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Monitoring Contractions in Obese Parturients

Electrohysterography Compared With Traditional Monitoring

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OBJECTIVE: To compare electrohysterogram-derived contractions with both tocodynamometry and intrauterine pressure monitoring in obese laboring women.

METHODS: From a large database of laboring patients with electrohysterogram monitoring, obese subjects were selected in whom data were recorded for at least 30 minutes before and after intrauterine pressure catheter placement for obstetric indication. Using a contraction detection algorithm, the relationship between the methods was determined with regard to both frequency and contraction duration.

RESULTS: Of the 25 subjects (median body mass index 39.6 [25th percentile 36.5, 75th percentile 46.3]), seven underwent amniotomy at the time of intrauterine pressure catheter placement. Tocodynamometry identified 248 contractions compared with 336 by electrohysterography, whereas intrauterine pressure catheter monitoring identified 319 contractions compared with 342 by electrohysterography. Using the Contractions Consistency Index, electrohysterogram contraction detection correlated better with the intrauterine pressure catheter (0.94±0.06) than with tocodynamometry (0.77±0.25), $P=.004$. Electrohysterogram-derived contraction lengths closely approximated those calculated from the intrauterine pressure catheter signal.

CONCLUSION: Contraction monitoring routinely is employed for managing labor, and tocodynamometry may be unreliable in obese parturients. In the obese women in this study, the electrohysterogram-derived contraction pattern correlated better with the intrauterine pressure catheter than tocodynamometry. Electrohysterography may provide another noninvasive means of monitoring labor, particularly for those women in whom tocodynamometry is inadequate.
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Dr. Euliano's husband is the President and Ms. Marossero and Mr. Nguyen are employees of Convergent Engineering (Gainesville, FL). Both Dr. Euliano and Ms. Marossero are listed on patents filed for some of the technology described in this article.

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The prevalence of obesity is increasing world wide and presents challenges to the care of women in labor. In women of child bearing years, nearly 52% are overweight or obese (body mass index [BMI] of 25 or more), and 8% are clinically severely obese (BMI of 40 or more).[1] Induction or augmentation of labor is common in obese women due to the increased risk of obstetric complications, such as diabetes and preeclampsia. The use of oxytocin is best monitored not only by fetal heart rate monitoring but also by monitoring the contraction pattern.

Uterine activity typically is monitored with a strain gauge (tocodynamometer), providing frequency and approximate duration of contractions. In obese patients, the distance from the skin to the uterus may be such that the tocodynamometer does not detect contractions reliably. In this setting, or when quantitative measure of intrauterine pressure is deemed necessary, an invasive intrauterine pressure catheter is required. Although generally a benign procedure, placement of the intrauterine pressure catheter might increase the incidence of intrapartum infection[2–4] and has been reported to cause uterine perforation or placental abruption in rare cases.[5,6] Recognizing that numerous studies have failed to demonstrate a benefit for intrauterine pressure monitoring during labor,[7–9] the American College of Obstetricians and Gynecologists states that these catheters "may be beneficial in women when the evaluation of contractions is difficult because of such factors as obesity. . .or when response to oxytocin is limited."[10]

A reliable method of noninvasive uterine activity monitoring that is robust to patient weight is needed. The electrical activity of the uterus long has been recognized as linked to mechanical activity, and can be monitored from the surface of the maternal abdomen, creating an electrohysterogram.[11–13] The purpose of this investigation was to compare electrohysterogram-derived contractions with both tocodynamometer and intrauterine pressure catheter monitoring in obese laboring women.

MATERIALS AND METHODS

Data for this analysis were culled from an ongoing study of noninvasive extraction of the fetal electrocardiogram and electrohysterogram during labor. The study protocol was approved by the University of Florida Institutional Review Board, and all subjects provided written, informed consent. This report includes all subjects with BMI of 34 or more who were enrolled between June 2005 and July 2006 who were in active labor with a singleton fetus in cephalic presentation and underwent data collection with a single amplifier for at least 30 minutes before and after intrauterine pressure catheter placement.

