Correlation between Intrapartum Cardiotocogram Findings and Cord Blood pH in Term and Preterm Labours

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Objectives:
To compare the correlation between abnormal intrapartum cardiotocogram findings and cord arterial blood pH values in high-risk labours that occurred before and after 34 weeks' gestation.

Methods:
Data from preterm labours of singleton pregnancies of between 24 and 34 weeks' gestation (preterm group) were retrospectively collected over a 36-month period and were compared with high-risk labours that occurred at or after 34 weeks' gestation (term group) during the same period. The incidence of abnormal cardiotocogram findings (scored using the Royal College of Obstetricians and Gynaecologists 2001 guidelines), immediate pregnancy outcomes, and cord arterial blood pH values at delivery, were compared.

Results:
Data from a total of 68 preterm labours were compared with those from 128 matched term high-risk labours. Suspicious cardiotocograms were more common in the preterm group than in the term group (31% vs 9%; p<0.001) while pathological cardiotocogram patterns were more common in the term group as compared to the preterm group (22% vs 7%; p<0.025). Despite the higher incidence of pathological patterns in the term group, the incidence of a low cord arterial blood pH value below 7.15 was higher in the preterm group (9%) than the term group (2%) [p<0.05].

Conclusion:
The correlation between abnormal intrapartum cardiotocogram patterns and cord blood pH appeared to be different in term and preterm fetuses. The correlation with low cord blood pH was apparently better in term fetuses than in preterm ones.

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Introduction

The original purpose of continuous electronic fetal heart monitoring during labour was to monitor the fetus to prevent intrapartum stillbirth[1], and to detect the development of acidosis from the accumulation of lactic acid due to anaerobic metabolism.

The use of continuous electronic fetal heart monitoring in preterm labours has been a controversial issue. Large randomised controlled trials that set out to compare electronic fetal heart monitoring with intermittent auscultation in low-risk pregnancies, such as the much-quoted 1985 Dublin study[2], excluded preterm cases from the trial because of the high-risk nature of these labours and possible differences in fetal physiology. It has been reported that there are differences between the cardiotocogram findings in term and preterm fetuses in labour[3,4]. The physiological manifestation of vagal effects on the cardiac pattern may affect the baseline heart rate and variability of the tracing, so that more suspicious intrapartum patterns

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are detected in preterm as compared to term labours, stemming essentially from an increased incidence of decreased variability in the former group[5]. Studies on extremely preterm fetuses, between 24 and 26 weeks, have shown that only abnormal baseline tachycardias and bradycardias are predictive of subsequent neonatal death[6], indicating that the common parameters used to interpret cardiotocograms in term fetuses are unreliable in the very preterm.

The antenatal events predisposing to preterm labour may also compromise the fetus even before labour commences. Fetal metabolic acidosis may develop following an antepartum haemorrhage[7] or where there is chorioamnionitis[8]. Metabolic acidosis may have different implications for a preterm fetus from those for a term fetus. Preterm babies are more prone to developing periventricular leukomalacia after prolonged metabolic acidosis[9] than those that are more mature.

Umbilical cord blood acid-base studies have been used extensively to assist with diagnosing hypoxic ischaemic encephalopathy and its related sequelae[10]. In term infants, the lower limit of arterial cord blood pH for normal outcomes is about 7.1 and that for venous blood is 7.20[11]. This standard has often been extrapolated to preterm fetuses, irrespective of their gestation. The general criteria used for electronic fetal heart monitoring interpretation (Royal College of Obstetricians and Gynaecologists [RCOG] 2001 guidelines[12]) in the term fetus have been generalised to the preterm fetus, despite the possible differences in physiological development. Nevertheless, making a diagnosis of hypoxic ischaemic encephalopathy in preterm infants is often difficult, as neurological sequaelae may be a result of prematurity and its complications, rather than intrapartum events. For this reason, the international consensus criteria on the relationship between intrapartum events and neurological deficits only include the early onset of severe or moderate neonatal encephalopathy in infants of over 34 weeks gestation as indicative of intrapartum asphyxia leading to cerebral palsy[10]. There is concern therefore about the reliability of intrapartum cardiotocogram abnormalities and the implications of such abnormalities for cord blood pH values in preterm fetuses. This study aimed to compare immediate pregnancy outcomes and the correlation between these two parameters in term fetuses and those fetuses delivered before 34 weeks. The results should help to establish whether the intrapartum cardiotocogram and cord arterial blood pH values should be interpreted in the same manner as for term fetuses.

