

SHORT REPORT

Fetal and maternal heart rate confusion during intra-partum monitoring: comparison of trans-abdominal fetal electrocardiogram and Doppler telemetry

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Objective: To compare intra-partum performance of trans-abdominal electrocardiogram with Doppler telemetry.

Methods: In this prospective longitudinal study, simultaneous monitoring with trans-abdominal ECG and Doppler telemetry was performed in 41 uncomplicated term singleton pregnancies during labour. **Results:** The overall success rate for FHR monitoring was similar between trans-abdominal ECG and Doppler telemetry ($88.5 \pm 16.7\%$ vs $89.4 \pm 7.6\%$), except for the second stage of labour. A significantly higher rate of confusion ($p < 0.001$) between fetal and maternal heart was found for Doppler telemetry ($4.5 \pm 4.5\%$) compared with trans-abdominal ECG ($1.3 \pm 1.9\%$), especially in the second stage and during maternal movements. **Conclusions:** Trans-abdominal ECG monitoring is feasible, with comparable success rate to traditional Doppler telemetry, without interfering with maternal mobility or requiring midwife intervention. The reduction in maternal/fetal heart rate confusion from trans-abdominal ECG could reduce incorrect obstetric interpretation.

Keywords: Doppler telemetry, intra-partum fetal monitoring, labour, trans-abdominal fetal ECG

Introduction

Antepartum fetal surveillance techniques based on assessment of fetal heart rate patterns have been in clinical use for almost three decades. Although, the gold standard is defined by fetal scalp electrode ECG, the use of cardiotocography (CTG), based on Doppler technology, has become a standard and accepted technique to monitor the state of the fetus before and during labor [1,2]. Nevertheless, clinical experience from more than 30 years, showed that CTG is characterized by some limitations: high sensitivity but low specificity in identifying compromised fetuses during the intra-partum period; CTG traces are often interpreted differently by different caregivers (inter-observer variation) and even by the same caregiver interpreting the same record at different times (intra-observer variation) [3,4]. High intra- and inter-observer variability in interpretation of tracing, partially explains the difficulties in classification of fetal patterns and, consequently, non homogeneous obstetrical intervention between the clinicians [3,4]. The poor performance in interpretation of the traces can also be partially explained by the presence

of the pitfalls, which are present more often than we are aware [5]. Over-counting, signal loss, feto-maternal heart rate confusion are just some examples. Indeed, the latter, when left undetected can lead to inappropriate intervention and/or adverse outcome.

It is common clinical experience that in the presence of inadequate Doppler monitoring, the midwife will advise the women to lay still, prioritizing the quality of the monitoring over the mobility and patient comfort. The recent Cochrane review reported that the restriction of the mobility during the labor prevents the use of massage, and alternative positions, as control and coping strategies during labor [6]. There is evidence that walking and upright positions in the first stage of labor reduce the length of labor and do not seem to be associated with increased intervention or negative effects on mothers' and babies' well-being [7,8]. Moreover ambulation or upright positions during labor have a number of physiological benefits, including the effect of gravity and increased pelvic dimensions, which may decrease the need for instrumental deliveries [8].

Up until recently, trans-abdominal recording of the fetal ECG (fECG) was not technically feasible. Recent technological improvements have led to the development of a new device that allows passive and non-invasive continuous recording of the fetal and maternal electrocardiogram (ECG) and maternal electrohysterogram (EHG) without interfering with maternal mobility.

The aim of our study was to compare the performance and FHR/MHR confusion of trans-abdominal fECG with standard Doppler telemetry during labor.

