Title:

Absence of fetal heart rate cycling on the intrapartum cardiotocograph (CTG) is associated with intrapartum pyrexia and lower Apgar scores.

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Abstract

Background*: Cycling consists of alternating periods of reduced and normal fetal heart variability, reflecting changes in fetal behavioural states. Occurrence of active and quiet sleep cycles is considered to be a hallmark of fetal autonomic nervous system integrity, demonstrating healthy interaction between the parasympathetic and sympathetic nervous systems. Cycling is an overlooked feature in most international cardiotocography (CTG) guidelines. The authors tested the hypothesis that fetuses showing no cycling in the intrapartum period have poorer outcomes.*

***Aim**: To investigate whether the absence of cycling at the commencement of intrapartum fetal monitoring is associated with poorer neonatal outcomes (umbilical arterial cord pH, Apgar scores and neonatal unit admission).*

***Methods**: Analysis of a database of sequentially acquired intrapartum CTG traces from a single centre. Only cases of singleton pregnancies over 36 weeks gestation in cephalic presentation with recorded umbilical artery cord pH were considered. Neonatal outcomes were assessed based on umbilical cord artery pH, Apgar ≤7 at 5 minutes and unexpected admission to the neonatal unit. Intrapartum pyrexia, presence of meconium stained amniotic fluid and mode of delivery were also recorded.*

***Results**: A total of 684 cases were analysed. Absence of cycling from the beginning of the intrapartum CTG recording was noted in 5% of cases. Cases with no cycling were more likely to have maternal pyrexia (≥37.8°C) (p=0.006) and Apgars ≤7 at 5 minutes (P=0.04). There was an association between increasing baseline fetal heart rate and the proportion of cases with no cycling. There was no significant difference between the two groups with regard to the mode of delivery or umbilical cord arterial pH <7.05 (p=0.53).*

***Conclusion:** Absence of cycling is associated with intrapartum maternal pyrexia and fetuses with absence of cycling are more likely to have poorer perinatal outcomes measured by Apgar ≤ 7 at 5 minutes, despite no association with fetal acidosis*.

Results from this research were presented at the XXVI European Congress of Perinatal Medicine in September 2018.

KEYWORDS: Cycling, fetal behavioural states, fetal monitoring, cardiotocography, chorioamnionitis, neonatal outcomes

INTRODUCTION:

Intrapartum cardiotocography (CTG) was introduced with the aim of identifying signs of fetal hypoxic-ischemia. It was hoped that recognition of features suggestive of intrapartum hypoxia on the CTG trace coupled with timely intervention may help avoid hypoxic-ischaemic encephalopathy (HIE) and perinatal mortality (1). However, it is well recognised that apart from hypoxia, there are multiple pathways of fetal neurological damage. These pathologies may be difficult to recognise with traditional CTG interpretation using the clinical guidelines which have been developed to identify intrapartum hypoxia.

Both intrapartum hypoxic-ischaemia and materno-fetal infection can independently lead to neonatal encephalopathy, however, the two are thought to also act synergistically to increase the risk of encephalopathy and cerebral palsy (2). Maternal hyperthermia at the time of or following a hypoxic-ischaemic insult has also been associated with adverse neurodevelopmental sequalae. Hyperthermic changes in fetal cerebral haemostasis, accelerated cell metabolism, altered cerebral blood flow and exotoxin release are thought to contribute towards neuronal cell apoptosis (3).

Fetal heart rate cycling is considered to be a hallmark of integrity of the autonomic nervous system. It consists of alternating periods of reduced and then normal fetal heart rate variability, reflecting the progression through different fetal behavioural states analogous to active and quiet sleep epochs. Pillai et al. (4) observed three fetal behavioural states – 1F ‘Quiescent state’ with alert eye movements, absent somatic

movement and narrow variability of the baseline heart rate, 2F ‘Active state’ with continuous eye movements, frequent bursts of somatic movement, heart rate accelerations and wider variability and 4F ‘Active state’ with continuous eye movements, almost continuous somatic movements and sustained tachycardia. In 96% of cases, cycling between the fetal states was seen within 100 minutes. 1F and 2F were the two most common states and these are comparable to quiet sleep (S1), and rapid eye movement (REM) sleep (S2), respectively in the newborn. The ratio of both sleep states is comparable in the term fetus (30 % quiet sleep vs 58 % active sleep) (4) and in the newborn (38.6% quiet sleep vs 52.1% REM sleep) (5). Well-defined fetal behavioural states have been observed after 36 weeks gestation, although between 28 and 36 weeks the quiet-active cycle of fetal heart rate can also be detected (6). Neonatal studies have shown disturbed sleep-wake cycles in newborns with HIE and sepsis (7) (8) whilst neonatal heart rate characteristic monitoring, with neonatal heart rate changes of reduced variability and decelerations, have been used as predictors of sepsis in newborns (9).

