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ARTICLE

Could electrohysterography be the solution for external uterine monitoring in obese women?

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Abstract

Objective To evaluate the influence of maternal obesity on the performance of external tocodynamometry and electrohysterography.

Study design In a 2-hour measurement during term labor, uterine contractions were simultaneously measured by electrohysterography, external tocodynamometry, and intra-uterine pressure catheter. The sensitivity was compared between groups based on obesity (non-obese/obese/morbidly obese) or uterine palpation (good/moderate/poor), and was correlated to maternal BMI and abdominal circumference.

Result We included 14 morbidly obese, 18 obese, and 20 non-obese women. In morbidly obese women, the median sensitivity was 87.2% (IQR 74–93) by electrohysterography and 45.0% (IQR 36–66) by external tocodynamometry ($p < 0.001$). The sensitivity of electrohysterography appeared to be non-influenced by obesity category ($p = 0.279$) and uterine palpation ($p = 0.451$), while the sensitivity of tocodynamometry decreased significantly ($p = 0.005$ and $p < 0.001$, respectively). Furthermore, the sensitivity of both external methods was negatively correlated with obesity parameters, being non-significant for electrohysterography (range p-values 0.057–0.088) and significant for external tocodynamometry (all p-values < 0.001).

Conclusions Electrohysterography performs significantly better than external tocodynamometry in case of maternal obesity.

Introduction

The prevalence of obesity has more than doubled worldwide since 1980. Currently, 20% of the women in the European Region and up to 33% of the population in the United States are obese [1]. The increase in obesity results is one of the greatest medical challenges for pregnancy and labor care in the 21st century [1].

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During pregnancy, obese women are at the risk of cardiovascular complications such as pre-eclampsia and gestational diabetes [2, 3]. Moreover, fetal ultrasound is compromised by the increased abdominal fatty layers resulting in suboptimal fetal (growth) surveillance [4]. Additionally, there is an increased risk of labor dystocia and emergency cesarean section during labor [5–7]. Given these additional risks, obese women particularly require close labor surveillance. Unfortunately, these requirements are often impossible to meet because external intrapartum monitoring is hampered by obesity [8–10].

Uterine contraction detection is one of the main intrapartum parameters during term labor [11]. Contractions are routinely monitored using external tocodynamometry (TOCO), measuring uterine activity non-invasively and indirectly by responding to external abdominal deformations [8]. The average sensitivity of TOCO is only 62–74%, which further decreases to 51% in case of maternal obesity [12, 13]. If external uterine monitoring is not sufficient, the obstetrician can decide to insert an intra-uterine pressure catheter (IUPC), provided that there is sufficient dilation and the membranes are ruptured [10, 14]. This invasive method is currently the gold standard for uterine activity monitoring [8]. Unfortunately, cases with severe IUPC-related complications such a placental abruption and uterine perforation have been described [15, 16].

Electrohysterography (EHG) is an innovative technology which could improve external uterine monitoring in obese parturients [17, 18]. EHG measures the uterine electrical activity non-invasively [18, 19]. These electrical currents are theoretically less compromised by abdominal adipose tissue in comparison to the mechanical coupling of TOCO [8]. Furthermore, EHG consists of adhesive abdominal electrodes, potentially providing more continuous monitoring. Based on these advantages of EHG, we evaluated the performance of EHG in obese laboring women by comparing it to the performance of TOCO relative to IUPC.

Materials and methods

We performed a prospective diagnostic study for uterine contraction monitoring in pregnant women during term labor. The Medical Ethics Committee of Máxima Medical Center approved the study protocol on 15th July 2014 (NL48951.015.14) and the study was registered in the Dutch trial register (NTR5894). All patients were recruited in our hospital from July 2014 until June 2016 and signed informed consent before start of the simultaneous measurements with three tocographic methods: IUPC, EHG, and TOCO. Further details on the study design and methods have been reported before pertaining to the general EHG test characteristics [20]. We here report our obesity analyses for which we included four additional morbidly obese women to achieve sufficient power (see section Statistical analysis).

We included pregnant women with a gestational age between 37 and 42 weeks, in term labor, carrying a singleton fetus in cephalic presentation. Labor was defined as clinical contractions ($\geq$3/10 min) and at least 3 cm of dilation [21]. Ruptured membranes were required for insertion of an IUPC and internal fetal heart rate monitoring was required in order to assure optimal placement of TOCO and EHG at the maternal abdomen. We excluded women at increased risk of infections, with signs of fetal distress, or with contra-indications for IUPC or the EHG patch. Full details on the exclusion criteria are available in our earlier publication [20].

