Available online at www.sciencedirect.com
SCIENCE DIRECT®
European Journal of Obstetrics & Gynecology and Reproductive Biology 116 (2004) 22–27
EUROPEAN JOURNAL OF OBSTETRICS & GYNECOLOGY AND REPRODUCTIVE BIOLOGY
www.elsevier.com/locate/ejogrb

The quality of intrapartum fetal heart rate monitoring

P.C.A.M. Bakker, G.J. Colenbrander, A.A. Verstraeten, H.P. Van Geijn*

Department of Obstetrics and Gynecology, Vrije Universiteit Medical Center, Mailbox 7057, 1007 MB Amsterdam, The Netherlands

Received 18 August 2003; received in revised form 28 October 2003; accepted 6 January 2004

Abstract

Objective: To determine the quality of fetal heart rate (FHR) recordings during the first and second stage of labor by quantifying the amount of fetal signal loss in relation to the method of monitoring: external ultrasound or directly via a scalp electrode. *Study Design*: Analysis of 239 intrapartum recordings stored between 1 January 2001 and 1 July 2001 from consecutive deliveries at the Vrije Universiteit Medical Center in Amsterdam. Singletons delivered via the vaginal route were included in the study. FHR recordings had duration of at least 1 h prior to birth of the infant. Subdivision in three groups took place on the basis of the recording technique which had been used; i.e. ultrasound, scalp electrode or a combination of both methods. FHR data was obtained using HP-M1350 cardiotocographs. The status (pen on, pen off, maternal signal) and the mode of the signals were acquired. The duration of pen lifts and maternal signals was divided by the total duration of the recording. Statistical analyses were performed with the Mann–Whitney *U*-test and the Wilcoxon signed ranks test. *Results*: Recordings obtained via ultrasound demonstrated significantly more fetal signal loss than those obtained via the direct mode, particularly in the second stage. The FIGO criteria for fetal signal loss with external ultrasound were not fulfilled during this stage for about half the cases. *Conclusion*: Intrapartum FHR monitoring via a scalp electrode provides far better quality FHR signals than external ultrasound and deserves a more prominent position in fetal surveillance than it currently has.

Keywords: Fetal heart rate; Cardiotocographs; Signal loss

1. Introduction

In the US 75 percent of the deliveries are monitored by electronic fetal heart rate monitoring (EFM) [1]. EFM is used to assess fetal well-being ante partum and during labor [2–4]. Since its introduction neonatal morbidity has been reduced but operative intervention has increased [2].

The value of EFM in clinical practice is surrounded by controversy [2–4]. Difficulty in interpreting intrapartum cardiotocographic patterns by the obstetrician is assumed to be the main cause [1–4]. To address this problem criteria for interpreting EFM have been established and computer-generated interpretations are being studied [5,6]. The assumption that interpretation of the cardiotocogram (CTG) is the only factor which makes the use of EFM complicated is misleading. It implicates that the quality of fetal heart rate (FHR) monitors is always adequate. Earlier experiences with external ultrasound recording during pregnancy and the first stage of labor suggest otherwise [7,8]. Quality of fetal heart rate recordings expressed by the amount of signal loss in these studies averaged from approximately 15% to almost 40%.

Generally guidelines lack information concerning the extent of signal loss acceptable for either recording method [9,10]. Only the FIGO guidelines report on signal loss. Below 20% signal loss is considered as acceptable. However, this limit of 20% is not based upon any research [9].

The purpose of the current study was to determine the quality of FHR recordings during the first and second stage of labor. We have quantified the amount of fetal signal loss in relation to the method of monitoring: external ultrasound or direct via a scalp electrode.

2. Methods

Recordings were from consecutive deliveries at the Vrije Universiteit Medical Center in Amsterdam 1 January 2001 till 1 July 2001. Cases with at least 1 h of fetal heart rate recording prior to birth of the infant were selected for further analysis. In this period 746 singleton deliveries took place, of which 591 were via the vaginal route. Twenty-six cases were excluded because of severe fetal anomalies or fetal

* Corresponding author. Tel.: +31-20-4442227; fax: +31-20-4444811.
E-mail address: hp.vangeijn@vumc.nl (H.P. Van Geijn).

