European Journal of Obstetrics & Gynecology and Reproductive Biology 205 (2016) 91–97

Contents lists available at ScienceDirect

European Journal of Obstetrics & Gynecology and Reproductive Biology

journal homepage: www.elsevier.com/locate/ejogrb

Quantitative cardiotocography to improve fetal assessment during labor: a preliminary randomized controlled trial

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ARTICLE INFO

Article history:
Received 6 January 2016
Received in revised form 29 July 2016
Accepted 1 August 2016

Keywords:
Cardiotocography
Clinical decision support systems
Acidemia
Fetal hypoxia
Cesarean section

ABSTRACT

Objective: To evaluate the effectiveness of a computerized decision support system, referred to as "quantitative cardiotocography" (qCTG), to reduce adverse birth outcomes compared to conventional CTG with fetal blood sampling.
Study design: A preliminary parallel randomized control trial in a tertiary maternity hospital (Sofia, Bulgaria) was conducted with a sample size of 360 women per trial arm ($N = 720$). Women in labor were recruited between March 2008 and March 2011. Unadjusted relative risks were derived to assess the effect of qCTG on outcomes of interest. A ROC curve was derived to determine the sensitivity and specificity of qCTG to detect acidemia (Clinical trial registration: Current Controlled Trials, http://www.controlled-trials.com/, ISRCTN46449237).
Main outcomemeasures: Primary outcomes were hypoxia (cord-artery blood pH < 7.20), acidemia (umbilical-artery blood pH < 7.05), cesarean delivery, and forceps extraction. Secondary outcomes were Apgar score <7 at five minutes, neonatal seizures, and admission to the neonatal intensive care unit (NICU).
Results: Reduced risks were observed for all outcomes of interest in women monitored using qCTG. There was a significant reduction in hypoxia (RR: 0.53; 0.33, 0.84), acidemia (RR: 0.31; 95% CI: 0.12, 0.84), cesarean delivery (95% CI: 0.45, 0.85), and admission to the NICU (RR: 0.33; 95% CI: 0.14, 0.77) in women monitored using qCTG versus conventional CTG.
Conclusion: qCTG may reduce risk of adverse birth outcomes; however, the small sample size and long recruitment period in this trial may overstate the benefits of this intervention. Further large-scale randomized control trials with sufficient sample size to detect rare adverse events are required prior to the adoption of qCTG in daily clinical practice.

Introduction

Cardiotocography (CTG) is often used for fetal assessment in obstetric practice; yet, interpreting CTG traces can prove challenging. Extensive research has found that the same CTG trace may elicit inconsistent interpretations between maternity care providers [1–5], which is disconcerting given the impact of CTG traces on clinical decision-making [6]. A CTG trace incorrectly identified as normal delays necessary intervention, potentially increasing risk of hypoxia or metabolic acidosis in the infant [6]. Conversely, a trace incorrectly identified as abnormal may result in unnecessary intervention, such as induction of labor or cesarean delivery.

Substantial research has been invested into improving CTG interpretation through concurrent assessment of fetal pulse oximetry [7], lactate level measurements [8], and fetal ECG waveform analysis [9] with limited success [7–9]. However, the use of computerized decision support systems may be an underutilized alterative to improve CTG interpretation by synthesizing clinical data to generate alerts and/or recommendations on appropriate interventions.

The potential for computerized decision support systems to improve CTG interpretation has resulted in on-going trials [10,11] and a recent Cochrane review [6]. Yet, despite growing interest [12–14], evidence in this area remains sparse. Therefore, the purpose of this trial was to evaluate the effectiveness of a

Abbreviations: CTG, cardiotography; qCTG, quantitative cardiotocography; NICU, neonatal intensive care unit; RR, relative risk; CI, confidence interval; ROC, receiving operator characteristic; AUC, area under the curve.

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http://dx.doi.org/10.1016/j.ejogrb.2016.08.023
0301-2115/

computerized decision support system, referred to as "quantitative cardiotocography" (qCTG), to facilitate CTG interpretation. The hypothesis of the trial was that the incidence of adverse birth outcomes would be reduced in women monitored with qCTG versus conventional CTG with fetal blood sampling.

Methods and materials

Setting and participants

A preliminary parallel trial was undertaken between March2008 and March 2011 at Second Municipal Hospital for Obstetrics and Gynecology Sheynovo, Sofia, Bulgaria, a large (~4000 deliveries per annum) tertiary maternity hospital. In 2011, the Second Municipal Hospital recorded a perinatal mortality rate of 7 per 1000 deliveries; the incidence of cesarean delivery was 32%.

