European Journal of Obstetrics & Gynecology and Reproductive Biology 199 (2016) 102–107

Contents lists available at ScienceDirect

European Journal of Obstetrics & Gynecology and Reproductive Biology

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

Gender-specific reference charts for cardiotocographic parameters throughout normal pregnancy: a retrospective cross-sectional study of 9701 fetuses

Célia Amorim-Costa [a,b,*], Joana Cruz [a,c], Diogo Ayres-de-Campos [a,b,c], João Bernardes [a,b,d]

[a] Department of Obstetrics and Gynecology, Medical School, University of Porto, Portugal
[b] Institute for Research and Innovation in Health (Instituto de Investigação e Inovação em Saúde – I3S), Institute of Biomedical Engineering (Instituto de Engenharia Biomédica – INEB), Center for Research in Health Technologies and Information Systems (CINTESIS), University of Porto, Portugal
[c] Department of Obstetrics and Gynecology, S. João Hospital, Porto, Portugal
[d] Department of Obstetrics and Gynecology, Hospital Pedro Hispano, Matosinhos, Portugal

ARTICLE INFO

Article history:
Received 26 October 2015
Accepted 29 January 2016

Keywords:
Antepartum
Cardiotocography
Fetal heart rate
Gender
Gestational age

ABSTRACT

Objective: To establish reference values for cardiotocographic (CTG) parameters from 24 to 41 weeks of gestation in normal pregnancies.
Study design: Retrospective cross-sectional study, using the first antepartum tracing of singleton fetuses with normal pregnancy outcomes (term birth, normal birthweight, normal umbilical artery pH and Apgar scores, no intensive care unit admission). Cases were consecutively selected from a hospital electronic patient record, and analyzed using the OmniviewSisPorto 3.7 system. Variables were compared between male and female fetuses, by gestational age, and percentile curves were constructed.
Results: A total of 9701 tracings (corresponding to 9701 fetuses) were analyzed. All CTG parameters changed significantly throughout gestation in both genders, with a decrease in baseline and decelerations, and an increase in average long-term variability (LTV), average short-term variability (STV), accelerations and uterine contractions. The mean baseline value decreased 9 bpm, and its range almost doubled from 24 to 40 weeks. Until 30 weeks the lower percentiles for average LTV were below 5 bpm, and the minimum value for average STV was never below 1bpm. The proportion of tracings without accelerations decreased from 30.1% at 24-25 weeks to 0.5% at 39 weeks. The median number of decelerations was practically zero for all gestational ages. All CTG variables, except decelerations and uterine contractions, showed statistically significant gender differences: baseline was consistently higher in females, while average LTV and average STV tended to be lower in females throughout most of pregnancy. Separate percentile curves were constructed for male and female fetuses.
Conclusion: This study provides reference values for CTG parameters throughout pregnancy, derived from the largest dataset of healthy fetuses published to date. For the first time, gender differences were clearly demonstrated in fetal life, and percentile curves constructed separately for male and female fetuses.

Introduction

Antepartum cardiotocography (CTG) is widely used for the assessment of fetal well-being, although there is no high-quality evidence to indicate that it improves perinatal outcomes [1]. The latter may be partly explained by the limited overall quality of studies, which were mostly conducted in the 1980s when clinical practice was considerably different [1]. In addition, CTG interpretation guidelines [2–5] are usually more focused on intrapartum monitoring and are frequently applied regardless of gestational age, despite the existing evidence of its influence on fetal heart rate (FHR) parameters [6–18].

Nonetheless, encouraging results have been reported with the use of computer analysis of antepartum CTGs, therefore appeals have been made for an urgent evaluation of this technology [1]. On the other hand, the adaptation in the interpretation of antenatal assessment tests for fetuses at lower gestational ages, has been pointed as an important research need [19]. The logical first step in

* Corresponding author at: Departamento de Ginecologia e Obstetrícia, Faculdade de Medicina do Porto, Alameda Prof. Hernâni Monteiro, 4200-319 Porto, Portugal. Tel.: +351 966165769.
E-mail address: celia.m.costa@hotmail.com (C. Amorim-Costa).

http://dx.doi.org/10.1016/j.ejogrb.2016.01.036
0301-2115/

this endeavour is the thorough characterization of normality of CTG features at different gestational ages.

Some studies have attempted this characterization using visual analysis of tracings [11,13–15,20–24], but it has been shown to be subject to wide intra and inter-observer disagreement [25–28]. Other attempts have fallen short because of the small number of cases included [8–18,20,21,24,29,30], the evaluation of a narrow gestational age interval [8,9,12,14,15,23,24,31–33], or of a limited number of CTG parameters [13,22–24,31,32]. Others have included all pregnancies in the analysis, regardless of fetal outcome [34,35]. Moreover, despite the existence of a few studies suggesting differences in FHR between male and female fetuses [36–40], the influence of fetal gender on CTG variables has never been thoroughly evaluated.

The only large study performed to date, using computer analysis of CTGs in a wide gestational period, exclusively in pregnancies with normal outcome, was published by Serra et al. [6]. However, the influence of fetal gender on FHR was not assessed, and it used a computer system [41] that samples the FHR at 3.75 s epochs and defines the CTG features differently from what is currently recommended [2–5] (Table 1).