0301-2115/$ – see front matter
doi:10.1016/j.ejogrb.2004.01.001

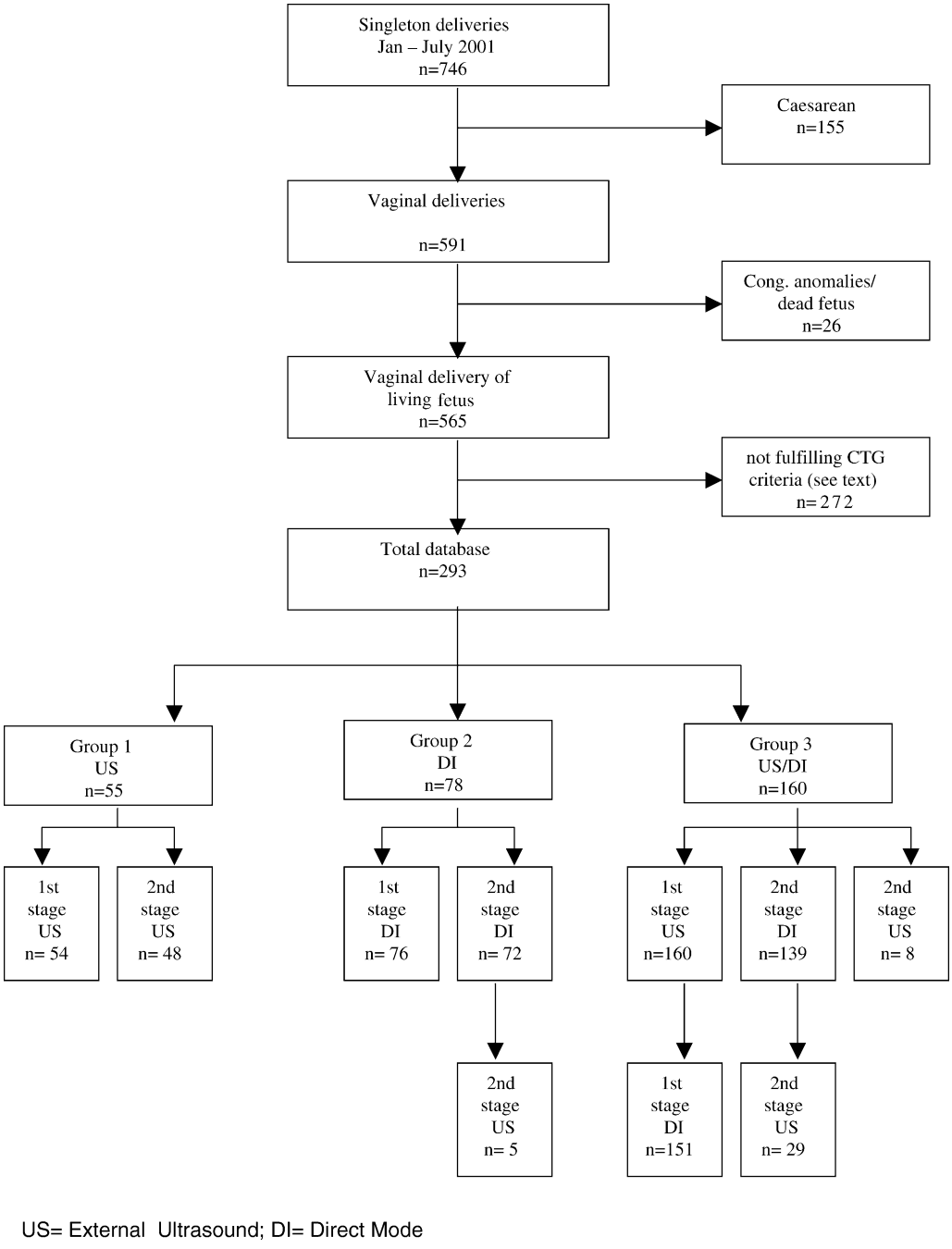

Fig. 1. Study profile.

demise. The study profile is presented in Fig. 1. In 263 cases the last recording prior to birth was shorter than 1 h, the recording ended more than 10 min before the delivery of the infant or storage of the CTG had failed. In nine cases the computer program could not analyze the CTG because its duration was longer than 15 h. The final database consisted of 293 cases. The subdivision in groups is presented in Fig. 1, patients' demographics in Table 1.