In our hospital, TOCO is the standard method for uterine contraction monitoring. For this study, we applied two additional techniques during labor: IUPC and EHG. First, an ultrasound was performed to locate the placenta after which IUPC was placed (Koala, Clinical Innovations, Murray, Utah, USA). Next, the real-time EHG device was positioned. We applied a single abdominal patch for recording the uterine electrical currents connected to a translation module containing the hardware and software for data acquisition (Graphium and PUREtrace, Nemo Healthcare, Eindhoven, The Netherlands) [20]. This EHG method has acquired CE- and FDA-approval. The abdominal surface was prepared with abrasive paper and checked for skin impedance (SIGGI II, MedCaT, Klazienaveen, Netherlands, target value <5 kΩ). Subsequently, a patch featuring two recording electrodes was placed on the maternal abdomen, next to or above the umbilicus depending on adequate uterine interface. The electrophysiological data were band-pass filtered between 0.3 and 0.8 Hz to suppress electrical activity from sources other than the uterus and were converted into a real-time tocogram, based on a mathematical model described by Rabotti et al. [22]. Finally, the TOCO was optimally positioned at the uterine fundus by the attending nurse and the elastic belt was tightly wrapped around the abdomen. Nurses checked the TOCO every 30 min, and repositioned if necessary.

Three CTG-monitors (Avalon FM30, Philips Healthcare, Eindhoven, The Netherlands) were applied to record the tocograms of all techniques in real-time. IUPC and EHG were directly connected, and for TOCO, a wireless connection was used due to logistic constraints. All data were stored automatically in the electronic patient record system including time synchronization (EZIS, Chipsoft, sampling frequency: 4 Hz). The main researchers (MV and KT) performed all study recordings which included measurement of the abdominal circumference at the height of the umbilicus and assessment of uterine palpation by using a subjective scale of good, moderate, or poor. All participants were monitored and observed for at least 30 min up till 120 min, and relevant events such as vaginal examinations and maternal movements were annotated by the researchers. Once 2 h were completed, we removed the external devices and IUPC remained until the end of the delivery.

Study outcomes

The sensitivity of EHG and TOCO for contraction detection in morbidly obese women (body mass index (BMI) >40 kg/m^2) was the main outcome parameter, with IUPC as the method of reference. The sensitivity was calculated per patient for the entire measurement period as the proportion of contractions by IUPC also detected by EHG and TOCO, respectively. Contractions were considered as correct positive if the contraction peak of the external methods was within 30 s of the IUPC peak. Secondary diagnostic parameters (defined in Vlemminx et al. [20].) were the positive predictive value (PPV), the contraction frequency per 10 min, and the contraction consistency index (CCI) [23]. Furthermore, we calculated the false-positive and false-negative contraction ratios, expressed per 100 contractions in EHG or TOCO.

As a secondary analysis, we assessed the influence of obesity parameters on contraction detection. First, the sensitivity of EHG and TOCO was compared in subgroups of non-obese ($BMI < 30\,kg/m^2$), obese ($BMI \geq 30$–$< 40\,kg/m^2$), and morbidly obese ($BMI \geq 40\,kg/m^2$) women. We used the BMI values based on the final reported weight before labor. Second, we compared the groups of women being assessed as good, moderate, or poor uterine palpation during labor. Third, the relation of the maternal BMI and abdominal circumference with the sensitivity of EHG and TOCO was assessed by linear regression, with BMI or abdominal circumference as the independent variable.

To assure an objective assessment of contraction detection, we applied a blinded computer-based algorithm (Mat Lab R2016B, MathWorks, Natick, Massachusetts, USA) which was developed by the Eindhoven University of Technology. The algorithm was based on previous literature, and was tested and customized before the start of the study measurements [23]. For the criteria and the output of the computer-based algorithm, see Vlemminx et al. [20].

