

Technical note

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## The fetal magnetocardiogram

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In magnetocardiography (MCG) the magnetic field, produced by the electrical activity of the heart, is measured. This paper presents the preliminary results of the human fetal magnetocardiography (FMCG).

The MCG of an adult heart was first recorded by BAULE and McFEE [1]. Recently, several research groups have utilized the superconducting quantum interference device (SQUID) in recording the MCG of the human heart [2, 4, 5]. Some of the MCG complexes are of high quality. The configuration of the complexes resembles the ECG but gives additional information about the electrical activity of the heart in various diseases [4].

### 1 Method

A gradiometer type SQUID magnetometer for studying MCGs in an unshielded environment was constructed [4]. The instrument was planned to reach the sensitivity of 10 nGauss with a 100 Hz bandwidth. With this instrumentation good quality MCGs of adult hearts have been obtained. The measurements of the FMCG were carried out in a wooden cottage in a suburban area about 70 m away from the nearest apartment block. In this way the construction of the expensive magnetically shielded room has been avoided. The mothers were in the supine position during the measurements. The detector, measuring the vertical component of the magnetic field, was placed just above the maternal abdomen.

For clarity, the simultaneous ECG of the mother was also recorded. Both signals were recorded on the magnetic tape and reproduced in the laboratory.

### 2 Results

A typical real time FMCG is seen in Fig. 1. The fetal peaks, about 50 nGauss in height, point downwards. The fetus was lying left side anteriorly. In Fig. 2 similar fetal signals point upwards, here the fetal right side was facing the detector. Signals comparable in magnitude to these peaks

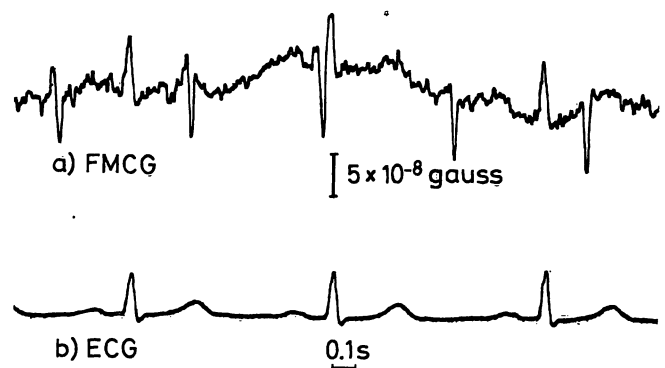


Fig. 1. The fetal magnetocardiogram of 39 weeks' gestation (upper trace). The fetus is lying in cephalic presentation the left side next to the detector. The fetal peaks are seen as negative spikes. The lower trace shows the simultaneous ECG of the mother. The QRS complex and the T wave of the mother are also visible in the MCG but they are masked by the noise. The bandwidth is 0.2–100 Hz. The oscillation of the background level is due to the mother's breathing and can be easily filtered out.



Fig. 2. The magnetocardiogram of a fetus of 41 weeks' gestation. The fetus is lying in cephalic presentation the right side next to the detector. Fetal peaks point upwards. The maternal peaks are also positive but much smaller.

have been found in fifteen recordings out of 28 from twenty fetuses of 30–40 weeks gestation. In our measurements there has been a **strong correlation between the fetal position and the fetal magnetic signal**. The fetal chest or left side facing the detector have been favorable positions and here the peaks were mostly negative. If the back or the right side of the fetus was towards the detector, the signal was often buried by the noise; when seen from the right side of the fetus the signal was positive. The instant determi-

### Summary

A gradiometer type superconducting quantum interference device (SQUID) magnetometer was used in an unshielded environment to detect and record the fetal magnetocardiogram (FMCG). The detector was placed just above the maternal abdomen. No electrode attachment either to the fetus or the mother was needed. The maximum peak values of the fetal magnetocardiograms were about 50 nGauss in magnitude and they were obtained in eleven fetuses out of 20 examined. Signals were found from fetuses of 30–40 weeks' gestation. The left side or the

