Prolonged saltatory fetal heart rate pattern leading to newborn metabolic acidosis

I. Nunes[1], D. Ayres-de-Campos[1], A. Kwee[2], K. G Rosén[3]

[1]Department of Obstetrics and Gynecology, School of Medicine, University of Porto, S. Joao Hospital, Institute of Biomedical Engineering, Porto (Portugal); [2]Department of Obstetrics and Gynaecology, University Medical Centre Utrecht, Wilhelmina Children's Hospital, Utrecht (The Netherlands); [3]Department of Engineering, University of Borås, Borås (Sweden)

Summary

Purpose: The saltatory pattern, characterized by wide and rapid oscillations of the fetal heart rate (FHR), remains a controversial entity. The authors sought to evaluate whether it could be associated with an adverse fetal outcome. *Material and Methods:* The authors report a case series of four saltatory patterns occurring in the last 30 minutes before birth in association with cord artery metabolic acidosis, obtained from three large databases of internally acquired FHR tracings. The distinctive characteristics of this pattern were evaluated with the aid of a computer system. *Results:* All cases were recorded in uneventful pregnancies, with normal birthweight singletons, born vaginally at term. The saltatory pattern lasted between 23 and 44 minutes, exhibited a mean oscillatory amplitude of 45.9 to 80.0 beats per minute (bpm) and a frequency between four and eight cycles per minute. *Conclusions:* A saltatory pattern exceeding 20 minutes can be associated with the occurrence of fetal metabolic acidosis.

Key words: Heart rate, fetal; Cardiotocography; Signal processing; Computer- assisted; Fetal hypoxia; Saltatory pattern.

Introduction

Most fetal heart rate (FHR) patterns are comprehensively described in the scientific literature, and their physiology is well known [1-5]. The saltatory pattern remains a controversial entity, and little is known about its pathophysiology or clinical significance. There is currently no agreement between major FHR interpretation guidelines on the description, significance, and management of this pattern. The International Federation of Obstetrics and Gynecology (FIGO) guidelines of 1987 describe the pattern of "increased variability", corresponding to a long term-variability in excess of 25 beats per minute (bpm), and classify it in the suspicious category [1]. The Royal College of Obstetricians and Gynecologists (RCOG) guidelines of 2001 [4], and the joint effort with the National Institute of Clinical Excellence (NICE) in 2007 [5], make no mention of this pattern or any other form of increased variability. The latest version of the American College of Obstetrics and Gynecologists (ACOG) guidelines, elaborated in association with the National Institute of Child Health and Human Development (NICHHD), and the Society for Maternal-Fetal Medicine (SMFM) [3], describe a pattern of "marked baseline variability" defined as a long term-variability greater than 25 bpm, and classify it in Category II FHR tracings.

The saltatory pattern appears to have been first described by Hammacher *et al.* in 1968 [6], as a "baseline variation" observed in intra-partum tracings, in association with cord complications. It was considered "a sign of fetal distress" and related to low Apgar scores. Edward Hon described a pattern of "marked irregularity" but did not attribute any specific pathological significance to this finding [7-9]. More recently, the saltatory pattern has been described as a pattern of unusual appearance, where rapid FHR variations occur with a frequency of three to six cycles per minute and an amplitude range greater than 25 bpm [10, 11].

In this case series the authors report four cases of FHR saltatory pattern occurring in the last minutes of labor that were associated with umbilical cord metabolic acidosis.

Materials and Methods

The authors searched two research databases [12,13] (n = 12,270) and the clinical database of a tertiary care university hospital (n = 1589), all containing internally monitored intra-partum FHR records acquired in near-term singleton fetuses, in order to select cases with a saltatory FHR pattern occurring in the last 30 minutes before birth and the documentation of cord artery metabolic acidosis. The saltatory pattern was defined as the occurrence of wide and rapid oscillations of the FHR with and amplitude exceeding 25 bpm. Metabolic acidosis was defined as adequately sampled umbilical blood gas values [14], with an umbilical artery (UA) pH < 7.05 and a base deficit in the extracellular fluid (BDecf) ≥ 12.0 mmol/l [15, 16]. Patient authorization for the use of their clinical data for research purposes was obtained during the construction of each database.