Statistical analysis

For this obesity study, a total of 52 pregnant women were included. We used the data of 48 participants included in our general diagnostic study, subdivided in 20 non-obese, 18 obese, and 10 morbidly obese women [20]. However, as described in our study protocol beforehand, we wanted to achieve sufficient power to compare the sensitivity of EHG and TOCO in the morbid obesity group. Therefore, we performed a sample size calculation based on the study results of Euliano et al. [12]. In their group of obese women ($BMI > 35\,kg/m^2$), the sensitivity of EHG was 82% ((standard deviation (SD) 27%) and with TOCO 51% (SD 30%). Additionally, we assessed the TOCO curves of all morbidly obese women ($BMI \geq 40\,kg/m^2$) in our hospital during 2013. Adequate TOCO registration ranged from 0% to 60% during labor, which was defined as a recognizable pattern of contractions each 15 min in disregard of inadequate calibration. These previous data resulted in our sample size calculation for the morbid obesity group. We assumed a sensitivity of 80% (SD 30%) for EHG and 45% (SD 30%) for TOCO, respectively, resulting in 14 morbidly obese to detect this difference with a power of 80% and a type I error of 5%. Thus, next to the 10 morbidly obese women who were already included in our general study, an additional four morbidly obese women were required.

Comparison of EHG and TOCO diagnostic values were statistically tested in morbidly obese women by using the Wilcoxon signed rank test for non-normally distributed data. For the comparison of sensitivity across non-obese/obese/morbidly obese groups and across women with good/moderate/poor uterine palpation, the Kruskal–Wallis Test was used for non-normally continuous data, and the Fisher's exact test for categorical variables. Furthermore, the correlation between the sensitivity of EHG or TOCO with the maternal BMI or maternal abdominal circumference was described by a linear regression and the Pearson-correlation coefficient.

Two researchers (KT and MV) collected all data using a structured surveillance form. Additionally, the obstetric outcome parameters were extracted from the electronic patient record system. Statistical analyses were performed in IBM SPSS 20 statistics for Windows (New York, USA). Two-sided p-values <0.05 were considered as statistical significant.

Results

From July 2014 till June 2016, 14 morbidly obese, 18 obese, and 20 non-obese women were included. The sociodemographic and clinical characteristics of these women are presented in Table 1. There were no significant differences between the obesity groups, apart from BMI values before pregnancy and during labor, abdominal circumferences, and uterine palpation category. The abdominal circumference of one woman and the final body weights of three women were unknown. Therefore, we considered their pre-pregnancy weight as well as their final pregnancy weight, which concerned BMI values of 20, 42, and 48. There were no other missing data. We did not have any (serious) adverse events or dermatologic skin reactions.

In the morbidly obese women, the median sensitivity of EHG was 87.2% (interquartile range (IQR) 74–93) for contraction detection, which was significantly better than that of TOCO of 45.0% (IQR 36–66). All other diagnostic parameters such as PPV, CCI, false-positive, and false-negative contraction ratios were also significantly better for EHG than for TOCO (Table 2).

The diagnostic values of EHG and TOCO were also compared between groups of non-obese, obese, and morbidly obese pregnant women (Table 3). Concerning EHG, the sensitivity and PPV medians did not significantly differ between these three groups. The median sensitivity of TOCO was significantly reduced by obesity ($p = 0.005$) with 12.4% reduction from non-obese to obese, and 32.7% reduction from non-obese to morbidly obese women. A similar decreasing trend was found for the PPV of TOCO ($p = 0.059$) with 10.3% reduction between non-obese and obese, and 21.3% reduction between non-obese and morbidly obese women (Table 3). When directly comparing the performance of TOCO and EHG in the group of obese women, the sensitivity of TOCO (median 65.3%) was

Table 1 Sociodemographic and clinical characteristics of non-obese (BMI <30 kg/m^2), obese (BMI ≥ 30–<40 kg/m^2), and morbidly obese (BMI ≥ 40 kg/m^2) pregnant women simultaneously monitored with electrohysterography, external tocodynamometry, and intra-uterine pressure catheter. Groups are defined on BMI values during labor