Methods

Data from consecutive singleton preterm labours and deliveries involving fetuses between 24 and 34 weeks' gestation (preterm group) with complete cord arterial blood pH data were retrospectively collected from a regional obstetric unit over a period of 36 months from July 2003 to July 2006. Data from 128 high-risk labours involving fetuses at or after 34 weeks' gestation delivered during the same period (term group) and managed using the same labour ward protocol in the same unit were used for comparison. The cases of high-risk labour selected for investigation were those that delivered after the index preterm cases, as listed in the labour ward registry, and had cord arterial blood pH data available for analysis. Blood gas values, however, were not analysed in this study, as such data were not being routinely collected. Women who underwent elective caesarean section, or caesarean section at the onset of labour without going into the active phase, and those with congenitally malformed fetuses, were excluded from the study.

Both investigators scored the intrapartum cardiotocogram tracings without referral to the patients' clinical details, gestation at delivery, or pregnancy outcomes. Using the RCOG 2001 guidelines[12], all tracings were classified as suspicious if there was one non-reassuring feature amongst either the baseline heart rate, variability, or presence of decelerations. They were classified as pathological when there was an abnormal feature or more than one non-reassuring feature. The scoring was agreed between the investigators. The arterial cord blood pH values, the main pregnancy outcome measures, including instrumental deliveries and caesarean sections, Apgar scores, admissions to the special care baby unit, and major neonatal morbidity including intracranial haemorrhages, seizures, hypoxic ischaemic encephalopathy, were extracted from the records. Student's *t* test and the Mann-Whitney *U* test were used as appropriate to compare the various continuous parameters between the two groups, while the Chi-square and Fisher's exact tests were used for discrete variables. A p value of <0.05 was considered statistically significant.

Table 1. Epidemiological data and pregnancy complications

Data*	Preterm (n=68)	Term (n=128)	p Value; mean difference/odds ratio (95% confidence interval)
Mean (SD) maternal age (yrs)	33.1 (5.3)	31.4 (4.7)	0.02; 1.69 (0.22 to 3.16)
Mean (SD) gestation at delivery (wks)	31.9 (2.5)	38.7 (1.2)	<0.001; -6.77 (-7.30 to -6.25)
Mean (SD) birth weight (g)	1853 (610)	3203 (418)	<0.001; 1349 (1204 to 1495)
Mean (SD) duration of labour (min)	334 (184)	368 (189)	0.21; -34 (-90 to 20)
Parity			
Primiparous	37 (54%)	72 (56%)	NS
Multiparous	31 (46%)	56 (44%)	
Gestational diabetes mellitus	8 (12%)	15 (12%)	NS
Hypertensive disorders	7 (10%)	12 (9%)	NS
Other medical conditions			
Antenatal anaemia	4 (6%)	8 (6%)	NS
Cardiac	0	3 (2%)	
Epilepsy	1 (1%)	1 (1%)	
Psychiatric disorders	3 (4%)	1 (1%)	
Thyroid disorders	3 (4%)	2 (2%)	
Antepartum haemorrhage	8 (12%)	0	
Previous caesarean section	11 (16%)	12 (9%)	NS
Induction of labour	4 (6%)	15 (12%)	NS
Meconium-stained liquor	3 (4%)	16 (13%)	NS
Intrauterine growth restriction	3 (4%)	6 (5%)	NS
Mode of delivery†			
Normal vaginal	34 (50%)	94 (73%)	<0.01
Instrumental	3 (4%)	4 (3%)	
Caesarean section	31 (46%)	32 (25%)	

