

Computerised analysis of intrapartum fetal heart rate patterns and adverse outcomes in the INFANT  
trial

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## **ABSTRACT**

### **Objective**

To assess if a computerised decision support system reliably identified abnormal fetal heart rate (FHR) patterns in fetuses with adverse neonatal outcomes in the INFANT trial, and whether its use reduced substandard care.

### **Design**

Prospective cohort study within a randomised controlled trial

### **Setting**

24 maternity units in the UK and Ireland

### **Population or Sample**

46,614 labours between Jan 6<sup>th</sup> 2010 and Aug 31 2013 in the INFANT trial.

### **Methods**

Panel review of intrapartum and neonatal care in infants with adverse outcome, and an assessment of the effectiveness of computerised interpretation of fetal heart rate in reducing substandard care. Descriptive analysis of other factors associated with adverse outcome.

### **Main Outcome Measures**

Incidence and detection rate of abnormal fetal heart rate patterns, other characteristics associated with perinatal adverse outcome, and frequency of substandard care.

### **Results**

Computer interpretation of FHR patterns was deemed to be completely valid in only 13 of 71 (30.6%) cases of adverse outcome. On a scale of 0-10 (completely invalid to completely valid) 28 cases (39.4%) had a score of 6 or less, mainly due to lack of recognition of decelerations (15 cases) or reduced variability (7 cases) or failure to recognise tachysystole (5 cases). There were multiple associated factors which modified the clinical assessment of FHR patterns. There was substandard care in 45/71 cases (63%).

### **Conclusion**

A significant proportion of abnormal fetal heart rate patterns were not detected accurately by computer analysis and its use did not reduce the incidence of substandard care.

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**Keywords**

Intrapartum fetal heart rate monitoring, risk factors, adverse outcome, suboptimal care

Tweetable abstract:

Improved recognition of abnormal fetal heart rate patterns is insufficient to reduce the incidence of substandard care

## INTRODUCTION

Continuous electronic monitoring of the fetal heart rate (electronic fetal monitoring, EFM) and uterine contractions (cardiotocography, CTG) during labour was introduced in the 1960-70s<sup>1</sup> as an alternative to intermittent auscultation. Despite meta-analyses reporting a 59% fall in intrapartum deaths attributable to intrapartum hypoxia<sup>2</sup> and a 50% reduction in the risk of neonatal seizures<sup>3</sup>, a Cochrane review published in 2017<sup>4</sup> concluded that "CTG during labour is associated with reduced rates of neonatal seizures, but no clear differences in cerebral palsy, infant mortality or other standard measures of neonatal wellbeing".

A possible explanation for the ineffectiveness of EFM is human error in interpreting the fetal heart rate (FHR) pattern. One study of 64 cases of legal claims for poor perinatal outcome reported that in 14 cases there was a significant abnormality of the FHR pattern that was either not noticed, or ignored<sup>5</sup>. Another concluded that "some junior doctors and midwives cannot recognise abnormal CTG traces"<sup>6</sup>. A 1999 National Health Service Litigation Authority (NHSLA) study of 100 stillbirth claims reported misinterpretation of fetal heart rate patterns in 34%<sup>7</sup>. The 2012/13 NHSLA Report<sup>8</sup> stated that "a key finding from the report has demonstrated the need to focus on improving the detection and response to a deteriorating fetal heart rate through better fetal monitoring". The 'Each Baby Counts' study of adverse perinatal outcomes in the UK during 2015 reported that of 727 cases with adequate review, there was substandard care in 552 (76%) and CTG interpretation was a factor in 341 (62%) of these<sup>9</sup>.

The INFANT trial<sup>10;11</sup> was a prospective randomised controlled trial investigating the ability of a decision support system to reduce the incidence of suboptimal care and poor perinatal outcomes. The hypothesis was that alerts from computer analysis of the FHR would improve clinician recognition and response to abnormal patterns. However, there was no significant difference in any short-term or two year clinical outcomes between the intervention (alerts visible to the birth attendants) and control arms (alerts not visible) of the trial. Despite an unexpectedly low overall perinatal mortality and morbidity, there remained cases of fetal adverse outcome. Our objective was to assess whether (a) there were factors in addition to an abnormal FHR pattern associated with an adverse outcome (b) abnormal FHR patterns were not detected by the software or birth attendant.