Four such cases were identified. The clinical records of these cases were reviewed in order to extract the main characteristics of pregnancy and labor. The corresponding tracings were analyzed with the aid of a system for computer analysis of the FHR [17], in order to quantify the main characteristics of the saltatory segments.

Revised manuscript accepted for publication August 1, 2013

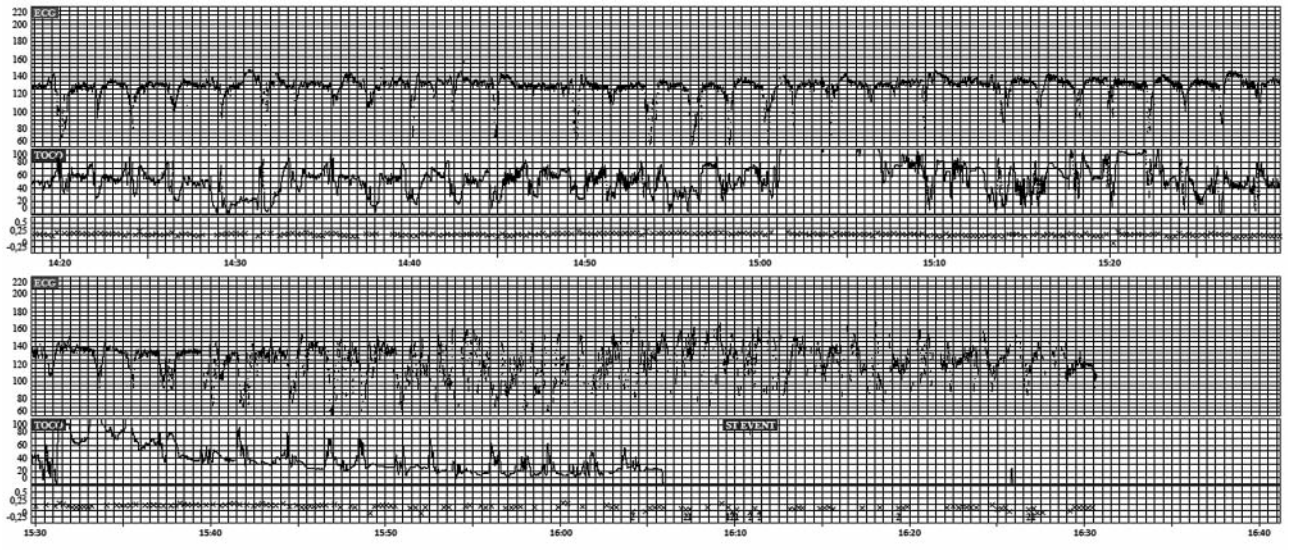

Figure 1. — Case 1. Paper speed: one cm/min. Internal FHR monitoring last 120 minutes of the tracing. ST event (16:10): biphasic ST.