Description	Morbidly obese (N = 14)	Obese (N = 18)	Non-obese (N = 20)	Significance
Body mass index (kg/m^2)				
Before pregnancy	41.7 ± 3.1	28.7 ± 3.8	21.8 ± 2.1	$p < 0.001$[a]
During measurement *	44.7 ± 2.5	34.0 ± 2.4	26.3 ± 2.6	$p < 0.001$[a]
Maternal age (y)	30.7 ± 4.6	33.7 ± 4.4	30.7 ± 3.5	$p = 0.090$[a]
Race				$p = 0.723$[b]
Caucasian	13 (93)	16 (89)	19 (95)	
Other	1 (7)	2 (11)	1 (5)	
Parity				$p = 0.644$[b]
Nulliparous	8 (57)	9 (50)	12 (60)	
Multiparous	6 (43)	9 (50)	8 (40)	
Gestational age (wk + d)	39 wk + 3d	39 wk + 3d	39 wk + 5d	$p = 0.696$[a]
Start of labor				$p = 0.466$[b]
Spontaneous onset	6 (43)	4 (22)	6 (30)	
Induction of labor	8 (57)	14 (78)	14 (70)	
Oxytocin usage				$p = 1.000$[b]
No	4 (29)	5 (28)	5 (25)	
Yes	10 (71)	13 (72)	15 (75)	
Labor analgesia				$p = 0.270$[b]
No analgesia	6 (43)	5 (28)	4 (20)	
Epidural analgesia	7 (50)	11 (61)	16 (80)	
Remifentanil	1 (7)	2 (11)	0 (0)	
Duration measurement (min)	111.5 ± 20.1	103.1 ± 36.2	100.8 ± 27.9	$p = 0.895$[a]
Cervical dilation (cm)				
Start measurement	5.3 ± 2.1	4.8 ± 2.1	5.1 ± 1.9	$p = 0.488$[a]
Stop measurement	7.3 ± 2.7	7.5 ± 2.9	8.0 ± 2.1	$p = 0.669$[a]
Mode of delivery				$p = 0.559$[b]
Spontaneous vaginal delivery	10 (72)	14 (78)	12 (60)	
Vacuum delivery	1 (7)	1 (5)	5 (25)	
Cesarean section	3 (21)	3 (17)	3 (15)	
Abdominal circumference (cm)[c]	140.5 ± 11.1	117.7 ± 7.2	102.3 ± 6.9	$p < 0.001$[a]
Palpation uterus				$p < 0.001$[b]
Good	1 (7)	5 (28)	16 (80)	
Moderate	0 (0)	7 (39)	4 (20)	
Poor	13 (93)	6 (33)	0 (0)	
Contraction frequency (10 min)				
Intra-uterine pressure catheter	3.8 ± 0.5	3.8 ± 0.8	3.8 ± 0.8	$p = 0.995$[a]
Electrohysterography	4.1 ± 0.5	4.3 ± 0.6	4.2 ± 0.5	$p = 0.277$[a]
External tocodynamometry	3.3 ± 0.6	3.9 ± 0.6	3.9 ± 0.7	$p = 0.074$[a]

Data are mean ± standard deviation, median (range), n, or n (%) unless otherwise specified

In three women, BMI during labor are missing (values of 20, 42, and 48 before pregnancy)

[a]Kruskal–Wallis test

[b]Fisher's Exact test

[c]In one woman, the abdominal circumference during labor is missing (from the non-obese group)

significantly lower than EHG (median 90.2%), $p < 0.001$ (Table 3).

We also divided all participants in groups based on our assessment uterine palpation, thereby providing an additional parameter for abdominal obesity. There was no difference in sensitivity of EHG sensitivity between these groups (median sensitivity resp. 90.6%, 86.4%, and 89.3%, $p = 0.451$) whereas there was a significant decrease of TOCO sensitivity when the uterus was less adequately palpable (median sensitivity resp. 80.3%, 69.0%, and 46.9%, $p < 0.001$) (Fig. 1).

Finally, the maternal BMI and abdominal circumference were correlated with the sensitivity values of both external methods. With increasing BMI before pregnancy, both EHG as well as TOCO revealed a decreasing sensitivity which was non-significant for EHG (slope $\beta = -0.32$, $r = 0.24$, $p = 0.083$) and significant for TOCO (slope $\beta = -1.10$, $r = 0.46$, $p = 0.001$) (Fig. 2). Comparable results were found for the relation of the BMI during labor (EHG sensitivity slope $\beta = -0.38$, $r = 0.27$, $p = 0.057$ and TOCO sensitivity slope $\beta = -1.28$, $r = 0.49$, $p < 0.001$), and the abdominal circumferences of our participants during labor (EHG sensitivity slope $\beta = -0.16$, $r = 0.24$, $p = 0.088$ and TOCO sensitivity slope $\beta = -0.59$, $r = 0.50$, $p < 0.001$) (Fig. 2).