The objectives of this study were: (1) to characterize CTG parameters, from 24 to 41 weeks of gestation in a large population of normal fetuses, using a computer system that follows the standard definitions of CTG features; (2) to evaluate the effect of fetal gender in each parameter throughout gestation; and (3) to construct percentile curves for each CTG variable by gestational age.

Materials and methods

A retrospective cross-sectional study was carried out, using the digital database of a large tertiary care university hospital. The first tracing of each singleton fetus born in that hospital between January 2004 and May 2013 was selected, if it had been performed at least 48 h before delivery (to guarantee it was acquired before labor), had a minimum duration of 20 min, a signal quality of at least 80%, and a signal loss below 33%. Only one tracing per fetus was included. Gestational age was calculated by first trimester ultrasound.

Tracings were subsequently excluded if pregnancies did not have a normal outcome. The latter was defined as delivery of a live newborn at 37 weeks or beyond, birth weight $\geq$ 10th percentile for gestational age [42], 5-min Apgar score $\geq$7, umbilical cord artery pH $\geq$7.05 (when available), and no admission to the neonatal intensive care unit.

CTGs were acquired with Doppler probes, using Corometrics 170 series or Hewlett-Packard M1350A/M1351 fetal monitors. All monitors use an autocorrelation function to calculate the heart periods in beats per minute (bpm), rounded to the nearest quarter of a beat, and provided FHR signals at a fixed rate of 4 Hz, via a digital RS232 port to the Omniview-SisPorto 3.7 system (Speculum, Lisbon, Portugal) [43–47]. Tracings were retrieved from the Omniview-SisPorto database and clinical data were obtained from the hospital's electronic patient record database (ObsCare, Medical School, University of Porto). Tracings were analysed using the Omniview-SisPorto 3.7 system, which closely follows the guidelines for fetal monitoring [2–5] (Table 1). Several FHR parameters were calculated by the system: baseline, accelerations, decelerations, average long-term variability (LTV) and average short-term variability (STV). The definitions of these parameters are presented in Table 1. The system also identifies uterine contractions (defined as increases in the signal above the mode of at least three points, reaching a peak in excess of 10 points, and lasting 20–240 s), FHR signal loss (the percentage of signals with values under 30 bpm) and FHR signal quality (the percentage of signals considered by the fetal monitor to be of high quality). No averaging or reduction of FHR and uterine contraction signals is performed by the system.

The number of accelerations, decelerations and uterine contractions was normalised for an average tracing duration of 30 min. CTG variables were evaluated according to the gestational age at recording (from 24 to 41 weeks), and percentile curves were constructed (3rd, 5th, 10th, 25th, 50th, 75th and 95th percentiles). The different CTG parameters were compared between male and female fetuses, for each gestational week.

Statistical analysis was performed with IBM SPSS Statistics for Windows, version 21.0. Armonk, NY: IBM Corp. Normally distributed variables were compared using the *t*-test for two independent samples (comparison between males and females) or One-way ANOVA (comparison between gestational age groups for longitudinal analysis), and described using the mean and standard deviation. Non-normally distributed variables were compared using the Mann–Whitney *U* test (comparison between genders) or the Kruskal–Wallis test (comparison between gestational age groups), and described using the median and interquartile range, unless otherwise stated. Statistical significance level was set at $p < 0.05$. The study was approved by the local ethics review board

Table 1
Comparison between definitions of the main FHR parameters according to FHR monitoring guidelines, Omniview-SisPorto and Sonicaid computer systems. RCOG/NICE definitions are presented, but FIGO or ACOG definitions are similar.

FHR parameter	Omniview-SisPorto system [43–47] (Speculum, Lisbon, Portugal)	Sonicaid System [41] (Huntleigh Diagnostics, Surrey, UK)	RCOG [3]/NICE [2] FHR monitoring guidelines
LT variability (LT variation for Sonicaid System)	Difference between maximum and minimum FHR values in a 1-min sliding window, in segments not considered to be accelerations or decelerations (bpm)	Difference between the minimum and maximum FHR epochs in one minute, including accelerations (ms)	Minor fluctuations in baseline measured by estimating the difference between the highest peak and lowest trough of fluctuation in a 1-min segment of the tracing (bpm)
ST variability (ST variation for Sonicaid System)	Difference between adjacent FHR signals (bpm)	Difference between the average pulse interval values for adjacent 3.75-s epochs, averaged over each minute and over the entire record (ms)	Changes in beat-to-beat intervals (definition according to FIGO guidelines[a])
Accelerations	Increases in the FHR above the baseline, lasting 15–120 s and reaching a peak of at least 15 bpm	Increases in FHR above the baseline lasting longer than 15 s and having an amplitude above 10 bpm	Transient increases in heart rate of 15 bpm or more and lasting 15 s or more
Decelerations	Decreases in the FHR under the baseline lasting at least 15 s, and with a minimal amplitude of 15 bpm	Decreases in FHR below the baseline with an amplitude greater than 10 bpm or 20 bpm, that last longer than 60 or 30 s, respectively	Transient episodes of slowing of FHR below the baseline level of more than 15 bpm and lasting 15 s or more

FHR, fetal heart rate; LT, long-term; ST, short-term; RCOG, Royal College of Obstetricians and Gynaecologists; NICE, National Institute of Clinical Excellence; FIGO, International Federation of Gynecology and Obstetrics; ACOG, American College of Obstetricians and Gynecologists.
[a] ST variability is only defined by FIGO.