Fetal Homologue of Infant Crying

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Short title: Fetal crying

Abstract

Four behavioural states are recognised in the human fetus and are comparable to those of the neonate: 1F (quiet sleep), 2F (active state), 3F (quiet awake) and 4F (active awake). State 5, or crying is not considered to have a fetal correlate. In a study assessing the effects of tobacco and cocaine exposure during pregnancy on fetal response and habituation to vibroacoustic stimulation, we observed what appears to be the fetal homologue of crying. These behaviours were seen on ultrasound, and have been captured on video recordings and include: an initial exhalation movement associated with mouth opening and tongue depression, followed by a series of three augmented breaths, the last breath ending in an inspiratory pause followed by an expiration and settling. To our knowledge, this is the first report/video documenting these behaviours and suggests the possibility of a State 5F.

Key Words: Crying, Fetal Behavioural State, Fetus

Introduction

Five distinct behavioural states are recognised in the neonate: 1: quiet sleep; 2: active sleep; 3: quiet awake; 4: active awake; and, 5: crying. In the fetus, four distinct behavioural states 1F, 2F, 3F, and 4F have been identified and correspond to the neonatal behavioural states 1-4 (Table 1) (4, 5).

Table 1. Neonatal and fetal state

Neonatal behavioral state	Descriptors	Neonatal behaviours	Fetal state correlate	Fetal behaviours	Fetal heart rate pattern
1	Quiet, asleep	Regular respirations, non-REM sleep	1F	FB: regular, if present FBM: rare gross movements, nondiscriminatory FEM: absent	A: Variability (10 bpm), isolated accelerations associated with movement
2	Active, asleep	Irregular respirations, REM sleep, activity non-discriminatory	2F	FB: irregular, if present FBM: small body movements, gross, nondiscriminatory, episodic FEM: absent	B: Variability (10-20 bpm), frequent accelerations of 10-20 bpm
3	Quiet, awake	Regular respirations, no gross activity	3F	FB: regular, if present FBM: no gross movements FEM: present	C: No accelerations, rate oscillates more regularly than in B
4	Active, awake	Irregular respirations, physically active	4F	FB: irregular, if present FBM: gross and small movements, continual FEM: present	D: “Unstable” rate, variability up to 25 bpm, accelerations of 25-30 bpm, occasional sustained tachycardia
5	Crying	Irregular respirations, physically active	Described here		

FB: Fetal breathing
FBM: Fetal body movement
FEM: Fetal eye movement

State 5, or the crying state, have no reported fetal correlate. We describe what we believe is the first documentation of crying behaviours in the fetus. These behaviours were elicited during vibroacoustic stimulations (VAS), which were undertaken as a research study assessing the effect of tobacco and cocaine exposure during pregnancy on fetal response and habituation to VAS (6).

Method

Fetal ultrasound assessments were undertaken on up to 3 occasions (29-31, 32-35 and 36+ weeks gestation). These assessments were made in a semi-darkened room using B-mode ultrasonography (Corometrics ALOKA 650 US). The ultrasound transducer was positioned for a lateral-oblique view of the fetus. Fetal eye movements and gross body movements were observed in real time by an observer and were recorded on video. Fetal heart rate was measured by continuous wave doppler (Corometrics Fetal Monitor 145) and recorded continuously on the built-in dual-channel strip chart recorder. Behavioural state was assessed from these sources..

The fetus was observed unperturbed for 20 minutes. After this initial observation period, and when the fetus appeared to be in a stable state (quiet or active sleep), the fetus was challenged with vibroacoustic stimulation (VAS). The VAS was provided by an artificial larynx (model 5c Western Electric) that emits fundamental tones of approximately 100 Hz and 95 dB and was mechanically altered to provide exactly 0.5 seconds (s) of stimulation. This duration was selected because longer stimulus durations have been associated with excessive fetal movements and prolonged tachycardia (7). The physiological intrauterine noise intensity has been reported to be approximately 85 dB (8). No adverse effects have been reported at this intensity, duration and frequency (7). Following stimulation, the fetus was observed for a blink-startle response for a duration of 10 s (9).