**Keywords:** Electrocardiography, fetus, heart rate, magnetocardiography.

### Zusammenfassung

#### Das fetale Magnetokardiogramm

Mit einem Magnetometer wurde in einer nicht abgeschirmten Umgebung das fetale Magnetokardiogramm (FMKG) registriert. Der Aufnehmer wurde auf dem mütterlichen Bauch angebracht, ein Elektrodenanschluß war weder bei der Mutter noch beim Feten notwendig. Die maximalen fetalen Magnetokardiogrammwerte lagen bei 50 nano-Gauss, sie wurden bei 11 von 20 untersuchten Feten abgeleitet. Das FMKG wurde von der 30. bis 40. Schwangerschaftswoche registriert. Ist die linke Körperseite oder die Brust des Feten dem Aufnehmer zugewendet

**Schlüsselwörter:** Elektrokardiographie, Fet, Herzfrequenz, Magnetokardiographie.

nation of fetal position could be done only by palpation. In a number of cases position was confirmed by sonar within three hours, all of them agreed with palpation. The sign convention is such that a field pointing towards the maternal abdomen is positive.

In the external FECG the amount of amniotic fluid and vernix caseosa probably diminish the fetal complexes, especially between 27 and 32 weeks of gestation. **These drawbacks are excluded in FMCG**. It is also to be noted that in FMCG no electrode attachment is needed. However, the **amplitude of the fetal complex strongly depends on the distance between the fetal heart and the detector**.

It has also been shown that fetal distress correlates with changes in the P wave and S—T segment [3], Q—T time and T wave of the FECG [6], although rather late. According to a recent report the adult MCG is more sensitive than the ECG to changes in the S—T segment [4]. At present we are constructing a more sensitive magnetometer for investigating the FHR and the shape of the FMCG in real time.

chest of the fetus next to the detector seems to give a larger and mostly negative deflection (Fig. 1) while the right side or the fetal back towards the detector is a less favorable position for recording, the deflections being smaller and more often buried in the noise (Fig. 2). The magnitude and polarity of the fetal peaks are strongly dependent on the distance between the detector and the fetal heart. We have succeeded in counting the FHR electronically from the FMCG. The maternal heart activity is less disturbing than in the external FECG.

(Fig. 1), scheint es einen größeren und meist negativen Ausschlag zu geben; liegt dagegen ungünstigerweise die rechte Körperseite oder der Rücken des Feten zum Aufnehmer hin, ergeben sich kleinere Ausschläge (Fig. 2), die z. T. bei Nebengeräuschen untergehen. Die Höhe und die Richtung des FMKG sind streng von dem Abstand zwischen Aufnehmer und fetalem Herz abhängig. Es gelang, die fetale Herzfrequenz elektronisch über das FMKG abzuleiten. Dabei stört die mütterliche Herzaktivität weniger als bei der externen Ableitung des fetalen Elektrokardiogramms zur fetalen Herzfrequenzregistrierung.

### Résumé

#### Le magnetocardiogramme foetal

Un magnétomètre de type gradiomètre SQUID (superconducting quantum interference device), fut utilisé dans un milieu non protégé, dans le but de détecter et d'enregistrer le magnétocardiogramme foetal (FMCG). Le détecteur était placé sur l'abdomen maternel sans qu'il soit nécessaire de fixer une électrode sur le foetus ou la mère. Les valeurs maximales du magnétocardiogramme furent de l'ordre de 50 nGauss d'amplitude, et on put les obtenir à partir de 11 foetus sur 20. Les signaux furent obtenus entre la 31ème et la 41ème semaine de gestation. Le meilleur signal fut obtenu lorsque le détecteur était placé en regard

du côté gauche ou de la poitrine du foetus (Fig. 1). Dans ce cas le signal était ample et le plus souvent représenté par une déflexion négative. Par contre, lorsque le détecteur était placé en regard du côté droit ou du dos foetal, les déflexions étaient petites et souvent noyées dans le bruit (Fig. 2). L'amplitude et la polarité des déflexions étaient strictement dépendants de la distance entre le détecteur et le coeur foetal. Nous avons réussi à établir une courbe de rythme cardiaque foetal à partir de ce magnétocardiogramme. L'activité cardiaque maternelle perturbe moins l'activité foetale que lors de l'enregistrement de l'électrocardiogramme foetal par voie externe.

**Mots-clés:** Electrocardiographie, foetus, magnétocardiographie, rythme cardiaque.

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