Following skin preparation by gentle rubbing with abrasive gel, ten 3-cm^2 Ag/AgCl$_2$ electrodes (Ambu, Glen Burnie, MD) were attached to the maternal abdomen in a defined configuration (four electrodes down the midline from fundus to near pubis, and two electrodes overlying each side of the uterus approximately 10 cm right and left of midline). The electrodes were connected to the amplifier in a monopolar fashion with common reference and common mode rejection leads in the center. Electrode positions were modified slightly for each patient, as required by the location of the tocodynamometer and ultrasound fetal heart rate monitor. Impedance of each electrode was measured (as compared with the reference) (General Devices EIM-105 Prep-Check, Ridgefield, NJ). Skin preparation was repeated as needed at each site until the measured impedance was below 10 kΩ where possible.

The recorded signals were fed to an eight-channel high-resolution, low-noise unipolar amplifier (Marossero DE, Erdogmus D, Euliano N, Principe JC, Hild KE. Independent components analysis for fetal electrocardiogram extraction: a case for the data efficient Mermaid algorithm. Presented at Neural Networks for Signal Processing, 2003. NNSP'03. 2003 IEEE 13th Workshop.). All eight signals were measured with respect to a reference electrode. The amplifier design employed driven-right-leg circuitry to reduce common-mode noise between the patient and the amplifier common. The amplifier 3-dB bandwidth was 0.1 to 100 Hz, with a 60 Hz notch. The amplifier gain was set to 6,500 V/V for the current experiments.

Data from each patient included a uterine activity channel from the maternal–fetal monitor (Corometrics, GE Medical Systems, Waukesha, WI) sampled at approximately 12 Hz with eight-bit resolution. This cardiotocograph output reports either the tocodynamometer- or intrauterine pressure catheter–derived contraction curve. Data also included output from eight abdominal channels sampled at 200 Hz with 16-bit resolution. The collected data were displayed in real time and stored electronically for subsequent analysis.

To produce the electrohysterogram contraction curve, the eight electrohysterogram signals were resampled at 5 Hz, and band-pass filtered between 0.4 Hz and 0.8 Hz to eliminate low and high frequency noise while preserving the main contraction power. They then were normalized to scale the signal from 0 to 100 units by dividing the signal amplitude by the mean of the 5% highest absolute values then multiplying by 100. After rectification, the signals finally were low-pass filtered at 0.015 Hz. For each patient, the channel with the highest signal-to-noise ratio was selected for this study.

Because data from the cardiotocograph had an irregular sampling rate of approximately 12 Hz, the signal was processed to a uniform sampling rate of 2 Hz. The signal then was median filtered with a window of 21 samples, and low-pass filtered at 0.03 Hz to remove artifacts. For comparison with the electrohysterogram data, the cardiotocograph signal finally was resampled at 5 Hz.

Contractions were detected with a three-step process. First, a moving window of 30 seconds duration was applied to the signal. In that window, the vertical change (maximum–minimum value) was calculated. Contraction onset was identified when this difference was greater than 5 units (normalized units for the electrohysterogram, mm Hg for cardiotocograph), and the maximum value was the last sample in the window. Upon identifying a contraction onset, a 10-second moving window was applied and the vertical change (maximum–minimum) calculated. A contraction offset was found when, for 3 consecutive seconds, the vertical change was less than 2 units, or the last sample value exceeded the minimum value in the window. Also, the last sample value must have been within 15 units of the value at contraction onset. Finally, contractions were detected when consecutive onset and offset were found, with duration (offset minus onset times) between 30 seconds and 180 seconds, and time elapsed after the last measured contraction peak was greater than 60 seconds.

To evaluate contraction consistency, we used the contractions consistency index defined by Jezewski et al[14]:

$$CCI = \frac{N_c}{\frac{1}{2}(N_r + N_E)}$$

where N_T is the number of contractions detected by standard uterine activity monitoring (tocodynamometer or intrauterine pressure catheter), N_E is the number detected in the electrohysterogram signal, and N_C is the number of consistent contractions. Contractions were consistent when the peak of a contraction from the electrohysterogram signal was within plus or minus 1 minute of the peak of a contraction from the cardiotocograph signal. Contraction lengths were compared using the mean value of related differences,[14] duration differences/mean of the paired values.