Fetal heart rate data was obtained using HP-M1350 cardiotocographs. These cardiotocographs sample the fetal heart rate at a frequency of 4 Hz and uterine pressure at 2 Hz. The status (pen on, pen off) and the mode of the signals (US/direct FECG, external/internal pressure) are acquired. The raw signals are stored on a network server with the MOSOS centralized monitoring system (BMA Company, The Netherlands).

In order to analyze the signals a special program was developed. This program detects signal loss for the complete FHR recording during the first stage of labor and the second stage of labor in relation to the method that had been used, direct or external monitoring. Starting point of the recording was defined as the beginning of the appearance of fetal heart

Table 1
Patients demographics (means and S.D.)

	Group 1 ($n = 55$)	Group 2 ($n = 78$)	Group 3 ($n = 160$)
Age (years)	32 ± 5	32 ± 5	32 ± 5
Gravidity	2.4 ± 1.6	2.7 ± 3.1	2.2 ± 1.2
Parity	0.7 ± 1.1	0.8 ± 1.0	0.7 ± 0.9
Gestational age (days)	260 ± 28	277 ± 11	277 ± 11
Birth weight (g)	2894 ± 927	3384 ± 510	3437 ± 571
Apgar score 1 min	8.3 ± 1.5	8.3 ± 1.3	8.3 ± 1.5
Apgar score 5 min	9.3 ± 1.4	9.4 ± 1.1	9.5 ± 0.8
pH umbilical artery	7.23 ± 0.1	7.22 ± 0.08	7.22 ± 0.08

rate traces on the cardiotocogram and lasted until the second stage. The start time of the second stage was looked up in the patients' chart and compared with the patterns of uterine activity obtained by internal pressure monitoring when available. Analysis of the fetal heart rate trace finalized when the recording ended.

In 49 cases it appeared that not the fetal heart rate but the maternal heart rate was recorded (Fig. 2). This occurred only when ultrasound had been used. The monitored heart rate was assumed to be the mother's if it suddenly dropped below 100 beats/min or more than 20 beats/min from the baseline for more than 30 s. The heart rate tracing also had to return acutely to the baseline. These criteria concern the first stage of labor. It is almost impossible to distinguish between the mother's heart rate and decelerations in the FHR during the second stage of labor. Finally, fetal signal loss is defined as the duration of pen lifts (pen off) plus the maternal signals divided by the total duration of the recording.

Table 2
Recording technique group 1 ($n = 55$)

n	First stage US ($n = 54$)	Second stage US ($n = 48$)
47	+	+
7	+	−
1	−	+

US: external ultrasound.

The FHR was acquired via the external ultrasound mode or via the direct scalp electrode. The department's policy is to start with external ultrasound, certainly as long as the membranes are intact. Transition to internal FHR monitoring generally occurs when the membranes are ruptured, when labor is induced with intravenous oxytocin and in case of an expected prolonged duration of the second stage of labor, in particular in nulliparas. Another reason for internal FHR monitoring can be difficulties with the interpretation of the cardiotocogram due to excess signal loss.

The recordings were divided into three groups (Fig. 1). The first group (Table 2) existed of 55 fetuses monitored by external ultrasound only. In this group, 47 fetuses were monitored throughout the full process of labor. In seven cases the recordings stopped at the beginning of the second stage and birth of the infant was within 10 min following full dilatation. In one case intrapartum cardiotocography was not started until the second stage.