## Methods

### The INFANT trial

The INFANT software produced alerts in the form of a colour coded 'ladder of concern'. A green level alert indicated that there were no identified abnormalities in the fetal heart rate pattern, a blue level alert indicated that there were minor abnormalities, a yellow level alert indicated that there were abnormalities requiring review by the birth attendants, and a red level alert indicated that there were abnormalities requiring review by a senior obstetrician. The nature of the concern was displayed in words on the tracing. For example, a single late deceleration generated a blue "severe deceleration"

warning, whereas three generated a yellow "severe decelerations" warning. Decelerations continuing for 25 min generated a red "severe decelerations" warning. These alerts were visible to the birth attendants in the intervention arm, but not to those in the control arm. The trial primary outcome was a composite of poor perinatal outcome, including deaths (intrapartum stillbirths plus neonatal deaths up to 28 days after birth, except for congenital anomalies deaths) and significant morbidity (moderate or severe neonatal encephalopathy, defined as the use of whole-body cooling or admission to the neonatal unit within 48 h of birth for 48 h or more with evidence of feeding difficulties or respiratory illness, with evidence of compromise at birth suggesting mild asphyxia or mild encephalopathy, or both).

Labouring women who had previously been informed about the trial and who gave consent to be included and randomised in the trial were at least 35 weeks of gestational age and without any known fetal anomalies, and continuous EFM was deemed appropriate. We defined adverse outcome as intrapartum stillbirth, neonatal death and all other infants with the trial primary outcome with a metabolic acidosis; cord-artery pH <7.05 with base deficit  $\geq 12$  mmol/l). We selected infants with a metabolic acidosis because EFM is regarded primarily as a screening test for hypoxia. The trial was designed before core perinatal outcome sets had been published. The study organisers included a representative of the National Childbirth Trust, London, UK (a patient advocacy group) who was also an active member of the writing committee and has commented on several drafts of this paper. There was no other direct patient involvement in the study, as it was designed and started before this became a recognised requirement.

### **Panel review and assessment of computerised interpretation of fetal heart rate**

There were 71 cases of adverse outcome satisfying the above criteria, including three intrapartum stillbirths and 10 neonatal deaths. Their clinical care was evaluated by a senior obstetrician (PJS), a senior neonatologist (IK) and a consultant midwife (CMcK for all cases except five where the midwife was MG), working together. The panel reviewed each case as if they were the clinical carers (i.e. they had access to the CTG alerts in the study cases but not in the control cases) and continued their discussions until they came to an agreed assessment. Care was graded according to the system developed by the Confidential Enquiry into Stillbirths and Deaths in Infancy, on a scale of 0 to 3. Grade 0 indicates no suboptimal care, grade 1 indicates suboptimal care but without any evidence that avoiding it would have prevented the adverse outcome, grade 2 indicates a substantial possibility that avoiding the suboptimal care would have avoided the adverse outcome, and grade 3 indicates a high likelihood that optimal care would have avoided the adverse outcome. The proportion of infants judged to have suboptimal care (by grade) and the proportion whose adverse outcome was judged to be related to CTG interpretation was reported by trial arm. The panel then assessed the performance of the INFANT software system and judged whether the alerts generated were appropriate using a scale of zero (invalid) to 10 (valid).

To assess the accuracy of the software when it indicated an abnormal fetal heart rate pattern, a sample of 500 CTG recordings flagged by the software as registering at least one red alert was examined by PJS. The number of red and yellow alerts generated from trial entry to delivery were also compared between the group of infants with an adverse outcome (n=71) and the group of infants with no adverse outcome (n=46,543) in the trial population. Risk ratios and 95% confidence intervals were calculated for differences in proportions between groups.

### **Characteristics associated with adverse outcome**

Where data was available for at least 99% of women participating in the trial, we compared the characteristics of the cases with an adverse outcome and the remainder of the trial population (total n=46,543). These were documented from the case records in the adverse outcome group and from the Guardian electronic record system on which INFANT software system runs for the remainder of the trial population. First we performed a univariable analysis, calculating the risk of having an adverse outcome for each factor, along with risk ratios and 95% confidence intervals. Then we conducted a multivariable analysis used a generalised linear model with a log link and robust standard errors to adjust for clustering due to twins. We included all the factors except birth weight centile, as it is highly correlated with gestational age and birth weight, and it was the least significant factor in a model including all three of these variables.

Some of the data fields in the Guardian system were poorly completed, and so for some characteristics we have been able to report only the data for the adverse outcome group. Other factors likely to be associated with adverse outcome have previously been identified<sup>12</sup>, for which we had data in the adverse outcome group, but not in the total trial population. As we could not perform a comparative analysis for these additional factors we present descriptive data in the adverse outcome group only.