Most international intrapartum CTG guidelines - International Federation of Gynaecology and Obstetrics (FIGO) (10), American College of Obstetrics and Gynaecology (ACOG) (11), National Institute for Health and Care Excellence (NICE) (12) currently do not include the presence or absence of cycling in their CTG classifications.

The aim of this study was to investigate whether the absence of cycling at the commencement of intrapartum fetal monitoring is associated with maternal pyrexia and poorer neonatal outcomes (umbilical arterial cord pH, Apgar scores and neonatal unit admission).

METHODS:

Anonymised data for this study were collected from a single centre. A database of intra-partum cardiotocography (CTG) traces and associated outcomes from 2012 were analysed.

The inclusion criteria were women with a singleton pregnancy, who delivered a phenotypically normal live baby at ≥36 weeks gestation, without major acute labour accidents such as abruption, eclampsia, cord prolapse or shoulder dystocia. Cases without arterial cord gases pH, where the CTG trace lasted <50 minutes or was of poor quality were excluded.

Cases were reviewed by two operators (a registrar and an obstetric consultant). Cycling was defined as alternating periods of reduced or borderline variability with periods of normal variability, irrespective of the presence or absence of accelerations or decelerations and was assessed over a period of at least 50 minutes. If there were any discrepancies between the two operators on the CTG evaluation, a third Obstetric Consultant's opinion was sought. All operators had over two years experience in physiological CTG interpretation (13). Reviewers were blinded to maternal and neonatal outcomes.

Data were recorded in a spreadsheet file and analysed using Minitab v18 (Minitab LLC., State College, Pennsylvania, USA). Data were tested for consistency with a normal distribution using the Ryan-Joiner test in Minitab to inform the choice of statistical tests used. Fisher's Exact Test was used to compare categorical data and the Mann-Whitney test was used to analyse continuous data; the level for statistical

significance was P < 0.05. In addition, binary logistic regression and odds ratio (OR) were used to compare groups. Descriptive statistics were expressed as median as well as first and third quartile.

Results

Overall records on 717 cases were assessed, of these 33 were excluded for the following reasons:

- 28 babies with shoulder dystocia
- 4 cases of known fetal anomaly (2 cases of gastroschisis, 1 case of spina bifida, 1 case of oesophageal atresia)
- 1 case eclamptic fit

Thus a total of 684 cases were analysed with summary demographic descriptive statistics given in Tables 1a and 1b. There was 100% concordance between operators in CTG evaluation used for final data entry. Absence of cycling from the start of the CTG trace was noted in 31 (5%) cases. The median birthweight in the cycling group was slightly higher than the no cycling group but the difference was not statistically significant (p=0.11). Gestation at delivery and umbilical artery pH were similar for both groups (Table 1a). The proportion of babies delivered by Caesarean section was also similar for both groups as was the proportion with meconium. The proportion of babies with an Apgar score less than or equal to seven at five minutes was 26/653 (4%) for the cycling group and 4/31 (13%) for the no-cycling group (p= 0.04). When comparing the cycling and no cycling groups (table 1b) there was no significant difference in the

occurrence of umbilical artery pH less than 7.05 (n= 16, p = 0.53) or neonatal unit admission (n = 34, p=0.06).

There was a significant difference ($p < 0.001$, Mann-Whitney test) in baseline fetal heart rate between the group with no cycling (median HR 150 bpm) compared with the group with cycling (median HR 130 bpm); the graph in figure 1 shows that the proportion of cases with no cycling increased with increasing baseline fetal heart rate. A baseline FHR higher than expected for gestation, defined as >160 bpm from 36 to 39 weeks and >= 150 bpm from 40 to 42 weeks, was seen in 18/31 cases where cycling was absent and in 123/527 cases where cycling was present ($p<0.001$, Fisher's Exact test). Within the non-cycling group, 23/31 (74%) had reduced variability (≤5 bpm) and 8/31 (26%) had normal variability (5- 25 bpm).