All data were reported as mean plus or minus standard deviation or median and quartiles. Two-tailed paired t tests were used to compare contractions consistency index and contraction duration between methods of contraction detection. A $P<.05$ two-tailed was considered significant. Nonsignificance was equated with an inconclusive result. For each question, the study had 80% power to detect a paired difference in means equal to 0.58 standard deviations, at $P=.05$, two-tailed. Pearson's correlation was used to investigate the mitigating effect of BMI.

RESULTS

A total of 26 patients met the inclusion criteria. Of these, one was eliminated because the intrauterine pressure catheter never functioned. Demographic characteristics of the subjects are listed in Table 1. Seven subjects (28%) underwent amniotomy at the time of intrauterine pressure catheter placement. All other subjects had ruptured membranes both during tocodynamometer and intrauterine pressure catheter monitoring.

Tocodynamometry identified 248 compared with 336 electrohysterogram contractions, whereas the intrauterine pressure catheter identified 319 compared with 342 electrohysterogram contractions. Using the above criteria for consistency, electrohysterography and tocodynamometry agreed on 237 contractions, whereas the intrauterine pressure catheter and electrohysterography concurred on 310. The contractions consistency indices between electrohysterography and each traditional method are presented in Table 2. The electrohysterogram correlates more closely with the intrauterine pressure catheter than with the tocodynamometry ($P=.004$). Increasing BMI did not correlate with the difference in contractions consistency index between the tocodynamometer and intrauterine pressure catheter ($r=0.28$, $P=.17$).

Table 1. Demographic Characteristics

Characteristic	Median (25th, 75th Percentile)
Body weight (kg)	233 (218, 268)
Body mass index	39.6 (36.5, 46.3)
Gestational age (wk)	39 (38, 40)
Cervical dilation (cm)	5 (4, 7)
Delivery	
Spontaneous	11
Vacuum extraction	2
Cesarean delivery	
? – Dystocia	9
Failure of descent	1
Fetal heart rate abnormality	2

Contraction length was comparable with all methods. The intrauterine pressure catheter contraction length was 74.7±11.7 s, whereas the electrohysterogram during the same time period had a contraction length of 77.9±14.0 s. Tocodynamometer contraction length was 68.2±14.5 s, with corresponding electrohysterogram contraction length of 76.6±14.8 s. The duration differences/mean of the paired values between electrohysterography and each traditional method are presented in Table 3.

DISCUSSION

Labor management requires assessment of uterine activity. Typically, external monitoring is adequate for normal, spontaneous labors. For those requiring induction or augmentation, the intrauterine pressure catheter often is used to quantify contraction intensity. According to several studies, however, this information does not change outcome,[8,9] and availability of frequency and contraction length alone are sufficient. Electrohysterography seems to provide this information reliably, if not an absolute measure of contraction intensity (Euliano T, Skowronski MD, Marossero D, Shuster J, Edwards R. Prediction of intrauterine pres-

Table 2. Comparison of Contractions Consistency Index

Contractions Consistency Index: Electrohysterography Compared With	Mean	SD	Quartiles	*P* (2-Tailed Paired *t* Test)
Intrauterine pressure catheter	0.94	±0.06	0.92, 0.95, 1.00	
Tocodynamometer	0.77	±0.25	0.64, 0.87, 0.96	
Intrauterine pressure–tocodynamometer (difference)	0.17	±0.26	0.00, 0.07, 0.29	.004

SD, standard deviation.

sure waveform from transabdominal electrohysterography. J Matern Fetal Neonat Med 2006; in press).[13]

The correlation of external and internal monitoring has been investigated. Miles et al[15] compared tocodynamometer and intrauterine pressure monitoring of uterine activity in 20 term patients in the active phase of labor. Their population had a median BMI of 31.8 and ranged between 22.2 and 42.3. The obese subjects were not analyzed separately. They reported a contraction frequency correlation of $r=0.75$ ($P=.001$), but poor correlation of contraction amplitude and duration. Paul et al[16] similarly studied 10 preterm patients in active labor between 20 and 35 weeks gestation, comparing the (obsolete) guard-ring tocodynamometer with an intrauterine pressure catheter. The external device detected 90.8% of intrauterine pressure catheter–detected contractions, with a "similar" duration. However, none of these patients were obese; maximum BMI was 33.9 with an average of 25.2±4.4.