* SD = standard deviation, NS = not significant

† Mantel Haenszel test

Results

There were a total of 68 patients in the preterm group and 128 in the control (term) group. The term group included: pregnancies complicated by intrauterine growth restriction with birth weights less than the 10th centile for gestation confirmed at delivery (n=28); those with abnormal intrapartum cardiotocogram tracings that necessitated intrapartum fetal blood sampling or obstetric intervention for delivery (n=72); and those with documented meconium-stained liquor at the onset of labour (n=28). The lowest gestation at delivery was 25 weeks. The mean gestation for the preterm and term groups was 31.9 weeks (standard deviation [SD], 2.5 weeks) and 38.7 weeks (SD, 1.2 weeks) respectively. The mean birth weight for the preterm group was 1853 g (SD, 610 g) and that for the term group was 3203 g (SD, 418 g). The mothers in the preterm group were older than the term mothers (33.1 vs 31.4 years; p=0.02), but there were no significant differences in the incidence of major antepartum complications including gestational diabetes mellitus or hypertension. Based on the preset selection criteria for selection, the term group cases consisted of 82 labours with abnormal intrapartum cardiotocogram tracings that necessitated intrapartum fetal blood sampling and / or obstetric intervention for delivery, 28 with documented meconium-stained liquor at the onset of labour, and 18 with fetal growth restriction (birth weight less than the 10th centile for gestation confirmed at delivery). Due to this preset selection criteria, the term group had a higher incidence of meconium-stained liquor and intrauterine growth restriction, but the duration of labour was similar between the two groups (Table 1).

Table 2. Pregnancy outcomes of term and preterm labours*

Pregnancy outcome	Preterm (n=68)	Term (n=128)	p Value	Odds ratio (95% confidence interval)
Suspicious CTG	21 (31%)	12 (9%)	<0.001	4.32 (1.97-9.48)
Suspicious due to decreased variability	18 (26%)	4 (3%)	<0.001	11.2 (3.6-34.6)
Pathological CTG	5 (7%)	28 (22%)	<0.025	0.28 (0.10-0.77)
Total abnormal CTG	26 (38%)	40 (31%)	NS	1.36 (0.73-2.52)
1-minute Apgar score ≤4	8 (12%)	4 (3%)	<0.05	4.13 (1.2-14.3)
5-minute Apgar score <7	4 (6%)	2 (2%)	NS	3.94 (0.70-22.1)
Cord blood pH				
<7.20	9 (13%)	3 (2%)	<0.01	6.36 (1.66-24.3)
<7.15	6 (9%)	2 (2%)	<0.05	6.3 (1.23-24.3)
Admission to SCBU	30 (44%)	8 (6%)	<0.001	11.8 (5.01-18)
Intraventicular haemorrhage	2 (3%)	0	NS	-
Neonatal seizures	0	1 (1%)	NS	-
Hypoxic ischaemic encephalopathy	0	0	NS	-
Perinatal deaths				
Total	3 (4%)	0	NS	-
Intrapartum	0	0		

* CTG = cardiotocogram, SCBU = special care baby unit, NS = not significant

The overall caesarean section rate was higher for the preterm group (46% vs 25%) [p<0.01].

Analysis of the cardiotocogram findings was based on review of an individual tracing made during a single labour. The overall incidence of abnormal (suspicious + pathological) cardiotocogram findings was similar in the preterm and term groups (38% vs 31%), but there were significantly more pathological patterns in the term group (9% suspicious, 22% pathological) compared to the preterm group (31% suspicious, 7% pathological) [p<0.001]. On the other hand, the incidence of suspicious cardiotocogram findings due to decreased variability was significantly higher in the preterm group (26%) than the term group (3%) [p<0.001]. Despite the higher incidence of pathological patterns in the term group, the incidence of cord arterial blood pH values below 7.20 or 7.15 was higher in the preterm group (13% and 9%) compared to the term group (2% and 2%) [p<0.01 and p<0.05 respectively]. The incidence of 5-minute Apgar scores below 7 did not differ between the two groups. There were no statistically significant differences in the incidence of neonatal seizures, hypoxic ischaemic encephalopathy or perinatal deaths between the two groups because of the small numbers (Table 2).