Those cases with no cycling were more likely to be associated with maternal pyrexia (OR 4.3, p=0.006). When low variability (≤5bpm) is combined with no cycling the OR was 6.3 (p=0.001).

As expected there was an association with increased fetal heart rate and maternal pyrexia. In the group of non-tachycardic fetuses, absence of cycling was also associated with maternal pyrexia in labour (table 2).

Discussion

To our best knowledge, this is the first study which has assessed the relation between intrapartum maternal pyrexia and absence of fetal heart rate cycling on the cardiotocograph. In this study on an unselected population of fetuses in labour at or near term (≥36 weeks), absence of cycling was seen in 5%. In 8/31 (26%) of the cases without cycling, baseline variability was normal.

The absence of cycling in the presence of a quantitively normal variability is easily overlooked but should prompt the clinician to look for both hypoxic and non-hypoxic causes of central nervous system depression. Possible non hypoxic causes of loss of cycling in fetal life are metabolic, inflammatory/ infectious (e.g. encephalitis), drug related (e.g opioids), and structural (e.g brain malformations, fetal stroke) (16,17).

Heart rate variability (HRV) reflects the rapid and dynamic changes in autonomic regulation caused by the interplay of the sympathetic and parasympathetic nervous systems. HRV is usually reduced during fetal sleep and if reduced for prolonged periods (>90 minutes) (11) it may signify neurological depression due to other causes rather than normal sleep. Reduced variability at a higher baseline fetal heart rate should never be assumed as sleeping because during the normal sleeping cycle in both fetuses and neonates, the fetal heart rate is either their normal or slightly below.

Our study shows associations between absence of cycling and maternal pyrexia as well as higher fetal heart rate, suggesting an association with chorioamnionitis. Other authors have documented an association between absence of cycling and clinical and subclinical chorioamnionitis (22).

Chorioamnionitis strictly refers to inflammation of the chorion and amnion with diffuse infiltration of neutrophils into the chorioamniotic membranes. It's associated with higher neonatal morbidity after adjustment for gestational age at birth (18, 19) and in pre-term and term infants has been found to be an independent risk factor for cerebral palsy (20, 21). Histologic chorioamnionitis is present in 3- 5% of term deliveries and Kim et al. discuss an increasing body of evidence that acute chorioamnionitis can be present without intraamniotic infection, named as 'sterile intraamniotic inflammation' (19). In the neonate, sepsis leads to reduced variability and transient decelerations of heart rate; these changes have been found to be evident before the clinical diagnosis of illness in newborn infants (9). The sleep wake cycling is also deranged in neonatal sepsis and correlates with neurological outcome (8).

Suggested features of chorioamnionitis on the CTG are a raised baseline for the given gestational age or persistent increase of the baseline FHR by 10% or more during labor (22) (16) (23) (24). Romero et al. looked at the diagnostic performance of clinical signs for identification of intra-amniotic inflammation in patients with clinical chorioamnionitis and found that fetal tachycardia ≥160bpm had a sensitivity 77.14%, specificity 30% and diagnostic accuracy of 66.67% (25).

We acknowledge the limitation of the study for not having histologic confirmation of chorioamnionitis. However, in routine clinical practice, histopathological diagnosis is a retrospective diagnosis and clinicians need to manage labour based on clinical signs of chorioamnionitis (i.e. maternal pyrexia and fetal tachycardia). We also acknowledge that maternal pyrexia may not be necessarily associated with chorioamnionitis, however in absence of any other source of maternal infection, it is the most likely diagnosis. Other causes of maternal pyrexia in labour include epidural

anesthesia, prostaglandin use, dehydration, hyperthyroidism, and excess ambient heat.

In our study there was no association between absence of cycling and cord arterial pH<7.05. This may be due to the fact that fetal metabolic acidosis is a late sign in sepsis, and delivery was accomplished prior to the onset of metabolic acidosis. Moreover, it is well known that depression of the fetal central nervous system may occur in the absence of intrapartum hypoxia and acidosis due to non-hypoxic causes.