## **RESULTS**

### *Characteristics associate with adverse outcome (Table 1)*

Adverse outcomes were more common in women with twin pregnancies (6.1 compared to 1.4 per 1,000 infants), and those who delivered at 35<sup>+0</sup> to 36<sup>+6</sup> weeks (5.4 compared to 1.3 per 1,000 infants). The frequency was also increased in small for gestational age infants (<10<sup>th</sup> centile; 3.6 compared to 1.4 per 1,000 infants), although only 7 (9.9%) were suspected of having fetal growth restriction antenatally. Together this resulted in a higher incidence of adverse outcomes in infants weight less than 2.5kg at birth (6.9 compared to 1.3 per 1,000 infants). There was also an increased incidence in women who did not have a spontaneous vaginal delivery.

Adverse outcomes were no more likely in the decision support arm of the trial than in the clinician interpretation arm. The only factors that remained statistically significant in the multivariable model were being born with a birth weight <2.5kg and not having a spontaneous vaginal delivery.

Analysis of factors reliably recorded only in the adverse outcome group showed that there were high rates of maternal obesity, induction and augmentation of labour, meconium staining of the amniotic fluid, prolonged labour and maternal pyrexia (Table 2).

Hyperstimulation of uterine contractions with prostaglandins or oxytocin (or both) can cause fetal hypoxia in labour resulting in stillbirth, neonatal death or long term brain injury<sup>13</sup>. Most inductions were performed using prostaglandins (29/39, 74.4%) and uterine hyperstimulation secondary to use of prostaglandin occurred in 4 cases (13.8% of cases where it was used). The use of syntocinon augmentation was common (46/71, 64.8%), and uterine hyperstimulation occurred in 11 cases (24% of those given oxytocin).

### **Assessment of computerised interpretation of fetal heart rate**

*Incidence of red and yellow levels of concern in infants with and without an adverse outcome (Table 3)*

#### *Red levels of concern*

In the adverse outcome group the proportion with at least one red alert was 11/71 (15.5%) compared with 4903/46,543 (10.5%) of the trial population with no adverse outcome. There was no significant difference in the rate of red alerts between the two trial groups (rate ratio adverse outcome vs no adverse outcome 1.10, 95% CI: 0.65 to 1.74).

#### *Yellow levels of concern*

In the adverse outcome group the proportion with at least one yellow alert was 63/71 (88.7%) compared with 34,407/46,543 (73.9%) of the trial population with no adverse outcome. There was a significantly elevated rate of yellow alerts in the adverse outcome group (rate ratio 1.33, 95% CI: 1.17 to 1.51).

#### *Accuracy of software recognition of abnormal fetal heart rate pattern (Figure S2)*

A sample of 500 CTG recordings flagged by the software as registering at least one red alert was assessed by PJS. Twenty consecutive recordings were downloaded from each of the 24 participating centres, and another 20 from one of them to make a round 500. Twenty-seven traces were technically unreadable and 5 were found to contain no red alerts, leaving 468 traces for analysis. The last red alert in each case was evaluated. 276 (58.4% of readable traces) were judged to be a valid cause for concern about fetal condition. In 128 cases (27.1 % of readable traces) the red alert was triggered by the unintentional recording of maternal heart rate (in 43 this was associated with the insertion of an epidural anaesthetic; positioning of the mother for epidural insertion often disturbs the placing of the ultrasound transducer, the most commonly used modality for fetal heart beat detection, causing it to record maternal blood vessel pulsation rather than fetal heart activity). Although these red alerts did

not indicate a true cause of concern about fetal condition, they did require clinician action (readjustment of transducers/application of a fetal electrode) to ensure adequate fetal surveillance and they could therefore be considered clinically relevant. In total, in 86.3% of cases the attention of the attending clinicians was necessary. However, 36 red alerts (8.2% of readable traces) were deceleration alarms triggered by a marked fetal heart rate acceleratory pattern and were therefore false positives. Such traces are also difficult for clinicians to categorise, and diagnosis requires assessment of the tracing immediately prior to the episode (almost always normal), the evaluation by palpation of fetal movements (when the pattern is acceleratory, the fetus is almost invariably very active; a fetus exposed to hypoxia stops moving which reduces oxygen consumption), and the continuing assessment of the heart rate pattern (most marked acceleratory patterns return to a quieter pattern over the next 40-60 minutes). Fourteen cases (3%) were sinusoidal pattern alarms in the presence of normal variability. These were all cases in the same maternity unit over a short period of time and were traced to a software fault which has since been corrected. In 14 cases (3%) there was a technical artefact in the fetal heart rate recording and in 5 cases (1%) there was no red alert.