The second group (Table 3) consisted of 78 fetuses monitored by direct scalp electrode. Sixty-five cases had direct monitoring during both stages of labor. Five were also

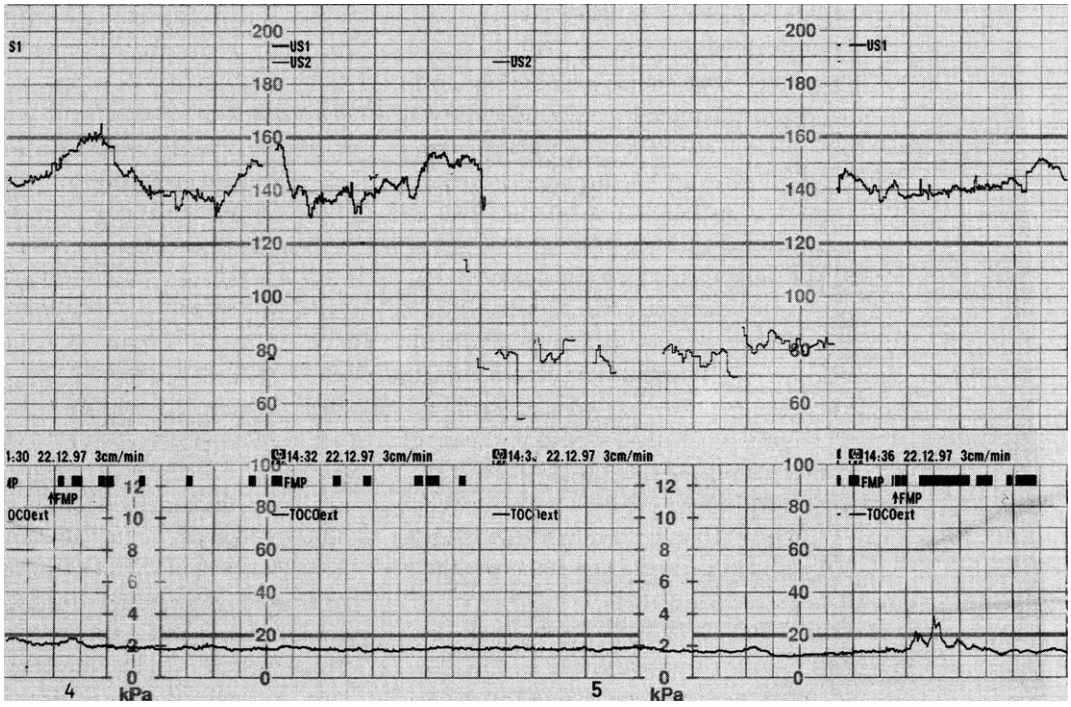

Fig. 2. Detection of the maternal heart rate due to loss of the fetal heart rate signal.

Table 3
Recording technique group 2 ($n = 78$)

n	First stage	Second stage	
	DI ($n = 76$)	DI ($n = 72$)	US ($n = 5$)
65	+	+	−
6	+	−	−
5	+	+	+
2	−	+	−

US: external ultrasound; DI: direct mode.

Table 4
Recording technique group 3 ($n = 160$)

n	First stage		Second stage	
	US ($n = 160$)	DI ($n = 151$)	DI ($n = 139$)	US ($n = 37$)
106	+	+	+	−
24	+	+	+	+
13	+	+	−	−
8	+	+	−	+
5	+	−	+	+
4	+	−	+	−

US: external ultrasound; DI: direct mode.

monitored by ultrasound during the last minutes prior to birth. Six were monitored only during the first stage of labor and two only during the second stage of labor.

In the third group (Table 4) with 160 fetuses, both methods for monitoring had been used. All 160 fetuses had ultrasound during the first stage of whom 151 later on were monitored with a scalp electrode. In the second stage, 139 cases had direct registration of whom 29 were later followed by ultrasound. Eight cases were monitored by ultrasound from the beginning of the second stage (Fig. 1). The remaining 13 cases ($160 - 139 + 8$) were monitored during the first stage only.

Statistical analyses were performed with the Mann–Whitney U-test and the Wilcoxon signed ranks test. Results are presented as medians and interquartile ranges. $P < 0.05$ for a two-tailed test was considered statistically significant.

3. Results

Comparison of group 2 (direct scalp electrode) with group 1 (ultrasound method) demonstrates significantly less fetal signal loss during the first stage of labor with application of the scalp electrode (median 0.8% versus 5.2%, $P < 0.01$) (Fig. 3, Table 5). Similar results are observed in group 3, in which both methods for monitoring have been used. In this group the median for fetal signal loss with the scalp electrode is 1.0% versus 7.2% with the ultrasound method ($P < 0.01$).