Discussion

In this obesity study, external uterine contraction detection in morbidly obese women was better achieved by EHG than TOCO. When comparing morbidly obese women with groups of obese and non-obese women, the sensitivity of EHG appeared to be non-influenced, whereas TOCO sensitivity significantly decreased in case of maternal obesity. Furthermore, our results showed that increasing maternal BMI and abdominal circumference are related to a sensitivity decrease of both external methods. This correlation was only significant for TOCO.

The main strength is that our diagnostic study is powered to compare the sensitivity of EHG to TOCO in morbidly obese women thereby providing sufficient power for this specific group. Moreover, our study design offers a direct comparison of all three currently available uterine monitoring techniques, including computer-based contraction detection to minimize observer bias. Additionally, we provided detailed reports of all measurements as we continuously observed all study participants.

The study has the following limitations. Due to our eligibility procedure at the labor ward, we included a relatively large percentage of women with epidural analgesia (65%). This could positively influence the sensitivity results because women with epidural analgesia are less restless

Table 2 The diagnostic values of electrohysterography and external tocodynamometry in morbidly obese women; with the intra-uterine pressure catheter as the method of reference ($N = 14$)

Description	EHG	TOCO	Difference	Significance
Sensitivity (%)	87.2 (74–93)	45.0 (36–66)	42.2	$p = 0.002$*
Contraction consistency index (%)	83.7 (67–90)	50.8 (37–66)	32.9	$p = 0.002$*
Positive predictive value (%)	80.9 (61–88)	56.2 (41–73)	24.7	$p = 0.005$*
False-positive contraction ratio (%)	19.1 (12–39)	43.8 (27–59)	24.7	$p = 0.005$*
False-negative contraction ratio (%)	12.7 (7–23)	64.9 (35–87)	52.2	$p = 0.002$*

Data are medians with interquartile range

EHG electrohysterography, *TOCO* external tocodynamometry

*Wilcoxon signed rank test

Table 3 Sensitivity and positive predictive value of electrohysterography and external tocodynamometry in subgroups of non-obese (BMI <30 kg/m^2), obese (BMI ≥ 30–<40 kg/m^2), and morbidly obese (BMI ≥ 40 kg/m^2) women

Description	Morbidly obese ($N = 14$)	Obese ($N = 18$)	Non-obese ($N = 20$)	Significance
Sensitivity EHG (%)	87.2 (74–93)	90.2 (87–97)	89.9 (83–93)	$p = 0.297$*
Sensitivity TOCO (%)	45.0 (36–66)	65.3 (60–79)[a]	77.7 (57–90)[a]	$p = 0.005$*
PPV EHG (%)	80.9 (61–88)	79.2 (70–91)	81.0 (62–93)	$p = 0.884$*
PPV TOCO (%)	56.2 (41–73)	67.2 (54–80)[b]	77.5 (61–92)[b]	$p = 0.059$*

Data are median with (interquartile range)

BMI values were determined on the final pregnancy weight before labor

EHG electrohysterography, *TOCO* external tocodynamometry, *BMI* body mass index, *PPV* positive predictive value

*Kruskal–Wallis test

[a]Sensitivity of TOCO was significantly lower than EHG in both non-obese and obese women ($p \leq 0.001$)

[b]PPV of TOCO was lower than EHG in obese women ($p = 0.006$) and in non-obese women ($p = 0.277$)

[a,b]Wilcoxon signed rank test

throughout labor (restless was observed in 67% (10/15) of the women without epidural compared to 12% (4/34) of the women with epidural), and are therefore less at risk of mechanical artifacts. However, the use of epidural analgesia was less predominant in the morbidly obese group (50%), probably because we actively recruited most of the morbidly obese women from the outpatient clinic instead of at the labor ward.

We are also aware that we measured only 2 h during the dilation and/or expulsion phase. On ethical grounds, we limited the duration to 2 h because the study measurements were quite intensive for the participants. Furthermore, the sample size was not calculated for obesity category or uterine palpation comparisons, resulting in small groups for these sub analyses. Post-hoc power calculation, however, revealed a power of 96% for detecting the sensitivity difference of TOCO between non-obese and morbidly obese women.