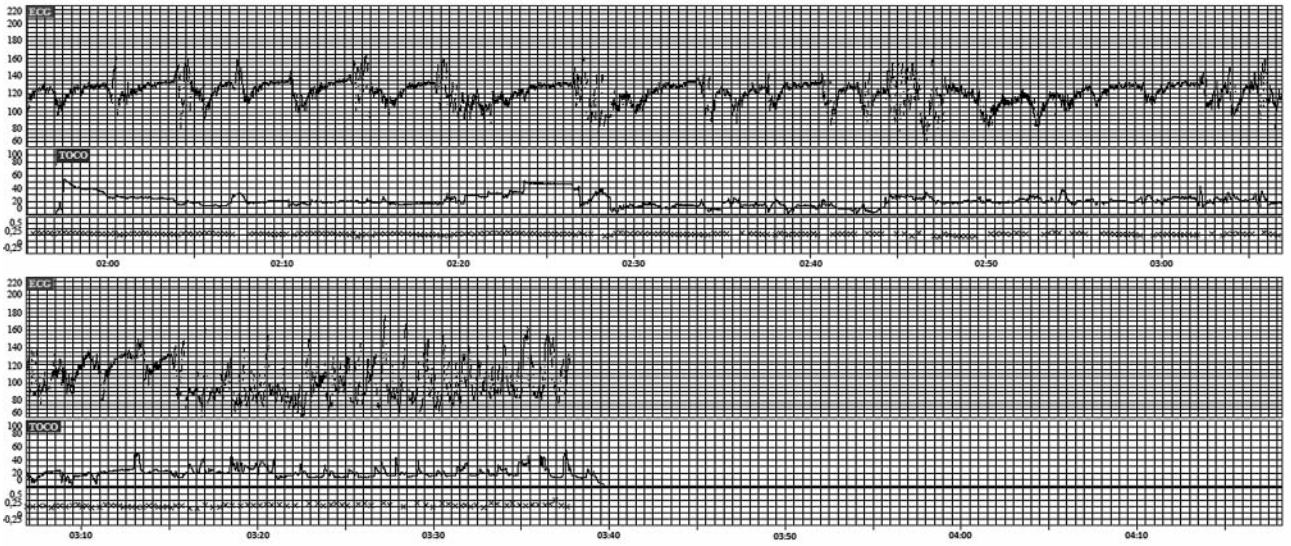

Figure 2. — Case 2. Paper speed: one cm/min. Internal FHR monitoring – last 105 minutes of the tracing.

Results

The main clinical characteristics of the selected cases are summarized below.

Case 1

Primigravida, uneventful pregnancy, spontaneous labor at 41 weeks, no epidural analgesia, ST Segment Analysis (STAN) for fetal intrapartum monitoring was started at 12:20 hours (Figure 1). Oxytocin was started at 12:42 hours at six mUI/min and raised to ten mUI/min at 13:17 hours. At 13:31, seven cm of dilatation with vertex presentation at stage 0 was recorded. At 13:52 oxytocin was increased to 14 mUI/min. Active pushing started at 15:40 hours. Birth occurred at 16:31 hours, of a newborn girl weighing 3,000 g, Apgar scores 4/7/9, UA pH = 6.89, BDecf = 12.8 mmol/l, umbilical vein (UV) pH = 7.18, admitted to the neonatal intensive care unit (NICU) because of meconium aspiration and pneumothorax requiring assisted ventilation. No neurological abnormalities were registered.

Case 2

Primigravida, uneventful pregnancy, induction of labor at 39 weeks due to premature rupture of membranes, no

