Ultrasound-Guided Second Trimester Fetal Electroencephalography in Two Pregnant Volunteers: A Technical Note

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Abstract

**Background and purpose**—Data from electroencephalography (EEG) in preterm infants and neonates suggest that electroencephalographic abnormalities are likely present during antepartum period or fetal stage. We describe our initial effort to record fetal EEG with emphasis on technical aspects since such technique has not been developed as a viable and reproducible method.

**Methods**—The fetal heads were located in two pregnant volunteers (29 years old and 26 years old) with 28 weeks of gestation by ultrasound imaging. Four surface electrodes were placed on maternal abdominal surface approximately 5 cm anterior to the lateral aspect of fetal head as confirmed by acoustic shadowing of the electrodes on ultrasound. A second set of recordings were performed in first volunteer with four electrodes placed on the maternal abdominal surface in front of the uterus distant to fetal head.

**Results**—The analysis in the first volunteer demonstrated that the activity consisted of mixture of theta (4–7 Hz) and delta (1–4 Hz) waves which formed approximately 70% and 30% of the background rhythm. The analysis in the second volunteer demonstrated that the activity consisted of mixture of theta and delta, which formed approximately 30% and 70% of the background rhythm. There was superimposed beta (13–30 Hz) and infrequently gamma (30–100 Hz) activity. Maternal electrocardiographic QRS complex and respiratory artifacts were seen in some leads. During second recording, the electrodes distant to fetal head recorded predominantly delta with lesser proportion of theta waves.

**Conclusions**—We report our initial experience in acquisition of fetal EEG. The findings reported here will help to guide further research into developing methodologies for the performance of fetal EEG.

**Keywords**
Delta activity; electroencephalography; electrodes; fetal brain; fetal head; fetus; ultrasound; theta activity

**Introduction**

Our current understanding of fetal brain structure and development is based on morphological assessment using ultrasound or magnetic resonance imaging (MRI) [1–5].

Electroencephalography (EEG) is a sensitive method for the detection of brain injury in preterm infants [6,7]. Depression of background activity, the presence of epileptic seizure activity or abundant rolandic sharp waves can be detected in preterm infants with cerebral injury and provide important information to guide management and assess prognosis [6,7]. Such changes should be detectable in at least one-third of patients with cerebral palsy in the antepartum period based on data acquired from serial electroencephalographs performed in preterm infants [6]. In neonates and infants, electroencephalographic monitoring will be performed using electrodes placed on surface outside the cranium. Such electroencephalographic monitoring is not possible in fetuses, because the position of the skull is not directly visualized to guide the placement of the electrodes. We describe a method using ultrasound to guide the position of electrodes to acquire a four-lead electroencephalograph in fetuses.
Case description

Two women volunteers (subject number 1, 29 years old and subject number 2, 26 years old) with 28 weeks of gestation were selected for the study. The mothers provided verbal informed consent for the ultrasound scan and EEG. The protocol was reviewed and approved by designated committee of PingAn Hospital, Shijiazhuang, China. The Doppler study was performed using General Electric (Logiq e, GE Healthcare, Little Chalfont, United Kingdom) [8] or Siemens (Acuson P300, Siemens Healthcare, Erlangen, Germany) ultrasound devices with 6–2 MHz curved array probe [9]. The EEG was performed using xitek Trex HD ambulatory video electroencephalographic systems (Natus Medical incorporated, Pleasanton, CA) [10]. The fetal head was located in cephalic presentation by ultrasound imaging and visualized in an axial view. The surface electrodes were placed on maternal abdominal surface anterior to the axial plane of fetal head after skin cleansing. An ultrasound was performed which demonstrated that the electrodes were approximately 5 cm anterior to the lateral aspect of fetal head based on acoustic shadowing of the electrodes (Figs. 1 and 2). All data were amplified, digitized, and archived for analysis.

We placed four electrodes on maternal abdomen anterior and close to fetal head. The reference and ground electrodes were placed on lateral aspect of maternal abdominal surface. The power cord of the ultrasound machine was disconnected to avoid any interference with electrical activity. The initial recording demonstrated two arti-
facts: contamination by maternal electrocardiography (EKG) and ultrasound appliance. Subsequently, the distant electrode was used as reference bipolar electrode in the vicinity of the recording electrode resulting in the elimination of maternal electrocardiographic contamination.

**Subject 1: First recording**

We analyzed all the recording acquired using parameters of 1 mV/mm gain with high-pass filter of 1 Hz and low-pass filter of 70 Hz, and notch of 60 Hz. The analysis demonstrated that the activity consisted of mixture of theta (4–7 Hz) and delta (1–4 Hz) waves, which formed approximately 70% and 30% of the background rhythm, respectively, (Fig. 1). The amplitude was low and ranged between 2–10 mV. There was superimposed beta (13–30 Hz) and gamma (30–100 Hz) activity with amplitude ranging between 1–3 mV.