Eligible participants were women ≥18 years of age with a singleton pregnancy in cephalic position and no known fetal structural abnormalities. Furthermore, women had to be in active labor. Sample size was based on the incidence of acidosis [15] using one-sided testing, with a 90% confidence level with 80% power. Accounting for potential attrition, approximately 720 women would be required to detect a significant decrease in acidosis incidence from 5.0% in women monitored with conventional CTG to 2.0% in women monitored with qCTG. Ethical approval for this trial was obtained from the Second Municipal Hospital for Obstetrics and Gynecology Research Ethical Committee (Reference: 00134/19.02.2008); all participating women providedinformed consent. This trial has been retrospectively registered on Current Controlled Trials website (http://www.controlled-trials.com/; Trial registration identification number: ISRCTN46449237; Registered 02/10/2014).

The intervention

The intervention was a computerized decision support system to facilitate CTG interpretation. This system, referred to as qCTG, uses external monitoring to synthesize the three domains of a CTG: microfluctuations in fetal heart rate, fetal heart rate and decelerations. Notably, the domain "microfluctuations" is distinct from fetal heart rate variability and refers to the number of extrema per minute, the mean beat-to-beat variability per minute and the oscillation amplitudes. These three domains are scored on a scale ranging between zero (normal measure) and six (highly abnormal measure) and summated for an overall CTG score. Thus, the overall CTG score ranges between zero (normal trace) and 18 (pre-terminal trace). Using cordocentesis, Roemer and Walden previously demonstrated a strong correlation between the overall CTG score and fetal pH at delivery [16,17]. Ignatov et al. undertook additional validation work of the qCTG system and modified the system to enhance prognostic ability [18,19]. In summary, this validation work identified slight measurement error between qCTG predicted pH values and "true" pH values based on blood gas analysis. When averaging the last six measurements taken prior to delivery, qCTG predicted pH values which ranged from −0.037 to +0.046 relative to the "true" pH value [18]. Moreover, the major parameters of a CTG (microfluctuations in fetal heart rate, fetal heart rate and decelerations) were not equal in terms of their prognostic ability of fetal pH, justifying the evaluation of specific subgroups of parameters [19]. To account for these measurement issues, Ignatov and Atanasov developed qCTG guidelines for clinical application [20] (Table 1).

Currently, qCTG is available in the NEXUS/OBSTETRICS system, formerly known as the ARGUS system (Nexus GMT, Frankfurt, Germany), which is one of several recognized fetal monitoring systems. In this system, predicted pH values are calculated and updated every five minutes. As seen in Fig. 1, the most recently predicted pH value is displayed in red font on the left side of the interface; previous pH values are represented by red points in the white area below the CTG reading. Microfluctuations in fetal heart rate, fetal heart rate and decelerations (abbreviated as OSZ, FRQ, and DEC respectively) are numerically presented on the lower left side of the interface.

Prior to the onset of the trial, four obstetricians and the head of the delivery ward received on-site specialized training from Nexus GMT representatives. Overall, seven obstetricians assisted in the implementation of the study. Women were enrolled into the trial by an attending obstetrician in the prenatal unit of the clinic.

Table 1
Clinical application guidelines for quantitative cardiotocography (qCTG).

CTG classification	Predicted pH values based on qCTG[a]	CTG-score components[b]	Management
Normal	7.350–7.237	All	Expectant Intermittent monitoring
Suspicious	7.237–7.137	OSZ OSZ + FRQ FRQ OSZ + DEC DEC FRQ + DEC OSZ + FRQ + DEC	Expectant Continuous monitoring <30 min Continuous monitoring >30 min Urgent delivery
Abnormal	≤7.137	OSZ OSZ + FRQ FRQ OSZ + DEC DEC FRQ + DEC OSZ + FRQ + DEC	<30 min Continuous monitoring >30 min Urgent delivery Urgent delivery

Abbreviations: CTG, cardiotocography; OSZ, microfluctuation; FRQ, fetal heart rate; DEC, decelerations.

[a] Although obstetric guidelines typically defined hypoxia as cord-artery blood pH < 7.20 and acidemia as umbilical-artery blood pH < 7.05, these thresholds were modified in this guideline to account for potential measurement error in qCTG. The degree of measurement error has been found to range between −0.037 and +0.046 (when compared to the reference standard of blood gas analyses).

[b] OSZ, OSZ + FRQ and FRQ subgroups of the CGT-score were found to be less accurate in predicting pH levels compared to the remaining subgroups [19]. Therefore, no immediate actions are advised when these are present. Expectant management is advocated if suspicious findings are observed based on these less accurate subgroups of the CGT-score. If abnormal prognostic pH readings are observed based on OSZ, OSZ + FRQ and FRQ and they persist longer than 30 min, urgent delivery is recommended.