It has been shown that the umbilical cord acid-base parameters alone are not sufficient to identify term infants with brain injury. Cahill et al. (35) performed a nested case-control within a prospective cohort of 8,580 women where 55 cases, with an arterial umbilical cord gas (aUCG) pH < 7.10, were temporally, age, and sex matched to 165 controls with an aUCG pH ≥ 7.20. There was no statistical difference in brain injury between the groups (adjusted odds ratio [aOR]: 1.8, 95% confidence interval [CI]: 0.7-4.4]).

Unlike Preti et al (17), who showed a strong association between lack of cycling prior to delivery and fetal acidosis, we have included the cases with absence of cycling

from the beginning of labour where pre-existing conditions such as chronic hypoxia and chorioamnionitis are more likely to be captured and not necessarily associated with low pH. Other studies have also shown clinical chorioamnionitis to be associated with low APGAR scores but not with acidosis at birth (22 33, 34). Despite the lack of association with low cord pH, the fetuses with no evidence of cycling during labour had a significantly higher risk of having low APGAR scores and although not statistically significant, a trend towards a higher rate of admission to the neonatal unit. This implies a suboptimal transition to neonatal life that could be associated with non-hypoxic causes such as ongoing inflammation and congenital pneumonia.

Conclusion

Absence of cycling is associated with intrapartum maternal pyrexia and fetuses with no cycling behaviour are more likely to have poorer outcomes measured by APGAR less than 7 at 5 minutes, despite no association with fetal acidosis. Cycling is a CTG feature that is easy to assess and has the potential to improve detection of non hypoxic pathways of fetal compromise. Based on our findings, we recommend that clinicians should include fetal heart rate cycling, in addition to baseline fetal heart rate variability whilst scrutinising the CTG trace for evidence of depression of the fetal central nervous system.

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Table 1a

	All	CTG with Cycling	CTG with no cycling	cycling cf no cycling
Number	684	653 (95 % of all)	31 (5 % of all)	
Gestation at delivery (wks)	40.6 (39.6 to 41.4)	40.6 (39.6 to 41.4)	40.4 (39.4 to 41.1)	p = 0.22
Birthweight (g)	3420 (3150 to 3740)	3425 (3150 to 3746)	3300 (3120 to 3500)	p = 0.11
Umbilical artery pH	7.23 (7.17 to 7.28)	7.23 (7.17 to 7.28)	7.23 (7.18 to 7.28)	p = 0.86

Table 1b

	All (% of total)	Number CTG with Cycling	Number CTG with no cycling	cycling cf no cycling
Nulliparae	522 (76 %)	501	21	p = 0.28
SVD	163 (24 %)	153	10	p = 0.28
Instrumental delivery	304 (44 %)	296	8	p = 0.04
Delivery by CS	217 (32 %)	204	13	p = 0.24
Induced	304 (44 %)	294	10	p = 0.20
Meconium	217 (32 %)	204	13	p = 0.24
Apgar ≤ 7 at l min	156 (23 %)	146	10	p = 0.20
Apgar ≤ 7 at 5 min	30 (4 %)	26	4	p = 0.04
Apgar > 7 at 5 min	654 (96 %)	627	27	
pH UA <7.05	16 (2 %)	15	1	p = 0.53
NICU admission	34 (5 %)	30	4	p = 0.06

Table 2

CTG observation		**Number with pyrexia / normothermic**	**Odds ratio**	**95% CI**	**P-Value**
Cycling	No cycling	5/26	4.3	1.5 to 12.0	0.006
	cycling	28/625			
FHR normal for gestation	No cycling	3/10	8.5	2.1 to 33.5	0.002
	cycling	18/509			
FHR higher than expected for gestation	No cycling	2/16			0.65*
	cycling	10/113			
Variability ≤ 5 bpm	Yes	12/135	2.2	1.0 to 4.6	0.037
	No	21/516			
FHR higher than expected for gestation	Yes	12/129	2.3	1.10 to 4.79	0.026
	No	21/519			

Table legends

Table 1a:
Median and interquartile range of gestation, birthweight and umbilical artery pH as well as the CTG cycling and no cycling groups.

Table 1b:
Delivery and neonatal outcomes in cases with and without cycling on the cardiotocograph (CTG).

Table 2:
Proportions and odds ratio of cases with maternal pyrexia. (p values from binary logistic regression except for * where p value from Fisher's Exact test).

Figure 1 legend:
Proportion of cycling and no cycling compared with baseline fetal heart rate.