Materials and methods

For the purposes of our study simultaneous monitoring with trans-abdominal ECG (Monica AN24®, Monica Healthcare) and standard CTG telemetry (Avalon CTS FM30®, Philips) was performed in women in first and second stage of labor on the labor ward of the Children's Hospital "Vittore Buzzi", University of Milano, Italy. The Monica AN24 is a portable battery powered device connected to 5 standard cardiac electrodes attached to maternal abdomen. The monitoring is entirely passive and acquires fetal and maternal ECG together with EHG. The device first identifies the maternal ECG waveform, which has a very different and characteristic shape with respect to the fECG, and then subtracts the maternal ECG from

the signal to leave the fECG. The fetal beat to beat R-R intervals are then used to compute the FHR. A moving 2 sec window is used to identify and average the available R-R intervals (both fetal and maternal) before outputting the fetal and maternal heart rates every ¼ second. Because the characteristics of the ECG shape (duration and amplitude) are used to differentiate the fetal and maternal complexes, the Monica AN24 does not suffer from the maternal-fetal confusion problems of Doppler based FHR devices.

The inclusion criteria were uneventful term singleton pregnancy with fetus in vertex. Multiple pregnancies, fetal abnormalities and/or the presence of maternal pathologies constituted the reason for exclusion. For all participants informed consent was obtained. Monitoring performed by trans-abdominal ECG was blinded to the staff. All clinical decisions and management were based exclusively on standard CTG evaluation. CTG transducers were repositioned in case midwives judged the trace of inadequate quality and/or loss of the signal. No readjustments were made on trans-abdominal ECG.

Following demographical characteristics of the participants were collected: age, BMI, parity and gestational age at recruitment. Labor and neonatal outcome data were recorded: type of delivery, birth-weight, pH, base excess, Apgar score, and admission to NICU.

The signal from trans-abdominal ECG and Doppler telemetry were simultaneously acquired in digital format every 0.25 seconds and stored for offline analysis in a CSV file using Microsoft excel.

The overall success rate of FHR monitoring together with possible maternal-fetal heart rate confusion using the Monica AN24 MHR as a reference, were compared between trans-abdominal ECG and CTG telemetry. Secondly, the performance and confusion rate for the two monitoring systems were analyzed in first and second stage of labor together with periods of low- and

high-maternal activity. The success rate for trans-abdominal ECG was defined as percentage of the quarter of a second epochs where a FHR value was produced. While neither trans-abdominal ECG nor Doppler telemetry represent the gold standard for fetal heart rate monitoring, the possibility of confusion between fetal and maternal heart rate was considered when the FHR was within 5 bpm of MHR acquired by trans-abdominal ECG. Maternal activity was obtained from the 3-axis accelerometer embedded in the trans-abdominal ECG monitor which was worn by the patient.

For the statistical analysis means were used with standard deviation. *t*-Test was performed and *p* value < 0.05 was considered statistically significant.

The study was approved by Ethics Committee of the local hospital (Istituti Clinici di Perfezionamento, number 255/2009).

Results

Forty-one women were recruited. Two cases (5%) were excluded from the analysis because no fECG signal was obtained with trans-abdominal ECG due to high electrical noise. The analysis was performed on 39 traces. Demographical characteristics of the women, labor data and neonatal outcome are represented in Table I. There were no admissions to neonatal intensive care unit nor Apgar score <7 at 5 minutes (Table I).

The mean length of synchronized recording was 200 minutes, 174 minutes for first stage and 45 minutes for second stage respectively. Twenty-one women were monitored for the whole length of the first and second stage of labor and 18 women had monitoring just during the first stage. Of the 18 patients, 5 patients were discontinued due to the necessity to perform caesarean section. Of the remaining 13 cases: in 5 women the Doppler telemetry monitoring was judged not satisfactory and was swapped to fetal scalp ECG; 2 women were unwilling to continue with the trial; one patient went under a shower; one monitoring was stopped 15 minutes before delivery; in 2 cases trans-abdominal ECG was switched-off by mistake; and in 2 patients there were no reason given for stopping the trial. For clarity, the trans-abdominal ECG was blinded to the staff, so the quality of trans-abdominal ECG monitoring was not a reason for stopping the trial.

The overall success rate for maternal heart rate monitoring with trans-abdominal ECG was 100%. The overall success rate for FHR monitoring was 88.5% (± 16.7) and 89.4% (± 7.6) respectively for trans-abdominal ECG and Doppler telemetry. Table II represents, in addition to overall success rate, performance during the first and second stage of labor together with the period of low- and high-maternal activity. There was no statistically significant difference between modalities, except for the performance in second stage of labor (Table II).