As obesity increases worldwide, this study describes an important challenge in women's health. Maternal obesity is one of the most common risk factors during pregnancy, which is related to gestational diabetes, macrosomia, hypertension, and pre-eclampsia [2]. A linear correlation between increasing BMI and hypertensive disorders is described [24]. Moreover, fetal ultrasound is compromised by obesity resulting in suboptimal fetal growth surveillance and screening for fetal anomalies [4]. Therefore, even before labor begins, obese women and their unborn children have several additional risk factors.

During labor, the magnitude of risk management expands even further. First, labor of obese women is more commonly induced because of pregnancy complications [2]. Additionally, a higher risk of dysfunctional labor, fetal distress, and cesarean section is described. [3, 5–7] Obstetricians do not prefer to perform a cesarean delivery in (morbidly) obese women due to surgical and anesthetic difficulties [3]. Obstetrical caregivers therefore aim to prevent a cesarean section. Labor monitoring can be optimized by invasive methods such as IUPC and fetal scalp recording [8, 11]. Unfortunately, case reports have described major IUPC complications [15]. With EHG, we can enhance maternal and fetal labor surveillance in the obese parturient without applying invasive techniques.

Our study has demonstrated that EHG performs significantly better than external TOCO in (morbidly) obese

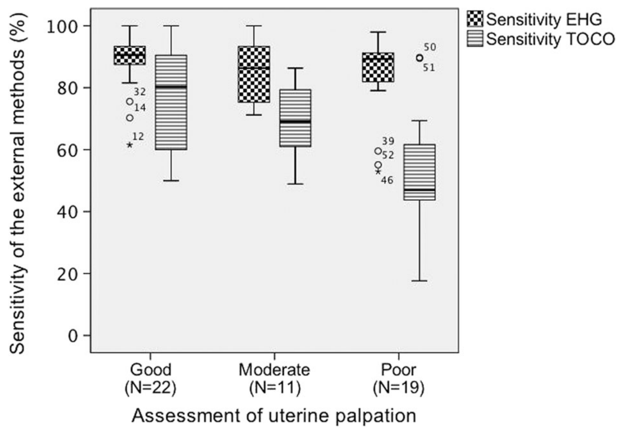

Fig. 1 Sensitivity of electrohysterography and external tocodynamometry for uterine contraction detection in women with good, moderate, or poor uterine palpation. The box plots represent the interquartile range from the 25th till the 75th quartile and the horizontal line in the box shows the median. Each box is lined by the minimum and maximum. The circles are cases with outlying values, whereas the asterisk is a case with an extreme outlying value. No significant differences between groups were found for EHG sensitivity (median sensitivity resp. 90.6%, 86.4%, and 89.3%, $p = 0.451$), while TOCO showed a significant decrease in sensitivity when the uterus was less adequately palpable (median sensitivity resp. 80.3%, 69.0%, and 46.9%, $p < 0.001$) (tested by Kurskal–Wallis). EHG electrohysterography, TOCO external tocodynamometry

women, and is not significantly influenced by increasing BMI. Our results are comparable with the results of Euliano et al. [12]. In their obesity analysis, sensitivity of EHG decreased by −11% (from 93% to 82%, $p = 0.10$), whereas TOCO decreased by −16% (from 67% to 51%, $p = 0.03$). They also demonstrated that as BMI increased, sensitivity values reduced in both TOCO ($r = -0.26$, $p = 0.04$) as well as EHG ($r = -0.23$, $p = 0.07$), which was only significant for TOCO [12]. However, the described EHG method of Euliano et al. could not be connected to standard fetal monitoring systems. Opposite results were shown by Cohen et al. [25]. Both external methods in their study showed no significant trend related to maternal BMI for the success rate or sensitivity: EHG $r = -0.004$, $p = 0.09$, and TOCO $r = -0.001$, $p = 0.842$ [25]. They even described a significant improvement of EHG sensitivity in the first stage of labor as BMI increased ($p = 0.025$). These results might be influenced by their inclusion criteria, as they described that EHG was only applied ‘once TOCO was working properly’.