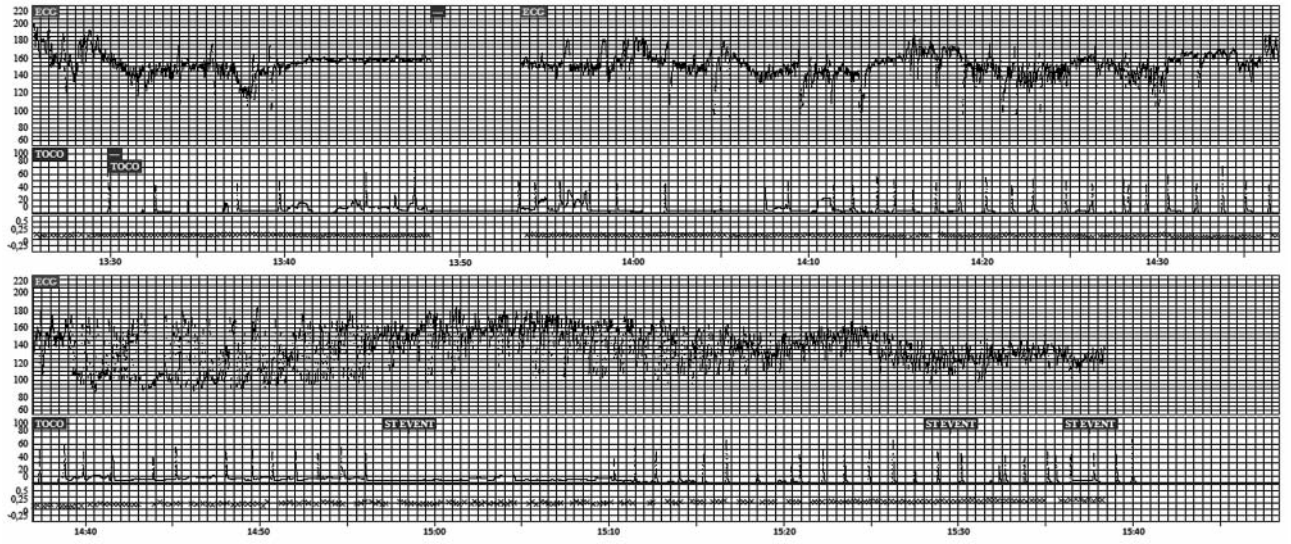

Figure 3. — Case 3. Paper speed: 1 cm/min. Internal FHR monitoring – last 135 minutes of the tracing. ST event (14:58): 0.06 baseline T/QRS rise; ST event (15:29): 0.09 baseline T/QRS rise; ST event (15:37): 0.11 baseline T/QRS rise.

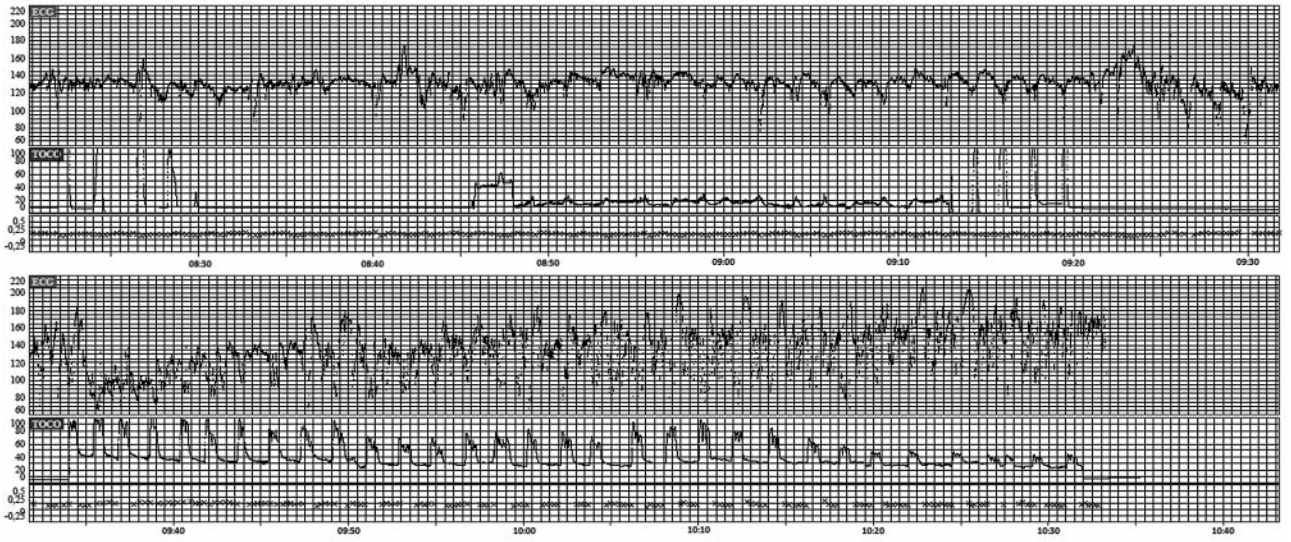

Figure 4. — Case 4. Paper speed: one cm/min. Internal FHR monitoring – last 140 minutes of the tracing.

epidural analgesia, STAN recording commenced at 01:54 hours (Figure 2). Active pushing started at 03:00 hours. Birth occurred at 03:37 hours, of a newborn girl weighing 2,990 g, with one nuchal cord, Apgar scores 8/8/9, UA pH = 7.04, BDecf = 13.8 mmol/l, UV pH = 7.28. No NICU admission, with an uneventful neonatal period.