#### *Suboptimal care and validity computer assisted interpretation (Table 4)*

The proportion of infants with adverse outcome judged by the panel to have had suboptimal care (overall 63.4%; grade 3 - 38%) are shown in Table 4 by trial arm (computer assisted interpretation versus not). As reported previously<sup>14</sup>, this was not statistically significant between groups (RR 1.18, 95% CI: 0.82 to 1.68). There was also no difference in the number of adverse outcomes judged to be related to CTG interpretation between the two groups. The number of infants with adverse outcome in which computer assisted interpretation was deemed to be completely valid (score 10) by all the members of the panel the panel was 13 (37.1%) in the decision support group compared to 11 (30.6%) in the clinician interpretation group, but this difference was not statistically different. In 28 cases where an interpretation score of 6 or less was given, the main reason was lack of recognition of decelerations (15 cases - in three of these a persistent bradycardia did not trigger an alert. This appeared to be a particular problem when the registration of contractions was technically inadequate). There were seven cases where markedly reduced heart rate variability did not trigger an alert. Although tachysystole (excessively frequent uterine contractions) was usually recognised more reliably by the software than by the clinicians, there were 5 cases where a contraction frequency of more than 5 in ten minutes did not trigger a computer alert.

## **Discussion**

### **Main findings**

In labours where continuous fetal monitoring by EFM was undertaken, compared with labours with no adverse outcome, adverse outcome was significantly associated with older mothers, earlier gestational age (35<sup>+0</sup> to 36<sup>+6</sup> weeks) and smaller babies. Spontaneous birth was less than half as

likely (table 1). There were also high rates of maternal obesity, induction and augmentation of labour, meconium staining of the amniotic fluid, prolonged labour and maternal pyrexia (table 2).

The incidence of FHR patterns triggering a computer alert was higher in labours with an adverse outcome than in cases without an adverse outcome, but the difference was small and only significant in relation to yellow alerts.

There were only three intrapartum stillbirths, a rate of one in 15,687, compared with one intrapartum stillbirth per 2200 births in the CTG arm of the 1985 Dublin randomised trial of intrapartum fetal heart rate monitoring<sup>15</sup>. Similarly, there were only 10 neonatal deaths up to one month of age, giving an extended perinatal mortality of 0.28 per thousand live births compared with a perinatal mortality of 2.14 per thousand in the CTG arm of the Dublin trial. However, despite this high level of overall safety, there was still suboptimal care in 63% of the 71 cases of adverse outcome, with the highest grade (3) in 38%. The computer alerts system worked acceptably well, with no evidence that it failed to flag important heart rate abnormalities. In the clinician interpretation group abnormal FHR patterns were recognised by the clinicians but it appeared that insufficient weight was being given to the interpretation of FHR abnormality in the context of often multiple coexisting risk factors. The judgement of the review group was that such failure to interpret (as opposed to recognise) the traces in context was common (35 of 71 cases, 49%). In particular, the vulnerability of late preterm infants seems to have been inadequately recognised, and the importance of intrapartum pyrexia (which predisposes to poor neonatal outcome<sup>18</sup>) also seems to have been under-appreciated. There were also management issues such as hyperstimulation of uterine contractions from either prostaglandin or syntocinon (15 cases, 21%), prolonged intervals between the decision to deliver and delivery (more than three hours in two cases), and failed ventouse/forceps in 3 cases (4.2%).

### **Strengths and limitations**

The study cohort was a clearly defined cohort where continuous EFM in labour was considered justified, and therefore low risk labours were excluded. All the adverse outcome pregnancies and labours were studied in detail by an experienced group of assessors using a de-identified photocopy of the original clinical records (subsequently destroyed). The main limitation was the much lower incidence of adverse outcomes than was expected. Patient involvement was limited to a representative of the National Childbirth Trust because the study was designed and started before patient involvement became a formalised requirement.

### **Interpretation**

From the results of the INFANT trial it seems unlikely that any substantial reduction in suboptimal care can be achieved by improving the recognition of FHR tracing abnormality. EFM is only a screening test, and while a normal fetal heart rate pattern is reassuring about fetal condition, a heart rate pattern abnormality should prompt a detailed and thorough re-evaluation of the risk status of the fetus, with

early involvement of the whole team including senior midwives and obstetricians to plan and implement care. A previous study has highlighted that only about half of infants needing active resuscitation at birth had an abnormal CTG tracing in labour<sup>12</sup>, their poor condition being due to other factors such as meconium aspiration<sup>13</sup>, trauma<sup>14</sup> and pyrexia<sup>15</sup>. Our study has highlighted the importance when assessing the significance of an abnormal fetal heart rate pattern of taking into account other relevant risk indicators. The 'Each Baby Counts' study of 1136 cases of adverse outcome in the United Kingdom during 2015 reported an average of six risk factors per case (but did not provide details and so they may have included additional factors that we have not categorised). We strongly support their conclusion that "When reviewing a CTG, identification and consideration of risk factors must become standard practice"<sup>9</sup>.