The study had ethical approval from the Charlotte Medical Center IRB, and the parents gave written informed consent for the study.

Case report

The mother was an African-American primigravida, who smoked <10 cigarettes per day. She did not abuse cocaine. The female fetus was assessed at 33 weeks gestation when the “cry” behaviours were seen. There were no complications during the pregnancy. At 40 weeks gestation there was spontaneous onset of labour. There was a normal vaginal delivery, and the infant’s birthweight was 3555g.

The video clip and Figures 1- 3 demonstrate what we believe is the fetal homologue of crying. The video begins with the quiet fetus prior to presentation of the VAS. The fetus is initially seen in an oblique view. The stimulus is presented. The fetus startles and turns

her head to a lateral view, and is seen in profile (Fig 1). The fetus then initiates behaviours consistent with crying. There is a brief expiration that is followed by a deep inspiratory phase with a subsequent pronounced expiratory phase. This expiration is associated with jaw opening, taut tongue and chest depression (Fig 2). It is immediately followed by three augmented breaths with progressive increase in chest rise and head tilt (Fig 3). Each end-inspiration is marked by chin quiver. The last augmented breath ends in an inspiratory pause, followed by an expiration and settling. Settling is associated with a turn of the fetal head to the oblique position, mouthing and swallowing. This pattern of behaviour was seen again when a repeat VAS was presented to the fetus at approximately 1 minute after the initial cry. These behaviours are demonstrated in the video and presented in a conceptualized form in Figure 4.

This behavioural response was not an isolated case. Once recognised, more episodes of these behaviours were seen during the VAS testing of other fetuses. Ten subjects demonstrated fetal crying behaviour, three of whom showed all of the characteristics on two separate occasions. Fetal crying behaviour was seen three times at the first assessment (gestation age 28-31.9 weeks), four times at the second assessment (aged 32-35.9 weeks) and on 6 occasions at the third assessment (aged >36). Four mothers smoked cigarettes during pregnancy, 3 smoked and used cocaine and 3 neither smoked nor used cocaine. The study population consisted of 3 groups of mother-fetal dyads: (1) cigarette smokers (n=54), (2) cocaine users (n=30), and (3) controls (n=60). Only one infant had a low Apgar at 1 minute and none at 5 minutes. Six of the infants were female and 4 were male. Birthweight and gestation did not differ from the sample as a whole (range: 2637 to 4138g and 36.7 to 41.7 weeks).

Discussion

Crying is a complex, rhythmical series of sounds that requires precise coordination between various motor systems including the musculature of the face, airway and respiration (10). Fundamental to postnatal cry is vocalization. Thus newborn and infant crying consists of both a vocal and non-vocal component. Hopkins (2000) suggests that the non-vocal accompaniments of crying are developed before birth; the vocal component being established with transition to the extrauterine life (11). The observations recorded from fetal ultrasounds support the concept that the fetus is capable of the complex motor behaviours that accompany the crying state.

These observations may have further developmental implications as the expression of crying implies more than execution of a motor pattern. Crying requires reception of a stimulus, association of that stimulus with a negative connotation, and incorporation of an appropriate motor response that itself recruits a complex pattern of more-primitive motor sequences. The sensory aspect of the cry response, that is, reception of the sound, implies intact afferent processes. Recognition of the stimulus as negative indicates development of more-rostral brain sites that mediate affect and further, integrates that affect with a motor response. The expression of crying thus indicates a several-stage maturation of sensory reception, processing of signals as potentially deleterious, a dimension of affect,

and recruitment of an appropriate response. Of this sequence, demonstration of affective integration, which incorporates limbic structures, implies more rostral neural maturation. The ability of the fetus to demonstrate affective integration of motor responses is supported by the observation that the fetal crying behaviours were seen only after VAS stimulation.