Case 3

Primigravida, type 1 diabetes with adequate blood glucose control (third-trimester estimated fetal weight in the 70th percentile), spontaneous labor at 39 weeks, no epidural analgesia, STAN monitoring commenced at 13:20 hours (Figure 3). Full dilatation and cephalic presentation at stage 0 registered at 14:40 hours, active pushing started 20 minutes later. Oxytocin infusion at four mU/min was begun at 15:00 and increased 15 minutes later to eight mU/min. Fetal blood sampling at 15:25 hours - pH 7.02, vacuum extraction began at 15:40 and oxytocin was increased to 16 mU/ml. Birth occurred at 15:44 hours, after three tractions, of a newborn boy weighing 3,700 g, Apgar scores 9/9/10, UA pH = 6.97, BDecf = 15 mmol/l, UV pH = 7.00. Admitted to a medium care unit for surveillance, with an uneventful neonatal period.

Case 4

Primigravida, uneventful pregnancy, labor induction at 41 weeks because of fetal tachycardia detected on intermittent auscultation. Continuous FHR monitoring began at 23:50, with ST information from 00:10 onwards (Figure 4). Failed epidural analgesia recorded at 00:14, pethidine 100 mg IV given at 2:30 and pethidine 150 mg IV given at 6:20. Oxytocin infusion began at 3:00 at two mU/min, increased in steps of two mU/min every 30 minutes. Full dilatation registered at 7:10, with oxytocin infusion at 16 mUI/min. Active pushing began at 9:24, oxytocin infusion increased to 20 mUI/min at that time. Birth occurred at 10:33 hours, of a newborn girl weighing 3,615 g, Apgar scores 5/6/6, UA pH = 7.00, BDecf = 13.0 mmol/l, UV pH = 7.11. Admitted to NICU, with an uneventful neonatal period.

In all these cases, the saltatory pattern started between 24 and 52 minutes before delivery, lasted 23 to 44 minutes, and exhibited a mean oscillatory amplitude (difference between maximum and minimum FHR values measured in one-minute windows) between 45.9 and 80.0 bpm. The frequency of oscillations varied between four and eight cycles per minute.

Discussion

The present report describes four cases of intra-partum saltatory pattern lasting more than 20 minutes shortly followed by the vaginal birth of a newborn with cord artery metabolic acidosis. In all cases, hypoxia appeared to be moderate, and there were no cases of hypoxic-ischemic encephalopathy.

To the authors' knowledge, this is the first report of saltatory patterns monitored internally in the final minutes before delivery, leading to newborn metabolic acidosis. The small interval between the occurrence of the FHR pattern and the documentation of metabolic acidosis at birth is necessary to establish a possible cause-effect relationship between the two, assuring that no other monitored or unmonitored FHR patterns occurred during the interval. Internal FHR monitoring assures the presence of good quality signals during the second stage of labor and does not use the processing algorithms that are applied to external signals (autocorrelation), and that provide only an approximation of real FHR values.

In a cohort of 1,304 term fetuses published in 1976 [18], Cibils reported a saltatory pattern in 7.8% of cases, and suggested that it occurs in a high number of cases of "fetal distress". It was observed in association with fetal tachycardia or alternating with periods of reduced long-term variability, or "disguising" a deceleration, possibly representing a subtle sign of "fetal distress" [18, 19]. In 1992, a retrospective observational study of 433 consecutive intra-partum tracings reported the saltatory pattern in 2.3% of cases, all at term and during the active phase or the second stage of labour [10]. All infants were born with Apgar scores of 8/9 or 9/9 but no cord blood gas values were reported. One year before, a case report was published describing a saltatory pattern at term associated with variable decelerations progressing to sustained tachycardia and ending in a prolonged deceleration, with low Apgar scores and cord blood gases consistent with mild respiratory acidosis [11].

Despite many proposed hypothesis, the physiopathology of the saltatory pattern remains uncertain. Some have suggested that it is associated with augmented alpha-adrenergic activity, causing selective vasoconstriction [20]. Experimental studies conducted in fetal sheep subjected to episodes of brief and acute hypoxia [21], identified a pattern of increased variability, followed by a decrease in this parameter as hypoxia was maintained [22, 23]. This biphasic pattern has also been documented clinically, using power spectral analysis, when comparing acidotic fetuses with controls [24]. The occurrence of fetal seizures is another proposed hypothesis. In 1999, an example of seizures and increased variability during "terminal" fetal hypoxia was reported by Westgate *et al.* [25]. Fetal seizures together with both abnormal breathing movements and fluctuation in blood pressure and heart rate resulting in increased FHR variability were observed in brain-damaged fetal sheep shortly after an asphyxic insult.