The same holds true for the quality of CTGs during the second stage of labor (Fig. 3, Table 6). Fetal signal loss in group 2 (direct scalp electrode) is significantly less than in group 1 (ultrasound method, median 3.0% versus 9.5%,

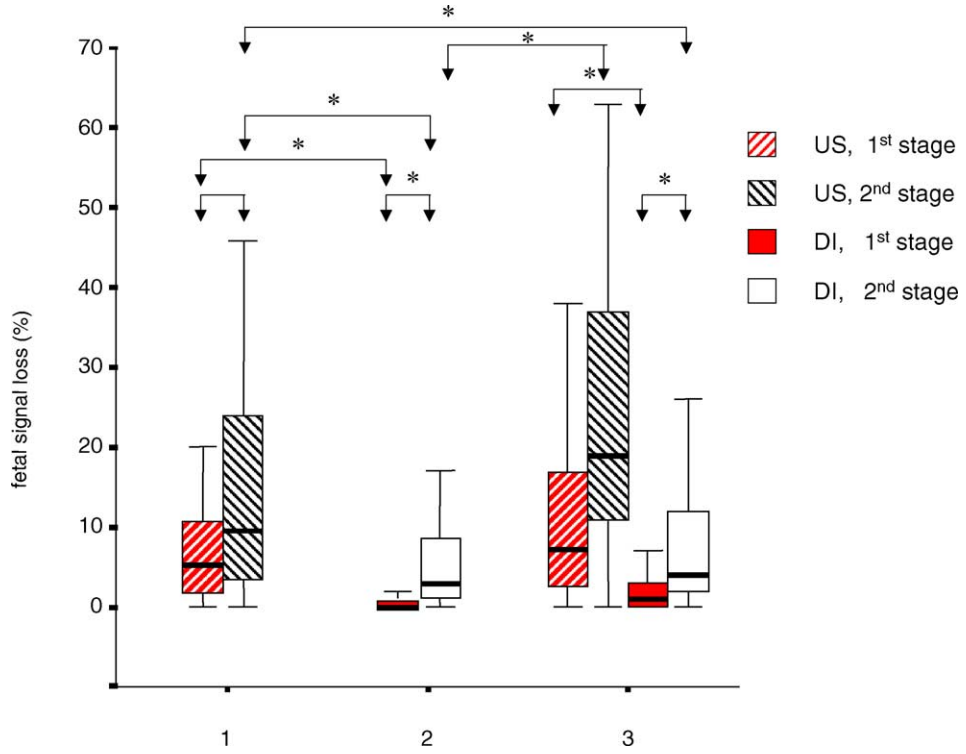

Fig. 3. Box-and-whisker plots of fetal signal loss of the three study groups during the first and second stage for external and direct mode. The boxes indicate the 25th and the 75th percentiles, and the line across the boxes indicates the median. The ends of the whiskers represent the 10th and 90th percentiles. *$P < 0.05$.

Table 5
Fetal signal loss during the first stage of labor

	Group 1	Group 2	Group 3	
	US ($n = 54$)	DI ($n = 76$)	US ($n = 160$)	DI ($n = 151$)
Duration recording (min)				
Median	102	247	54	139
Interquartile range	157	246	75	260
Fetal signal loss (%)				
Median	5.2	0.8	7.2	1.0
Interquartile range	9.3	0.8	14.5	3.0
Not fulfilling FIGO [9] criteria (>20%)				
Cases	9	0	35	4
Percentage	17	0	22	2.6

US: external ultrasound; DI: direct mode.

$P < 0.01$), while in group 3 the difference between both methods is even more remarkable (median 4.0% versus 19.0%). Five fetuses in group 2 were monitored by ultrasound in the second stage for a short period (median duration 7.0 min), with a median fetal signal loss of 32.0%.

In all groups the medians for signal loss were higher in the second stage than in the first stage (Fig. 3, Tables 5 and 6).

4. Discussion

The current study has compared the two ways of FHR monitoring with the purpose to assess the quality of EFM. Our results demonstrate that fetal signal loss is significantly higher with the use of the ultrasound mode, particularly in the second stage of labor.

