S. Food and Drug (FDA)-approved SQUID magnetometer

FIGURE 1 Equipment Used in This Study



(A) SQUID and **(B)** OPM fMCG systems. The OPM sensor array **(circled)** was supported by attaching it to a SQUID system. fMCG = Fetal magnetocardiography; OPM = optically pumped magnetometer; SQQID = superconducting quantum interference device.

FIGURE 2 **Comparison Between OPM and SQUID Recordings**



Comparison between OPM and SQUID recordings from 4 fetuses with sustained arrhythmia. Postnatal ECGs (**E**, **H**, **K**) are shown for the last 3 fetuses. All tracings are 5 s long. **(A and B)** are from a fetus at 33-4/7 weeks with extreme QTc prolongation (QTc >700 ms), resulting in 3:1 AV block. The T waves are indicated by **arrows**. **(C and D)** Tracings are from a fetus at 29 weeks with QTc prolongation. **(F and G)** are from a fetus at 33-6/7 weeks with a complex, irregular rhythm. The predominant rhythm was ventricular bigeminy, in which a sinus beat alternates with a premature ventricular contraction. **(I and J)** Tracings are from a fetus at 30-1/7 weeks with a low atrial rhythm characterized by a low heart rate, inverted P wave, and short PR interval. ECG = electrocardiogram; other abbreviations as in Figure 1.

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