Only four cases of prolonged saltatory pattern resulting in cord artery metabolic acidosis were found in the three large databases evaluated in this study, suggesting this association to be rare. However, the present study was not designed to allow an estimation of incidence. Several saltatory segments of lesser duration were identified in the final minutes before delivery in association with normal cord blood gas values. Saltatory segments of different length also occurred in earlier stages of labor, but the absence of an objective marker of hypoxia close to their occurrence, precluded any inference of their significance. Finally, there was uncertainty regarding the classification of the saltatory nature of many segments. There is no consensus in the scientific literature as to the definition of this pattern, and the well-demonstrated inter-observer disagreement in visual interpretation of FHR tracings is another limitation of this study. It was felt that, for a true evaluation of the incidence of saltatory segments, it is necessary to develop a computer algorithm that is able to identify them and to run this algorithm in the entire database. Such a project is currently being undertaken.

The saltatory pattern has inherent characteristics that allow it to be identified by computer algorithms, and thus real-time alerts can be generated on its occurrence. This could prove to be a useful clinical adjunct, particularly for the less experienced healthcare professionals in the labor ward. For the development of such algorithms, it is essential to identify "index cases", such as the ones described in this study, where good quality signals, a short interval to birth, and a well-documented newborn hypoxia are pres-

ent. A similar line of thought can be applied for the building of clinical experience.

It may be that the clinical significance of prolonged saltatory patterns, as described in the current paper, is different from the transient episodes that have been observed in labor in association with normal fetal outcome [10]. The fact that some of these reports do not include umbilical blood gas values raises additional uncertainties. It is well known that episodes of moderate and/or time-limited hypoxia may not reflect on Apgar scores.

Conclusion

The present case series suggests that clinicians need to be aware of saltatory patterns exceeding 20 minutes duration, as these can be associated with the occurrence of fetal hypoxia. There is a need to determine whether similar patterns may also result in normal neonatal outcomes.

Aknowledgments

The study was financed by grant Eureka Eurostars E!5649 – Omnianalysis, of the European Commission.

References

[1] FIGO subcommittee on Standards in Perinatal Medicine: "Guidelines for the use of fetal monitoring". *Int. J. Gynecol. Obstet.*, 1987, *25*, 159.

[2] American College of Obstetricians and Gynecologists: "Practice bulletin 106: Intrapartum fetal heart rate monitoring: nomenclature, interpretation, and general management principles". *Obstet. Gynecol.*, 2009, *114*, 192.

[3] Macones G.A., Hankins G.D.V., Spong C.Y., Hauth J., Moore T.: "The 2008 National Institute of Child Health and Human Development workshop report on electronic fetal monitoring: update on definitions, interpretation, and research guidelines". *JOGNN*, 2008, *37*, 510.

[4] Royal College of Obstetricians and Gynaecologists: "The use of electronic fetal monitoring. Evidence-based clinical guideline, number 8". London: RCOG Press, 2001.

[5] National Collaborating Centre for Women's and Children's Health, commissioned by the National Institute for Health and Clinical Excellence: "Intrapartum care". London: RCOG Press, 2007.

[6] Hammacher K., Huter K., Bokelmann J., Werners P.: "Foetal heart frequency and perinatal condition of foetus and newborn". *Gynaecologia (Basel)*, 1968, *166*, 348.

[7] Hon E.H.: "Electronic evaluation of the fetal heart rate". *Am. J. Obstet. Gynecol.*, 1962, *83*, 333.

[8] Hon E.H.: "The classification of fetal heart rate". *Obstet. Gynecol.*, 1963, *22*, 137.

[9] Hon E.H., Quilligan E.J.: "The classification of fetal heart rate". *Conn. Med.*, 1967, *31*, 779.

[10] O'Brien-Abel N.E., Benedetti T.J.: "Saltatory fetal heart rate pattern". *J. Perinatol.*, 1992, *12*, 13.

[11] Gimovsky M.L., Goh W., Fitzgerald K.: "Fetal monitoring casebook. The saltatory fetal heart rate pattern". *J. Perinatol.*, 1991, *11*, 386.