Signal acquisition and processing by a FHR monitor varies according to the method used to record the FHR signal: external ultrasound or direct via the fetal electrocardiogram. Ultrasound FHR monitors are based on the Doppler shift that occurs after insonation of a moving object. The transducer sends ultrasound signals from the maternal abdominal wall, which are reflected when they encounter a moving interface. There will be a frequency change (Doppler shift) in the reflected signal, which is converted into an electronic signal. Next autocorrelation takes place; the monitor compares the incoming signals with a stored version of the previous ones. The intervals between peaks of this autocorrelation function actually reflect the rate of the regular component of the signal and these are used to derive the record [11,12].

Table 6
Fetal signal loss during the second stage of labor

	Group 1	Group 2	Group 3	
	US ($n = 48$)	DI ($n = 72$)	US ($n = 37$)	DI ($n = 139$)
Duration recording (min)				
Median	24	41	9	26
Interquartile range	46	40	14	44
Fetal signal loss (%)				
Median	9.5	3.0	19.0	4.0
Interquartile range	21.3	7.8	28.5	10.0
Not fulfilling FIGO [9] criteria (>20%)				
Cases	17	6	18	15
Percentage	35	8	48	11

US: external ultrasound; DI: direct mode.

The ECG signal with direct registration is obtained from the fetus using a scalp electrode. Once the FECG signal has been obtained, the interval between R wave peaks can be measured [11,12].

Few other studies have addressed this subject. They link signal loss with movements of the mother or the baby. Dawes reported on signal loss with ultrasound during gestation. The average failure time between 30 and 40 weeks was 40%. Maternal movements were sometimes associated with signal loss in ultrasound recordings but not substantially. They considered the possibility that rotation of the fetal body, not perceived by the mother, causes signal loss [8]. Another study, by Spencer found that in recordings (external or direct) with more than 2% signal loss during the first stage, the mother moved or had been moved. The average loss in this selected group was 15.6% with ultrasound and 2.3% with direct ECG [7]. Fetal signal loss in our study is much lower than signal loss in the previous study by Spencer. Difference can be explained by selection bias. While Spencer distinguished between cases with more than 2% signal loss and cases with less than 2% signal loss, the current study made no distinction. Another reason for better results in our study can be attributed to the improvement in signal acquisition and processing of fetal monitors over the years.

Loss of signals may also occur with large variable decelerations in labor if the FHR changes quickly. Frequent extrasystoles and other forms of cardiac arrhythmias will disturb the signal as well; the irregularity in the RR intervals leads to increased detection of ‘‘artefacts’’ [13]. The observation of marked signal loss often will be the reason to switch to the direct mode. Signal loss using a scalp electrode, can also occur as a result of loss of contact, e.g. with vaginal examinations and maternal pushing [11].

Solum studied the influence of obesity and placental location on three methods for external fetal cardiography; phonocardiography, abdominal electrocardiography and ultrasound. He found that placental localization and obesity had no influence on the quality of ultrasound recordings [14].

Recording of the maternal heart rate can occur with both recording techniques. In case of external ultrasound the transducer detects the maternal heart rate if the transducer is inadequately directed at the fetal heart. The signals detected are then from the blood flow in a maternal vessel. In doubt if the detected signals originate from the fetus or the mother, real-time ultrasonography is recommended [11,12].

In the rare event that the fetus is dead, and there is no fetal electrocardiographic signal, the amplifier in the CTG monitor will increase the gain until a recognizable R wave is

identified; in this case the R wave in the maternal ECG complex [11,12].

Many obstetricians believe that due to the improved ultrasound Doppler technology, the quality of the produced external traces is comparable with those generated by direct registration. Also Dawes stated that ultrasound is an adequate method for recording the FHR [8]. Rupture of the membranes to apply a scalp electrode by many is considered not necessary in order to generate a good quality trace [8,11,15,16].

On the basis of our results we disagree; traces acquired with direct registration are of significantly better quality than those acquired with external ultrasound. A point of criticism could be that in our study the quality of external traces was influenced by incorrect application of the ultrasound transducer. Despite unfavorable circumstances throughout the process of labor and delivery, we found less fetal signal loss than others.

