Maternal and Ultrasound Measurements of Elicited Fetal Movements: A Methodologic Consideration

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Two methods of evaluating fetal movement responses elicited by vibroacoustic stimulation—maternal perceptions and ultrasound scan observations—were compared in 58 low-risk and 35 high-risk pregnancies from 23–36 weeks' gestation. Maternal perception of vibrator-elicited fetal movement was poor compared with ultrasound scan observation. Regardless of gestational age or risk status, the mothers perceived 27–75% fewer movements than observed with ultrasound scan. In addition, maternal movement perceptions on vibrator versus no-stimulus control trials were not reliable until 29–32 weeks' gestation, with the percentage of movement responses increasing across gestation from 11 to 48%. In contrast, ultrasound scan observations of movement were reliable on vibrator compared with no-stimulus control trials from 26 weeks, with the percentage of movement responses increasing from 22% at 23–25 weeks to 94% at 35–36 weeks. We conclude that maternal perceptions of fetal movements cannot be substituted for ultrasound scan observations for accurate assessment of fetal movements during vibroacoustic stimulation testing. ***(Obstet Gynecol 77:889, 1991)***

In current efforts to develop an acoustic/vibroacoustic test for the assessment of fetal well-being, it has been suggested that maternal perception of fetal body movements is a reliable method of evaluating fetal response[1] in both low-risk[2] and high-risk pregnancies.[3] The relationship between this subjective measure of elicited fetal behavior and the more objective ultrasound measure has not been established. Maternal perception is a simpler method of obtaining fetal movement response (ie, it is readily available and does not require expensive equipment or technical skill) compared with ultrasound scanning; therefore, if both techniques yield similar results, then the methodology used to determine movements during stimulation testing could be simplified.

Fetal responses to sound and vibration are influenced by both stimulus characteristics and subject variables. In relation to stimulus characteristics, the intensity,[4] frequency,[5] and number of stimulus applications[6–8] affect whether a response will be elicited and the magnitude of the response. In relation to subject variables, state of arousal and maturation have been examined; yet their influence on fetal response has not been clearly delineated. For example, state of arousal influences fetal response;[9] however, fetal state is difficult to determine. Although rest-activity cycles have been identified in fetuses younger than 36 weeks,[10,11] fetal state and state transitions are not well organized or recognizable until at least 36–38 weeks.[12,13] To overcome the difficulty of identifying state, studies of fetal behavior often include some measure such as no-stimulus trials to control for state of arousal.

Results from several studies, with and without controls for state of arousal, have provided a picture of the maturation of fetal responses elicited by external stimuli. For example, using ultrasound scanning techniques, it has been established that fetal movements are elicited by vibroacoustic stimuli as early as 26 weeks[14] and that the percentage of fetuses responding increases with advancing gestation from approximately 30% at 24 weeks to 95% at 37 weeks.[15] Although little is known about the reliability of maternal perceptions across gestational ages compared with these ultrasound observations, maternal perceptions and ultrasound observations at 36–38 weeks were shown to be similar at stimulus intensity levels of 103 and 109 dB, but questionable at 92 dB.[16] At the lower

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Supported by Natural Sciences and Engineering Research Council of Canada Grant OGP0041862 and a Queen's University Principal's Development Fund Grant to BSK. Dr. Kisilevsky is supported by an Ontario Ministry of Health Career Scientist Award.

 0029-7844/91/$3.50

intensity, not only were fewer movements observed with ultrasound, replicating earlier findings,[4,17] but fewer movements were detected by the mothers than by ultrasound scan.

The purpose of the present study was to compare maternal perceptions and ultrasound observations of fetal movements elicited by a vibroacoustic stimulus to determine whether the two procedures yielded similar results and could be used interchangeably. Comparisons were made across gestational ages in groups of low-risk and high-risk pregnancies using a vibroacoustic stimulus previously shown to elicit a movement response from 92% of term fetuses (ultrasound observation) with no significant response decrement over eight repeated trials.[18]

Materials and Methods

Two groups of pregnant women gave written consent for the investigation. A low-risk group included 58 volunteers, each of whom was at least 18 years of age, had an uncomplicated pregnancy, and attended prenatal clinics at a community teaching hospital. This group included singleton pregnancies at each of the following ages: 23–25 (N = 12), 26–28 (N = 12), 29–31 (N = 12), 32–34 (N = 11), and 35–36 (N = 11) weeks' gestation. Gestational age was calculated from the first day of the last menstrual period or by early ultrasound scan. Neonatal outcome measures confirmed the gestational age and good health of the fetuses studied; ie, delivery at 37–42 weeks, birth weight over 2800 g, 5-minute Apgar scores of 6 or more, and no neonatal complications during the hospital stay.