The overall confusion rate between fetal and maternal heart rate, as defined previously, was 1.3% (± 1.9) and 4.5% (± 4.5) respectively for trans-abdominal ECG and Doppler telemetry. Table III represents the confusion rate in first and second stage

Table I. Demographical characteristics of cohort and neonatal outcome.

Factors	Demographical characteristics
Age (min-max)	33.7 (26-41)
BMI (\pm sd)	26.8 (± 3.5)
Parity	
0	69% (27/39)
≥ 1	31% (12/39)
GA at recruitment wks (\pm sd)	40 (± 7)
Type of delivery	
vaginal	32/39 (82%)
ventouse	3/39 (8%)
CS	4/39 (10%)
Factors	Neonatal outcome
Birth-weight g (\pm sd)	3348 (± 446)
pH (\pm sd)	7.25 (± 0.1)
Base excess mmol/L (\pm sd)	-6.3 (± 3.8)

BMI, body mass index; sd, standard deviation; GA, gestational age; wks, weeks; g, grams.

Table II. Success Rate of trans-abdominal ECG and Doppler telemetry divided for 1st and 2nd stage of labour, low- and high-maternal activity.

Success rate	Trans-abdominal ECG N% (\pm sd)	Doppler telemetry N% (\pm sd)	<i>p</i> value (<i>t</i> -test)
Overall (1st + 2nd stage)	88.5 (± 16.7)	89.4 (± 7.6)	0.77
First stage	89.8 (± 16.1)	89.9 (± 7.9)	0.98
Second stage	66.5 (± 21.3)	83.7 (± 7.4)	0.001
High maternal activity	86.7 (± 20.0)	82.8 (± 12.9)	0.30
Low maternal activity	88.7 (± 16.2)	90.8 (± 6.8)	0.45

Table III. Confusion rate of trans-abdominal ECG and Doppler telemetry divided for 1st and 2nd stage of labour, low and high maternal activity.

Confusion rate	Trans-abdominal ECG N% (\pm sd)	Doppler telemetry N% (\pm sd)	<i>p</i> value (<i>t</i> -test)
Overall (1st + 2nd stage)	1.3 (\pm 1.9)	4.5 (\pm 4.5)	<0.001
First stage	1.0 (\pm 1.9)	3.9 (\pm 4.6)	<0.001
Second stage	4.6 (\pm 5.0)	11.3 (\pm 8.2)	0.002
High maternal activity	1.8 (\pm 2.9)	5.2 (\pm 7.2)	0.003
Low maternal activity	1.2 (\pm 1.7)	4.3 (\pm 3.9)	<0.001

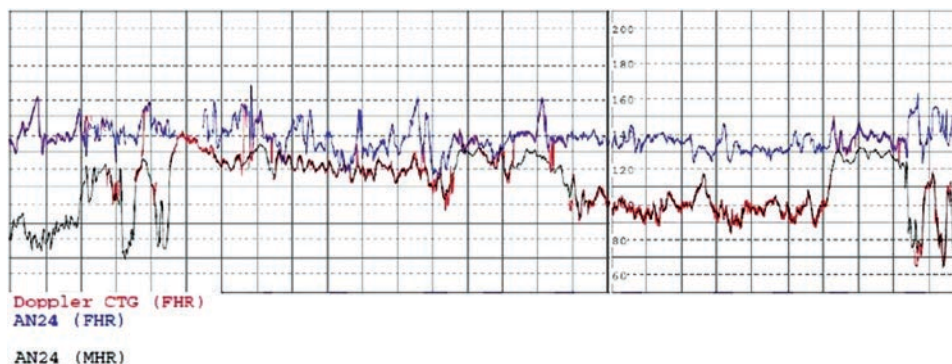


Figure 1. Example of Doppler confusion with maternal heart rate. (CTG, cardiotocography; AN24, trans-abdominal ECG; FHR, fetal heart rate; MHR, maternal heart rate).

of labor together with periods of high- and low-maternal activity. Statistically significant difference was found for all comparisons. Table III.