## **Conclusion**

Computerised recognition and classification of abnormal fetal heart rate patterns was inaccurate in a significant proportion of labours with an adverse neonatal outcome. Its use did not reduce the incidence of substandard care. Evaluation of risk in labour is multifactorial and improved recognition and classification of abnormal fetal heart rate patterns is unlikely to reduce the incidence of adverse neonatal outcome.

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### **Disclosure of interests**

KG is a founding shareholder of K2 Medical Systems, and was clinical director for development of the INFANT and Guardian systems until 2005. CM is an employee and shareholder of K2 Medical Systems. All other authors declare no competing interests.

### **Contribution to authorship**

All members of the writing committee contributed to the development of the protocol and management and running of the trial. PJS, IK, CM and MG carried out the analyses of the adverse outcome cases. PJS and LL carried out the statistical analysis and PJS wrote the article with amendments from LL. All other members of the INFANT writing committee have seen and approved the submitted paper.

### **Ethics**

Research ethics committee approval for the study was granted by the National Research Ethics Service—Northern and Yorkshire Research Ethics Committee (09/H0903/31).

## Reference List

- (1) Gillmer MDG, Combe D. Intrapartum fetal monitoring practice in the United Kingdom. *Br J Obstet Gynaecol* 1979; 86:-760.
- (2) Vintzileos AM, Nochimson DJ, Guzman ER, Knuppel RA, Lake M, Schiffrin et al. Intrapartum electronic fetal heart rate monitoring versus intermittent auscultation: a meta-analysis. *Obstet Gynecol* 1995; 85(1):149-155.
- (3) Thacker SB, Stroup DF, Peterson HB. Efficacy and safety of intrapartum electronic fetal monitoring: an update. *Obstet Gynecol* 1995; 86(4 Pt 1):613-620.
- (4) Alfirevic Z, Devane D, Gyte GM, Cuthbert A. Continuous cardiotocography (CTG) as a form of electronic fetal monitoring (EFM) for fetal assessment during labour. *Cochrane Database Syst Rev* 2017; 2:CD006066.
- (5) Ennis M, Vincent CA. Obstetric accidents: a review of 64 cases. *BMJ* 1990; 300:1365-1367.
- (6) Vincent CA, Martin T, Ennis M. Obstetric accidents: the patient's perspective. *Br J Obstet Gynaecol* 1991; 98(4):390-395.
- (7) NHSLA. Study of Stillbirth claims. 2009 Available from: NHS Resolution, 2nd Floor, 151 Buckingham Palace Road, London, SW1W 9SZ, UK
- (8) NHSLA. NHS Litigation Authority Report and accounts 2012/13. Available from: URL:[https://www.google.co.uk/?gws\\_rd=ssl#q=NHSLA+report+2012/13](https://www.google.co.uk/?gws_rd=ssl#q=NHSLA+report+2012/13)
- (9) Alfirevic Z, and the each baby counts team. Each Baby Counts. 2018. Available from <https://www.rcog.org.uk/eachbabycounts>
- (10) Brocklehurst P, The INFANT Collaborative Group. A study of an intelligent system to support decision making in the management of labour using the cardiotocograph – the INFANT study protocol. *BMC Pregnancy and Childbirth* 16:10. 2016.
- (11) Computerised interpretation of fetal heart rate during labour (INFANT): a randomised controlled trial. *Lancet* 2017; 389(10080):1719-1729.
- (12) Lissauer TJ, Steer PJ. The relation between the need for intubation at birth, abnormal cardiotocograms in labour and cord artery blood gas and pH values. *Br J Obstet Gynaecol* 1986; 93:1060-1066.
- (13) Steer PJ, Eigbe F, Lissauer TJ, Beard RW. Interrelationships among abnormal cardiotocograms in labor, meconium staining of the amniotic fluid, arterial cord blood pH and Apgar scores. *Obstet Gynecol* 1989; 74:715-721.
- (14) Walsh CA, Robson M, McAuliffe FM. Mode of delivery at term and adverse neonatal outcomes. *Obstet Gynecol* 2013; 121(1):122-128.
- (15) Badawi N, Kurinczuk JJ, Keogh JM, Alessandri LM, O'Sullivan F, Burton et al. Intrapartum risk factors for newborn encephalopathy: the Western Australian case-control study. *BMJ* 1998; 317(7172):1554-1558.