A high-risk group included 35 volunteers admitted to the hospital for threatened preterm delivery with contractions, bleeding, and/or premature rupture of membranes. This group included singleton pregnancies at 23–25 (N = 5), 26–28 (N = 10), 29–31 (N = 8), and 32–34 (N = 12) weeks' gestation at the time of testing. Infants in this group had variable outcomes. Twenty-nine infants were born preterm (between 23–36 weeks), four were born at term, and two not delivering at this center were lost to follow-up. Birth weights ranged from 610–3760 g. There were four neonatal deaths (three tested at 23–25 weeks, one tested at 26–28 weeks) and two minor congenital anomalies (ventricular septal defect and multiple hemangiomas).

Each fetus received three vibrator and three no-stimulus control trials intermixed and randomly presented. Vibration trials consisted of a 2.5-second application of the tip of a cylindrical (3.5 × 25.2 cm), battery-powered, hand-held commercial vibrator (Allied Traders Ltd., Kowloon, Hong Kong) to the maternal abdomen over the site of the fetal head. Spectral analysis (Eventide Real Time Spectum Analyzer Model A1B 232; Eventide Clockworks, Inc., New York, NY and Apple II Computer; Apple Computers, Cupertino, CA) of the vibrator sound, recorded in air, showed a broad-band noise including frequencies from 100–5000 Hz with a sound intensity of 64 dB SPL (sound pressure level) (C scale Bruel & Kjaer Impulse Precision Sound Level Meter [Bruel & Kjaer, Naerum, Denmark] measured at a distance of 10 cm). Spectral analysis of the sound of the vibrator recorded in a water bath demonstrated a narrow band (100–1250 Hz) of low frequency with peaks at 125 and 160 Hz. It should be noted that a vibroacoustic device delivers both airborne sound and mechanical stimulation to the fetus. However, the salient characteristic(s) (ie, whether the fetus is responding to the sound, the vibration, or both) is yet to be determined.

During 2.5-second control trials, the vibrator was turned on and placed over the fetus' head but did not touch the maternal abdomen. Activity on control trials was used to determine whether elicited movements could be reliably differentiated from spontaneous activity during testing. The minimum inter-stimulus interval was 1 minute; trials were delivered only when no movements were seen on ultrasound scan.

Movements were observed and recorded as "yes" or "no" within 5 seconds of stimulus onset using three methods of scoring. First, the mothers were asked to judge whether they felt any movements from the time the investigator said "onset" until she asked, "Did you feel any movement?" Although the mothers knew whether they received a vibrator or control trial, they could not see the ultrasound image. Second, a trained research assistant judged fetal movement from a real-time ultrasound image of a cross-section of the fetal trunk using a Siemens LX ultrasound scanner (Siemens, Erlangen, Germany). She was blinded to whether a stimulus or control trial was being administered. Given the size of the preterm fetus, limbs as well as trunk were often visible on the ultrasound monitor; movement of trunk and/or limbs was scored. Finally, the investigator announced the stimulus onset to the mother and the research assistant when she delivered the stimulus; she also scored movements from the ultrasound monitor.

Results

Table 1 presents the percentage of agreement between the two ultrasound scorers. Because the agreement across gestational ages, stimulus conditions, and risk status was high (97%, range 90–100), further analyses included only the data from the blind observer.

Table 1. Percentage of Agreement Between Two Ultrasound Observers*

Gestational age (wk)	Vibrator trials		Control trials	
	Low-risk group	High-risk group	Low-risk group	High-risk group
23–25	100	100	97	93
26–28	100	90	100	100
29–31	94	96	94	96
32–34	91	97	94	100
35–36	97		100	
23–36	97	95	97	98

* One blinded to stimulus and control trial status.

Table 3. Number of Vibrator-Elicited Fetal Movements

Gestational age (wk)	Mother	Ultrasound observer	Mother and ultrasound observer
23–25	6	12	2
26–28	12	36	8
29–31	20	44	18
32–34	21	58	20
35–36*	16	31	16

* Low risk only.

Table 2 shows that, across gestational age and risk status, the mothers perceived 27–75% fewer vibrator-elicited movements than observed with ultrasound scan. In addition, whereas the percentage of response trials increased from 22% at 23–25 weeks to 94% at 35–36 weeks with ultrasound scan observation, the percentage of response trials increased only from 11 to 48% with maternal perception.

Table 3 illustrates that it was not until 29 weeks' gestation that those movements reported by the mothers were also seen on ultrasound scan. From 23–28 weeks, only 56% of the movements felt by the mother were seen on ultrasound scan, compared with 95% agreement at 29–35 weeks' gestation.