Crying consists of a sequence of vocal and non-vocal behaviours. Although crying is phenomenologically self-evident in both the term and preterm infant, there is no unified or accepted definition that incorporates all aspects of the cry behaviour. Well-described are the facial accompaniments of cry: grimace or frown, trembling of the chin, swallowing, and eye closure (11). Others describe movement of the extremities (10, 13). These behaviours are tightly linked to the respiratory cycle (14). In the newborn, each cry cycle displays a consistent displacement of respiratory volume, suggesting a precise coordination between various motor systems and that of the respiratory system (15). Cries are produced primarily in the expiratory phase; however, the newborn is capable of inspiratory "voicing" (16). Thus, Wolff's (1969) classic description of infant cry as a rhythmic repetition consisting of an expiratory sound lasting 0.6-1.3 s, a brief pause of 0.2 s, and an inspiratory sound or whistle of about 0.1-0.2 s followed by another pause of 0.2 s prior to the next sound made on expiration, continues to provide the most comprehensive description of the infant cry (17). The behaviours shown in the video correspond to the neonatal cry with the vocalization component occurring during the expiratory phases.

By 20 weeks gestational age, the fetus possesses the complete motor repertoire necessary for cry behaviours: coordinated breathing efforts, jaw opening, mouthing, chin quiver, tongue extension and swallowing (18-20). Furthermore, it is well known that the preterm infant of about 24 weeks gestational age is capable of producing crying sounds (21, 22) and can respond to environmental noise (23). Thus, the fetus is capable of responding to sound and other perturbations with highly coordinated movements that mimic the temporal and behavioural components of the extra-uterine cry. This phenomenon suggests a prenatal origin of crying, and supports the contention that the fetus does have a comparable state 5; that is, state 5F. This concept provides a developmental continuity between the pre and postnatal life.

The method of Nijhuis at al (1982) for determining fetal state required that the 3 state variables (body movements, eye movements and heart rate pattern) are maintained for 3 minutes (5). This process follows the strategy used for the assessment of state in the newborn (24). Periods less than 3 minutes are referred to as periods of coincidence, and may represent chance occurrence. It may be inappropriate to apply the 3 minute criterion to 5F, as crying in the neonate is often of shorter duration. In our case, the observed cry behaviours lasted 15 to 20 s.

The fetal "cry" behaviour, or state 5F, was seen in our study only after VAS. This observation might suggest that the "fetal cry" is elicited only when the fetus is disturbed. The behaviours were seen in all gestational ages studied, indicating that the behaviour occurs as early as 28 weeks gestation, and possibly earlier. The behaviour was observed

equally in controls (non-smokers and no cocaine use), suggesting these behaviours are not specific to tobacco or cocaine exposure.

Finally, what we have observed is similar to the rare, but well authenticated phenomenon of vagitus uterinus, a term used to describe the audible cry of the fetus in utero (25). Cases of vagitus uterinus are generally found at term, are associated with ruptured membranes that have allowed air to enter the uterus, and some operative intervention usually has occurred which has stimulated the fetus. Our case occurred 7 weeks before delivery, and although the body and facial movements were consistent with crying, an audible cry was not heard.

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Competing interest

None

What is already known

Four behavioural states are recognised in the human fetus and are comparable to those of the neonate: 1F (quiet sleep), 2F (active state), 3F (quiet awake) and 4F (active awake). State 5, or crying is not considered to have a fetal correlate.

What this study adds

In a study assessing the effects of tobacco and cocaine exposure during pregnancy on fetal response to vibroacoustic stimulation, we observed what appears to be the fetal homologue of crying. This is the first report/video documenting these behaviours and suggests the possibility of a fetal state 5F.

Figure Legends

Figure 1
The fetus is seen in profile. The upper position of the anterior chest wall is marked with a horizontal line at baseline. The initial angle of the chin is also shown.

Figure 2
The figure shows the beginning of the "cry". The head is seen in profile, the mouth is open, the anterior chest is below the original position, indicating the initial expiratory movement.

Figure 3
The notations in this figure mark the increase in chest elevation and head tilt during the three augmented breaths.

Figure 4
The figure graphically represents the movement of the anterior chest wall during one cry cycle. The notations identify the associated behaviors. The asterisk shows when chin quiver occurred.

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