External monitoring is more difficult in the obese parturient, yet these patients are at increased risk for labor induction and complications.[17–19] In women attempting a trial of labor, obesity was associated with a higher failure rate (39.3% compared with 15.2% in normal weight parturients) and a five-fold increased incidence of uterine rupture or dehiscence.[20] It is possible that some of these problems could be exacerbated by inadequate monitoring. Our data suggest that external uterine activity monitoring in the obese parturient might be better achieved with electrohysterography than tocodynamometry. The performance of the electrohysterogram in contraction detection was superior to tocodynamometry, and approximated that of invasive intrauterine pressure monitoring.

Several groups have investigated the electrohysterogram, most focusing on the power spectrum of the signal itself.[11,21] To date, Jezewski et al[14] are the only investigators to compare electrohysterography with standard monitoring. They studied 108 electrohysterogram and tocodynamometer tracings in term patients before the onset of labor. No information was provided regarding the patients themselves or the data collection environment, so we can make no inference regarding BMI. They report an overall contractions consistency index of 0.91 on 1,238 total contractions, with a minimum contractions consistency index of 0.77. Contraction duration correlated poorly between the methods. Due to lack of details regarding the clinical portion of their study, it is difficult to contrast with our work. In addition to differences in signal acquisition and filtering, our patients were in active labor in the obstetric suite, adding perhaps more noise to the signal. Furthermore, we limited our study population to obese women, in whom tocodynamometry is known to fail more often. This characteristic of our study population may explain why our average tocodynamometer contractions consistency index only approached their minimum contractions consistency index.

Limitations to our study are numerous. First, we did not simultaneously collect tocodynamometer, intrauterine pressure catheter and electrohysterogram data. To circumvent the inability of our cardiotocograph monitor to collect two simultaneous uterine activity channels, we examined uterine activity at similar times–immediately before and after intrauterine pressure catheter placement, disregarding the placement and zeroing times of the catheter. Over that time period (average 75.3±18.8 minutes), it is unlikely that there was a dramatic change in contraction frequency, even in those women who underwent amniotomy. Further, the number of electrohystero-

Table 3. Comparison of Contraction Length Using Related Differences

Variable: Electrohysterography Compared With	Mean	SD	Quartiles	*P* (2-Tailed Paired *t* Test)
Intrauterine pressure catheter	0.042	±0.108	–0.05, 0.05, 0.08	
Tocodynamometer	0.129	±0.306	–0.07, 0.09, 0.25	
Intrauterine pressure catheter–tocodynamometer	–0.087	±0.292	–0.25, –0.03, 0.29	.15

SD, standard deviation.

gram-detected contractions changed little (336 compared with 342 during tocodynamometer and intrauterine pressure catheter periods, respectively), yet correlated well with the intrauterine pressure catheter, suggesting that the tocodynamometer significantly underrecognized contractions in the group as a whole. Another limitation of this study is the arbitrary selection of parameters for contraction detection; however the consistent application of such parameters should limit bias. The electrohysterogram overdetection rate was related to contractions in the intrauterine pressure catheter that did not reach our selected threshold, some double counting when the electrohysterogram detected a "double hump" contraction (but the intrauterine pressure never fell below threshold), and system noise in one patient that accounted for nearly one third of the extra contractions. Finally, the large number of electrodes on the maternal abdomen and requirement for skin preparation would make routine use of this monitor cumbersome. It seems, however, that fewer electrodes should be sufficient. In the study of Jezewski,[14] only four electrodes were placed midline down the maternal abdomen, with a reference on the left hip. For the present study we used only one electrohysterogram signal (three electrodes) for each patient, selecting the one with the best signal-to-noise ratio. Although further studies are needed, it is expected that four or five electrodes would be sufficient.

Although contraction frequency information alone should be sufficient for active management of labor and titration of oxytocin, inability to obtain this information externally is an indication for intrauterine pressure catheter placement.[22] Intrauterine pressure catheter use is known to increase the risk of chorioamnionitis, particularly when use is prolonged.[2–4] Similarly, obesity is associated with both prolonged labor and an increased incidence of infection.[18] Although data on the frequency of intrauterine pressure catheter use in the obese population is not available, perhaps these factors are linked. Electrohysterography may provide an improved method of noninvasive uterine activity monitoring, particularly in obese women.

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