Figure 1 illustrates an example of Doppler confusion with maternal heart rate. Red signal represents Doppler monitoring which in this case recorded, for more than 40 minutes, maternal heart rate (in black).

Discussion

Doppler technology remains the most commonly used modality for fetal heart rate monitoring during the labor. Both standard Doppler CTG and Doppler telemetry, under some circumstances provide less accurate information due to the FHR/MHR rate confusion, and other artefacts. It is a common clinical scenario in which mothers are immobilized in order to improve the quality of recording. This is an important limitation, while mobility and possibility to assume analgesic position in the first stage of labor, constitute an important advantage for the women, reducing the length of labor and improving the maternal and fetal well-being.

The idea of non-invasive trans-abdominal fECG recording has been present in obstetrics for more than 60 years [9,10]. Many Authors tried to set up the method, resulting in complicated systems or poor results mostly due to technological barriers. The introduction of novel trans-abdominal feto/maternal ECG system made this type of recording feasible. With this study, we wanted to compare the performance of new maternal-fetal monitoring system based on ECG recording with Doppler telemetry.

The overall success rate in this cohort is not statistically different between Doppler telemetry and trans-abdominal ECG, while the possible FHR/MHR confusion is significantly higher in Doppler than in trans-abdominal ECG. During periods of high maternal activity confusion rates for trans-abdominal fECG remained significantly lower than Doppler Telemetry. This constitutes an important issue, while misdiagnosed confusion between the fetal and maternal heart rate could lead to inappropriate obstetrical intervention or, with even worst consequences, to

lack of intervention. Figure 1 shows one example of undiagnosed feto/maternal confusion with Doppler telemetry system. Low confusion rate for trans-abdominal ECG results from underlying technology that differs from Doppler methodology. The fact that maternal ECG is primarily identified and is different from fECG allows the recognition of two biological signals at origin and their subtraction. Consequently, even in the case when maternal and fetal heart rates are at similar frequency, simultaneous display allows to identify different patterns of two heart rates.

Trans-abdominal ECG showed lower success rate of recording in the second stage of labor. Partially this could be explained by high electrical noise due to maternal pushing efforts. Nevertheless, we have to acknowledge the presence of bias in our study: while in the presence of inadequate quality of FHR monitoring with Doppler telemetry there was the option to swap to scalp monitoring, no such option was possible for trans-abdominal ECG since the latter was blinded to staff and therefore even in the presence of a "bad signal", monitoring was not interrupted. The result is that lower quality stage II traces acquired by trans-abdominal ECG were counted whilst lower quality stage II Doppler Telemetry traces were not counted. Looking at the confusion rate in the second stage, it becomes obvious that major confusion for Doppler telemetry occurs in this stage. There is a signal, but the confusion between maternal and fetal heart rate is high. Moreover, while continuous adjustments to Doppler probe were made when the signal was inadequate, no such action was undertaken for trans-abdominal electrodes.

We conclude that trans-abdominal feto/maternal ECG monitoring in labor is feasible with comparable success rate to traditional Doppler telemetry. This monitoring solution does not interfere with maternal mobility, nor does it require any midwife or nurse intervention to re-position the transducer during or after ambulation, representing important advantages. From a clinical perspective, the most interesting aspect of trans-abdominal ECG is represented by the low confusion rate between the maternal and fetal heart rate thanks to its underlying technology. Separate recognition of maternal and fetal R-R

intervals contributes to reduction of the confusion between the two heart beats, avoiding the pitfall that can occur with Doppler methodology. Indeed, erroneous interpretation of fetal heart rate when confused with maternal, could lead to inappropriate obstetrical intervention or even lack of required intervention. Therefore we speculate that trans-abdominal ECG could represent a new feto-maternal monitoring system able to reduce incorrect obstetrical interpretation and consequently improve the obstetrical care.

Declaration of Interest: The authors report no conflicts of interest.

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