Discussion

The RCOG 2001 guidelines for the interpretation of intrapartum cardiotocograms distinguish between two levels of abnormalities, suspicious and pathological, but the gestational age at which such criteria are applicable has not been specifically stated[12]. In the NICE (National Institute for Health and Clinical Excellence) guidelines published in September 2007—*'CG 55: Intrapartum care: management and delivery of care to women in labour'*—the definitions and classifications of fetal heart rate tracing also omit their applicable gestational age[13].

It has been documented that preterm fetuses may exhibit abnormal baseline heart rates and decreased variability because of the relative immaturity of their autonomic nervous control[14]. Our findings were consistent with our previously reported finding of an increase in the incidence of suspicious decreased variability patterns in preterm labours[5]. In that study, clinical discrimination that took into account gestation-related differences in cardiotocogram findings, meant no significant increase in obstetric intervention rates was observed[5]. In the present study, we observed a higher incidence of pathological cardiotocogram patterns in the term group, but the incidence of caesarean sections

was actually higher in the preterm group, indicating that many of these interventions could be based on prematurity risks rather than on the cardiotocogram findings. Another recent case-controlled study found that electronic fetal monitoring alone is not able to identify preterm infants with neonatal white matter brain injuries, a major precursor for cerebral palsy. In that study, neonates with cerebral white matter brain injuries had few late decelerations during the last hour before delivery. Although fetuses with severe metabolic acidosis had a significant increase in decreased short-term variability, this finding had poor predictive value[15]. Such evidence highlights the poor correlation between intrapartum fetal heart patterns and subsequent neurological abnormalities in preterm fetuses, lending support to the exclusion of fetuses less than 34 weeks from the international consensus criteria for establishing a relationship between intrapartum events and subsequent neurological deficits and cerebral palsy[10].

The indications for routine or selective measurement of cord arterial blood pH have been a subject of debate. It is recommended that cord arterial blood pH studies should be used in conjunction with Apgar scores when assessing evidence of hypoxia in term newborns. They are listed as essential criteria for making a diagnosis of intrapartum hypoxia leading to cerebral palsy[10].

Investigations in term babies have shown that the combination of intrapartum fetal heart rate patterns, cord blood pH studies, and Apgar score assessment is better than any of those parameters alone when evaluating fetal status immediately after delivery[16]. The use of selective criteria for performing cord arterial pH, including prolonged labours, or assisted deliveries, or fetal distress, was found to have high sensitivity for detecting fetal acidosis, but low specificity[17]. Considering the cost, the accumulated published data, the non-specificity of electronic fetal monitoring for the evaluation of fetal oxygenation and presence or absence of hypoxia, it may indeed be more rational to implement universal cord blood pH and blood gas analysis[11]. It has also been advocated that for routine cord blood gas determinations, only a single cord arterial pH value will be needed since this reflects fetal or newborn status more accurately than all other measurements, and is extremely useful for ruling out the diagnosis of birth asphyxia in the depressed newborn[18]. Due to the limited availability of full blood gas studies, it was also our practice to perform cord arterial pH studies only at the time of the study.

The case for routinely performing cord arterial pH studies to assess preterm babies appears even stronger than for term fetuses. It has been shown that 1- and 5-minute Apgar scores are directly influenced by the infant's level of maturity[19]. Neonates with very low gestational ages and birth weights are much more likely to have low Apgar scores than larger or more mature infants[20]. In a study of viable preterm babies delivered between 24 and 36 weeks, more than 82% of neonates with 5-minute Apgar scores less than 7 had normal cord blood gases. On the other hand, there was no significant difference in the arterial blood gas values of the preterm and term infants in that series[21]. Our data contradict those findings, as we found the preterm babies had significantly higher rates of low cord blood pH values but did not have a greater incidence of low Apgar scores. This could be explained by the fact that in our study, most of the preterm deliveries occurred beyond 28 weeks, so the expected low Apgar scores in very preterm babies did not occur frequently. The overall incidence of significantly low cord blood pH was also low—around 4%—thus a larger series may be needed to delineate the precise relationship between low Apgar scores and gestation.