Despite the adequate EHG performances in our obesity study, we are aware that uterine electrical signals are not immune to subcutaneous fatty layers [19, 26]. Our study results have shown a correlation on the margin of significance between EHG sensitivity and several obesity parameters (p-values ranged from 0.06 to 0.09). We positioned the patch at the abdominal zone with the greatest myometrial interface which was determined by manual palpation. For example, in our morbidly obese population, the patch was positioned above the umbilicus in half of the participants. Another challenge is when obese women change position, which alters the inter myometrium-electrode position and distance, and could therefore affect the performance of EHG.

In our group of morbidly obese women, the median EHG sensitivity was 87.2% thus approximating the performance of IUPC. However, EHG did not reach adequate diagnostic values in all morbidly obese women as the values ranged from 53% up to 96%. Therefore, in the few cases that uterine monitoring is inadequate by both EHG as well as TOCO, there should still be place for invasive methods as uterine monitoring is an essential part of fetal surveillance. We are also aware that current evidence does not support standard IUPC use because a large randomized controlled trial comparing TOCO with IUPC showed no improvement of obstetric outcome. Remarkably, there was a 12% crossover from TOCO to IUPC, which concerned women with a

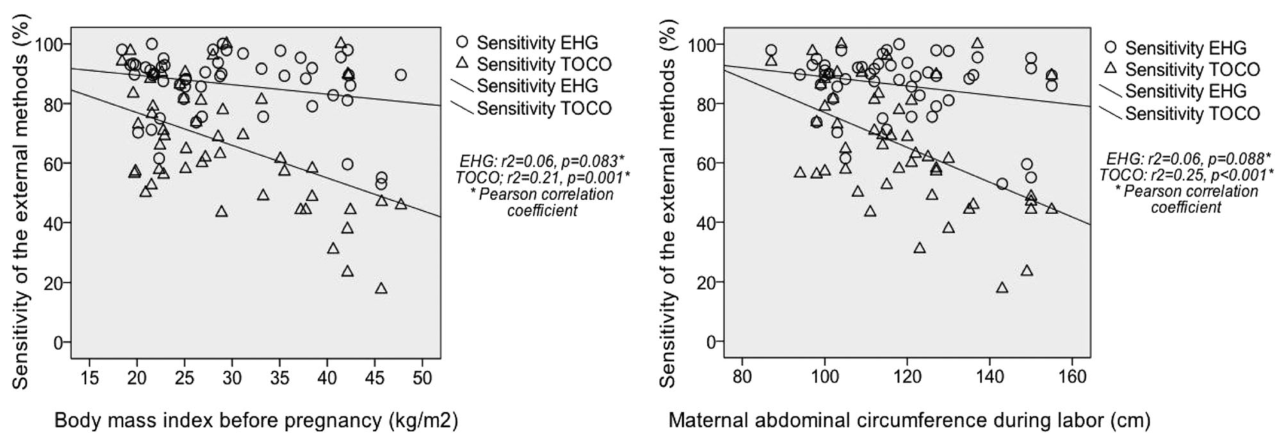

Fig. 2 Correlation of obesity parameters with the sensitivity of electrohysterography and external tocodynamometry ($N = 52$). Left: correlation with the maternal body mass index before pregnancy. Right: correlation with the maternal abdominal circumference during labor. EHG electrohysterography, TOCO external tocodynamometry

higher average BMI [27]. Hence, we agree with the American College of Obstetricians and Gynecologists that IUPC ‘may be beneficial in obese women when contraction monitoring is difficult’ [14]. Yet, we suggest to add that both TOCO and EHG should have been attempted, before applying IUPC.

In conclusion, EHG can non-invasively improve uterine monitoring in (morbidly) obese women. Further research is necessary to evaluate whether application of EHG affects obstetric outcome parameters in this high-risk population.

Compliance with ethical standards

Conflict of interest Author Professor Oei is a gynecologist and the Head of the Obstetric Department of Máxima Medical Center and leader of the fundamental perinatology research group from Eindhoven University of Technology. From this scientific research, the described EHG device and the company Nemo Healthcare has originated. Máxima Medical Centre has a research collaboration with Nemo Healthcare. Professor Oei has no affiliations with or involvement in Nemo Healthcare with any financial interest. During the study, authors MV, KT, and BvdH were financially supported by a general gift of the independent Dutch ‘Stichting De Weijerhorst’ for electro-fetal-maternal monitoring. From 2016, author KT is being paid by a grant from the European Framework Research and Innovation Program ‘Horizon 2020’ (Grant number 719500). Authors GB and JD have no conflicts of interest.

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