Nevertheless, the percentage of our recordings that exceeds the acceptable limit of 20% reported by the FIGO guidelines in the first stage for ultrasound varies from 17 till 22%. In the second stage this is even more: between 35 and 48%. While the direct mode has better results, there are still four cases (2.6%) in group 3 during the first stage in which this 20% limit is outnumbered. During the second stage the percentage not fulfilling the FIGO criteria for the direct mode varies from 8 till 11% (Tables 5 and 6).

Since complications with the scalp electrode are negligible, if properly used, the direct mode can be considered as the best method for monitoring during labor and delivery, provided that the membranes are ruptured and no contraindications exist [17]. If one decides to monitor the fetal condition with cardiotocography, one should do it closely and apply the most feasible and best method available. In addition, the direct mode can provide supplementary information about the condition of the fetus from the analysis of the T/QRS ratio and the ST segment within the FECG complex [2].

References

[1] Shewa A, Hacker TW, Nuovo J. Interpretation of the electronic fetal heart rate during labour. Am Family Phys 1999;59(9):2507–12.

[2] Amer-Wåhlin I, Hellsten C, Norén H, et al. Cardiotocography only versus cardiotocography plus ST analysis of fetal electrocardiogram for intrapartum fetal monitoring: a Swedish randomised controlled trial. Lancet 2001;358:534–8.

[3] Strachan KB, Sahota DS, van Wijngaarden WJ, James DK, Chang AMZ. Computerised analysis of the fetal heart rate and relation to academia at delivery. Br J Obstet Gynaecol 2001;108: 848–52.

[4] Strachan BK, van Wijngaarden WJ, Sahota D, Chang A, James DK. Cardiotocography only versus cardiotocography plus PR-interval analysis in intrapartum surveillance: a randomised, multicentre trial. Lancet 2000;355:456–9.

[5] Kripke CC. Why are we using electronic fetal monitoring? Am Family Phys 1999;59(9):2416, 21–2 [Editorial].

[6] Parer JT, King T. Fetal heart rate monitoring: is it salvageable? Am J Obstet Gynecol 2000;182:982–7.

[7] Spencer JAD, Belcher R, Dawes GS. The influence of signal loss on the comparison between computer analyses of the fetal heart rate in labour using pulsed Doppler ultrasound (with autocorrelation) and simultaneous scalp electrocardiogram. Eur J Obstet Gynecol Reprod Biol 1987;25:29–34.

[8] Dawes GS. Numerical analysis of the human fetal heart rate: the quality of ultrasound records. Am J Obstet Gynecol 1981;141:43–52.

[9] Rooth G, Huch A, Huch R. Guidelines for the use of fetal monitoring. Int J Gynecol Obstet 1987;25:159–67.

[10] Clinical Effectiveness Support Unit. The use of electronic fetal monitoring. The use of cardiotocography in intrapartum fetal surveillance. Evidence-based clinical guideline number 8. London: RCOG Press, 2001.

[11] Ingemarsson I, Ingemarsson E, Spencer JAD. Technical aspects of fetal heart rate monitoring. In: Fetal heart rate monitoring a practical guide. Oxford: Oxford University Press, 1993. p. 12–26.

[12] Freeman RK, Garite JT, editors. Instrumentation, artefact detection, and fetal arrhythmias. In: Fetal heart rate monitoring. Baltimore: Williams & Wilkins, 1981. p. 28–54.

[13] Van Geijn HP, Jongsma HW, de Haan J, Eskes TK. Analysis of heart rate and beat-to-beat variability: interval difference index. Am J Obstet Gynecol 1980;138:246–52.

[14] Solum T. A comparison of the three methods for external fetal cardiography. Acta Obstet Gynecol Scand 1980;59:123–6.

[15] Gibb D, Arulkumaran S, editors. Introduction. In: Fetal monitoring in practice. Oxford: Butterworths/Heinemann, 1992. p. 1–7.

[16] Neilson JP. Fetal electrocardiogram (ECG) for fetal monitoring during labour (Cochrane methodology review). Cochrane Library, No. 4, 2003.

[17] Zuspan FP, Quilligan EJ, Iams JD, Van Geijn HP. Predictors of intrapartum fetal distress: the role of electronic fetal monitoring. Report of the National Institute of Child Health and Human Development. Consensus Development Task Force. Am J Obstet Gynecol 1979;135:287–91.