[12] Westerhuis M.E., Visser G.H., Moons K.G., van Beek E., Benders M.J., Bijvoet S.M., *et al.*: "Cardiotocography plus ST-analysis of the fetal electrocardiogram versus cardiotocography only for intrapartum monitoring: a Dutch randomised clinical trial". *Obstet. Gynecol.*, 2010, *115*, 1173.

[13] Luttkus A.K., Norén H., Stupin J.H., Blad S., Arulkumaran S., Erkkola R., *et al.*: "Fetal scalp pH and ST analysis of the fetal ECG as an adjunct to CTG. A multi-center, observational study". *J. Perinat. Med.*, 2004, *32*, 486.

[14] Westgate J.A., Garibaldi J.M., Greene K.R.: "Umbilical cord blood gas analysis at delivery: a time for quality data". *Br. J. Obstet. Gynecol.*, 1994, *101*, 1054.

[15] Siggaard-Andersen O.: "An acid-base chart for arterial blood with normal and pathophysiological reference areas". *Scand. J. Clin. Lab. Invest.*, 1971, *27*, 239.

[16] Wiberg N., Kallén K., Olofsson P.: "Base deficit estimation in umbilical cord blood is influenced by gestational age, choice of fetal fluid compartment, and algorithm for calculation". *Am. J. Obstet. Gynecol.*, 2006, *195*, 1651.

[17] Ayres-de-Campos D., Sousa P., Costa A., Bernardes J.: "Omniview-SisPorto 3.5 - a central fetal monitoring station with online alerts based on computerized cardiotocogram+ST event analysis". *J. Perinat. Med.*, 2008, *36*, 260.

[18] Cibils L.A.: "Clinical significance of fetal heart rate patterns during labor. I. Baseline patterns". *Am. J. Obstet. Gynecol.*, 1976, *125*, 290.

[19] Cibils L.A.: "Clinical significance of fetal heart rate patterns during labor. II. Late decelerations". *Am. J. Obstet. Gynecol.*, 1975, *123*, 473.

[20] Nageotte M.P., Gilstrap L.C.: "Intrapartum fetal surveillance". In: Creasy R.K., Resnik R., Iams J.D., Lockwood C.J., Moore T.R. (eds). *Creasy & Resnik's Maternal-Fetal Medicine: Principles and Practice*. 6th ed. Philadelphia: Saunders Elsevier, 2009, 397.

[21] Parer J.T., Dijkstra H.R., Vredebregt P.P., Harris J.L., Krueger T.R., Reuss M.L.: "Increased fetal heart rate variability with acute hypoxia in chronically instrumented sheep". *Eur. J. Obstet. Gynecol. Reprod. Biol.*, 1980, *10*, 393.

[22] Dalton K.J., Dawes G.S., Patrick J.E.: "Diurnal, respiratory and other rythms of fetal heart rate in lambs". *Am. J. Obstet. Gynecol.*, 1977, *127*, 414.

[23] Stånge L., Rosén K.G., Hökegård K.H., Karlsson K., Rochlitzer F., Kjellmer I., Joelsson I.: "Quantification of fetal heart rate variability in relation to oxygenation in the sheep fetus". *Acta Obstet. Gynecol. Scand.*, 1977, *56*, 205.

[24] Siira S.M., Ojala T.H., Vahlberg T.J., Jalonen J.O., Välimäki I.A., Rosén K.G., Ekholm E.M.: "Marked fetal acidosis and specific changes in power spectrum analysis of fetal heart rate variability recorded during the last hour of labour". *Br. J. Obtet. Gynecol.*, 2005, *112*, 418.

[25] Westgate J.A., Bennet L., Gunn A.J.: "Fetal seizures causing increased heart rate variability during terminal fetal hypoxia". *Am. J. Obstet. Gynecol.*, 1999, *181*, 765.

Address reprint requests to:
D. AYRES-DE-CAMPOS, M.D.
Department of Obstetrics and Gynecology,
Faculty of Medicine, University of Porto
Alameda Hernâni Monteiro
4200-319 Porto (Portugal)
e-mail: dcampos@med.up.pt