We did not routinely check for paired arterial / venous cord blood samples unless there was doubt or difficulty choosing the correct vessel for sampling. Previous studies have shown that paired samples enable better distinction between metabolic and respiratory acidosis[22]. Nevertheless, the difference between arterial and venous sample pH values should be small, with a minimal venous-arterial pH difference of 0.02[23] quoted by some, and a negative venous-arterial pH difference accepted by others[24]. As our data involved interpretation of pH values only, we believed the bias from inadvertent venous sampling should be small.

In term fetuses, cord blood arterial or venous pH values, PCO_2 and PO_2 values are interrelated, but these parameters often correlate weakly with 1-minute and 5-minute Apgar scores. A wide difference in arterial and venous PCO_2, however, usually indicates very low fetal-placental blood flow, and is more sensitive for predicting

asphyxiated infants, seizures, hypoxic-ischaemic encephalopathy, and abnormal development in the neonatal period[25]. It has also been recently proposed that the use of cord arterial base excess values could facilitate timing of the hypoxic injury[26]. It remains to be seen whether such parameters are useful for preterm fetuses, or whether routine paired arteriovenous cord blood samples and full blood gas studies might be of value in preterm deliveries.

We selected high-risk term deliveries matched for age and parity with the preterm cases in order to attempt to match the preterm group's risk for metabolic acidosis or perinatal complications. Our finding of a lower incidence of metabolic acidosis in the term group, despite a much higher incidence of pathological cardiotocogram patterns in this group, suggests that abnormal cardiotocogram findings tend to be less specific in term fetuses than preterm fetuses. On the other hand, because the higher incidence of decreased variability in the preterm fetuses' cardiotocograms leads to suspicious patterns, the clinical interpretation of suspicious cardiotocogram patterns in preterm labours and the use of variability as a key predictor of acidosis are likely to be less reliable in the preterm fetus. Nevertheless, our findings of a much higher caesarean section rate in the preterm group, despite a lower incidence of pathological cardiotocograms in this group, indicate that many of these caesarean sections were dictated essentially by their preterm gestation, or a preference for abdominal delivery by either the patient or the obstetrician, rather than by the cardiotocogram findings.

New techniques may improve the reliability of intrapartum electronic fetal monitoring. A recent review found that the incorporation of ST waveform analysis of fetal electrocardiography into cardiotocography could improve the standard of intrapartum fetal monitoring[27]. Fetal pulse oximetry has also undergone extensive study. OxiFirst (Nellcor FS-14; Corometrics, Colorado, USA) [pulse oximetry system] has already gained conditional approval from the US Food and Drug Administration for use in clinical practice, allowing opportunities to study the use of this tool as an adjunct to fetal heart rate tracing. Other new techniques include infrared fetal spectroscopy and refinement of computerised information systems for presentation, communication, storage and retrieval of perinatal data[28]. The data on the use of these new technologies on preterm fetuses are still far from comprehensive, however. The algorithms for analysis in both term and preterm pregnancies should be investigated and compared during the assessment of these new tools.

Conclusion

It is apparent that the current established criteria and guidelines for correlating abnormal intrapartum cardiotocogram patterns and cord arterial pH values are based on data from term fetuses. Our finding of a higher incidence of lower cord arterial pH values in preterm fetuses highlights the limitations of the criteria we currently use for the interpretation of cardiotocograms during preterm labours. Further research into intrapartum monitoring of preterm deliveries should explore the need for a different set of criteria for preterm fetuses, as well as the use of additional parameters such as blood gas profiles and base excess values during these high-risk labours.

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