**Subject 2: First recording**

We analyzed all the recording acquired using parameters of 2 mV/mm gain with high-pass filter of 1 Hz and low-pass filter of 70 Hz and without notch. The analysis demonstrated that the activity consisted of mixture of theta and delta waves, which formed approximately 30% and 70% of the background rhythm, respectively (Fig. 2). The amplitude ranged between 10–30 mV. There was superimposed beta activity with amplitude ranging...
between 4-20 mV. The gamma activity was observed infrequently. Maternal electrocardiographic QRS complex and respiratory artifacts were observed in two leads (amplitude ranging between 20–50 mV).

Subject 1: Second recording

We performed a second recording using four electrodes on maternal abdomen anterior and close to fetal head and a second set of four electrodes placed on the maternal abdominal surface in front of the uterus distant to fetal head. The purpose was to determine whether there
is electrical activity specific to fetal head independent of maternal abdomen and anterior wall of uterus. We analyzed all the recording acquired using 5 mV/mm gain with high-pass filter of 1 Hz and low-pass filter of 70 Hz and without notch. The analysis demonstrated that the activity recorded near the fetal head consisted of mixture of theta and delta waves that formed approximately 50% and 50% of the background rhythm, respectively. The amplitude ranged between 20–100 mV. Maternal electrocardiographic QRS complexes were observed in all leads. The activity recorded distant to the fetal head consisted of predominantly delta with lesser proportion of theta activity. The respiratory artifact was very prominent in the form of slow waves (1/2 to 1/3 Hz with amplitude ranging between 70 and 150 mV). There was no synchrony between the activity recorded proximal and distant to fetal head.

**Discussion**

It remains unclear whether the electrical rhythmic activity recorded from the electrodes placed on maternal abdomen in proximity to fetal head represented brain electrical activity or activity from another source (physiological artifact). The morphological appearance of the activity consisted of a combination of delta and theta activity with frequency components ranging between 1–4 and 4–7 Hz range, respectively. The theta bursts and high-amplitude delta waves have been observed in previous studies of recordings from preterm infants [11–14]. There was beta and gamma activity superimposed on the delta and theta waves. However, we did not observe the short periods of inactivity on electroencephalograph described in preterm infants that constitute up to 45% of total recording time [11,15]. The other concern was similar (although not synchronous) and electrical activity pattern was recorded from maternal surface distant to the fetal head. We also identified maternal electrocardiographic QRS complexes and slow activity generated by breathing (artifacts) recorded within the electroencephalograph.

There are some theoretical considerations in acquisition and interpretation of fetal electroencephalograph. The first issue is whether the diminution of electrical signal due to distance between fetal head and maternal abdominal surface precludes successful signal acquisition. A typical human slow wave electroencephalograph signal is about 100 to 500 mV in amplitude [15], but the voltage strength declines with the square of distance between source and recorder. Therefore, if the distance of the skull is too far from the electrodes, the electrical activity is more difficult to detect than activity near the electrodes. We positioned the electrodes using ultrasound guidance is necessary to ensure proximity of the electrodes to the fetal skull. In both the fetuses, the distance was less than 5 cm between the fetal head and recording electrodes. Experience from patients with subdural hemorrhage in whom the distance between the brain and recording electrodes maybe 3–5 cm suggests that electrical activity on electroencephalograph is detectable despite such distances [16,17].

Generation of electrical activity from the abdominal and uterine muscles interpositioned between the electrodes and fetal head create difficulties in the identification of source of electrical activity in recordings. The frequency of the electrical activity generated from muscles typically ranges in 20–100 Hz range [18,19]. The uterine wall activity includes a slow wave (0.01 < frequency < 0.03 Hz) and a fast wave with variable frequency and occurs concurrent with intrauterine pressure increase [20]. In scalp electroencephalographic recordings, there are three other signals generated by physiologic processes: the R-wave vector of electrocardiograph passing through the neck, electromechanical activity of scalp muscles, and activity generated by movement of the electrical dipoles within the eyeballs due to eye movements [21]. Because of greater recognition of characteristics of noncerebral activity including differences in frequency range, the amplifier can limit such activity on the final recording by band-pass filtering the signal [21]. With greater experience in the recording of fetal electroencephalographs, such filtering algorithms may be developed.

**Conclusion**

We report our initial experience in the acquisition of fetal electroencephalography. The findings reported here will help guide further research into developing methodologies for acquisition and interpretation of fetal electroencephalographs.

**References**


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10. Natus Medical Incorporated Pleasanton, CA Xltek Trex HD ambulatory video electroencephalographic systems.