Figure 1 shows the average movement scores (summed across three trials) at each gestational age determined by ultrasound scan and maternal perception. Repeated-measures analyses of variance[19] indicated that, although the ultrasound observer saw little movement at 23–25 weeks, when movement did occur it tended to appear on vibrator rather than control trials ($P = .05$). From 26 weeks, the ultrasound observer reliably reported more movements on vibrator compared with control trials ($P < .00001$). Furthermore, there were no differences in fetal movement responsiveness between the low- and high-risk groups. In contrast, at 29 weeks, the mothers reported more movements during vibrator compared with control trials ($P < .01$) only in the high-risk group ($P < .01$). It was not until 32 weeks (6 weeks later than with ultrasound scan) that the mothers reported more movements on vibrator compared with control trials ($P < .01$) for both low- and high-risk pregnancies. Furthermore, Figure 1 shows that even when maternal perceptions of movement were significantly greater on vibrator than on control trials, the number of response trials was small.

Table 2. Percentage of Movement Responses on Vibrator Trials

Gestational age (wk)	Low-risk status			High-risk status		
	Mother	USS	Difference	Mother	USS	Difference
23–25	11	22	50	13	27	52
26–28	17	53	68	20	57	65
29–31	17	69	75	58	79	27
32–34	24	85	72	36	83	57
35–36	48	94	49			

USS = ultrasound scan observations.

Discussion

Our findings indicate that maternal perception of vibrator-elicited fetal movement is poor compared with ultrasound scan observation. In this study, mothers not only perceived fewer movements regardless of gestational age or risk status, but their perceived movements were not consistent with those observed using ultrasound scan until 29–32 weeks. In addition,

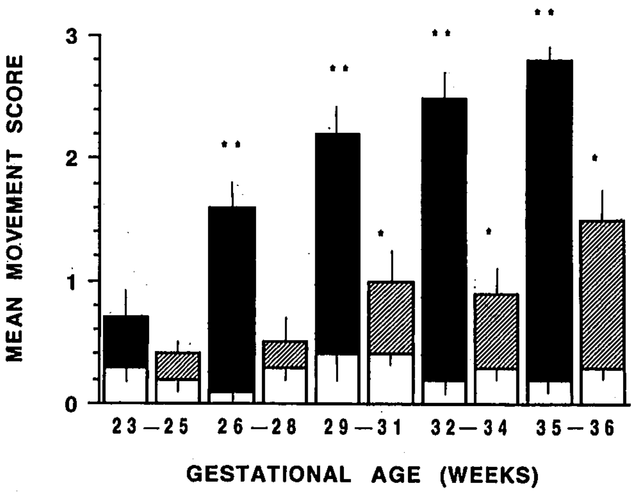

Figure 1. Mean movement scores as a function of gestational age and scoring method for vibrator and control three-trial blocks. Solid bars = ultrasound observation; striped bars = maternal perception; open bars = control. Vertical bars indicate standard error of the mean. **$P < .00001$; *$P < .01$.

comparisons of maternal perceptions of movement on vibrator versus no-stimulus control trials demonstrated that movement responses were not reliable until 29–32 weeks' gestation, 3–6 weeks later than when using ultrasound scan. Furthermore, even though perceived movements were shown to be statistically reliable, the number of movements perceived (about one of every three vibrator trials) is probably too small to be clinically useful. Given these findings, we conclude that this simpler method cannot be substituted for ultrasound scan observation for an accurate assessment of fetal movement during vibroacoustic stimulation testing.

Using ultrasound scan, our observations replicate earlier reports of maturation and response rates to vibroacoustic stimulation by investigators who assessed fetal movements elicited by an artificial larynx.[14,15] For example, in the present study, movements were reliably observed from 26 weeks' gestation, and the percentage of response trials increased with advancing gestation from 22% at 23–25 weeks to 94% at 35–36 weeks.

Given the recent suggestion that vibrator intensity may influence maternal perception of fetal movement,[16] it may be that the "intensity" of our vibrator (airborne sound component 64 dB SPL) is lower than that of the artificial larynx (airborne sound component 100 dB SPL),[15] eliciting a less vigorous response from the fetus. Because maternal perception of movements is influenced by the duration of the movement[20] and the number of fetal body parts contributing to the movement,[21] one would expect that less vigorous movements would be felt less often by the mother. Nevertheless, using ultrasound scan, our findings indicate that our vibrator is as effective in eliciting fetal movements as is the artificial larynx.

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Received July 19, 1990.
Received in revised form November 20, 1990.
Accepted January 14, 1991.