CAN FETAL HEART RATE MONITORING ULTIMATELY BECOME A USEFUL TOOL IN OBSTETRICAL PRACTICE?

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ABSTRACT

Currently, fetal heart rate (FHR) monitoring is the most widely used method for antepartum and intrapartum fetal surveillance. Antenatally, the introduction of FHR monitoring has been associated with a parallel decrease in perinatal mortality. However, a number of small scale controlled studies has failed to demonstrate the usefulness of FHR monitoring, both antenatally and intrapartum. Several possible explanations could be responsible for this apparent incongruous observation. Although FHR is normally easy to record, the quality of tracing is often sub-optimal, and adds to the complete lack of uniform interpretation shown in studies comparing interobserver and intra-observer variations. In addition, there is now an abundance of human observations and animal studies demonstrating that gestational age, in addition to the development of fetal behavioural status, are the most important factors that will alter FHR patterns under normal conditions and in response to hypoxaemia. It is also becoming evident that growth-restricted fetuses have inherent differences in FHR patterns when compared to normally-grown fetuses, possibly due to a delay in the maturation of the autonomic control of the fetal heart in response to chronic hypoxaemia. Therefore, in order to use electronic FHR monitoring, it is becoming necessary for the clinician to start learning about the physiology of the fetus, its changing evolution with advancing gestation, and the various ways these are represented in FHR tracings under stress or distress. With the development of computerized FHR analysis that virtually eliminates interobserver and intra-observer variation in interpretation, in addition to the knowledge of the factors influencing FHR, it is now possible and timely to conduct a properly designed, large scale, randomized clinical trial to demonstrate whether or not both antenatal and intrapartum FHR monitoring can ultimately become useful tools in obstetrical practice.

RESUME

La surveillance de la fréquence cardiaque du foetus (FCF) est actuellement la méthode de surveillance antepartum et intrapartum la plus fréquemment utilisée. Avant la naissance, on a lié l'adoption de la surveillance de la FCF à une diminution parallèle de la mortalité périnatale. Cependant, un certain nombre d'études contrôlées à petite échelle n'ont pas permis d'établir l'utilité de la surveillance de la FCF, à

la fois avant la naissance et pendant l'intrapartum. On pourrait donner plusieurs explications de cette observation apparemment incongrue. Bien qu'il soit normalement facile d'enregistrer la FCF, la qualité du tracé est rarement optimale et elle favorise la totale absence d'uniformité d'interprétation constatée dans les études comparatives des écarts entre les observateurs et chez un même observateur. De plus, on dispose maintenant de nombreuses observations humaines et d'études animales révélant que l'âge gestationnel, ainsi que le développement des états comportementaux du foetus, constituent les plus importants facteurs d'altération des tracés de la FCF, dans des conditions normales et en réaction à l'hypoxémie. Il devient aussi évident que les foetus manifestant un retard de croissance présentent des différences inhérentes quant aux tracés de la FCF par comparaison avec les foetus dont la croissance est normale, peut-être en raison d'un retard de maturation du contrôle autonome du coeur foetal en réaction à une hypoxémie chronique. Ainsi, pour recourir à la surveillance électronique de la FCF, le clinicien doit se familiariser avec la physiologie du foetus, son évolution pendant le déroulement de la gestation et les divers moyens servant à représenter ces éléments dans les tracés de la FCF en cas de stress ou de souffrance. Grâce au perfectionnement de l'analyse informatisée de la FCF, qui élimine pratiquement les écarts d'interprétation entre les observateurs et chez le même observateur, en plus de la connaissance des facteurs ayant une incidence sur la FCF, il est maintenant possible d'effectuer rapidement un essai clinique randomisé, à grande échelle et bien conçu, pour vérifier si la surveillance de la FCF, à la fois avant la naissance et pendant l'intrapartum, pourra éventuellement devenir un outil utile pour exercer l'obstétrique.

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INTRODUCTION

Since its introduction into clinical practice in the mid-1970s, intrapartum continuous electronic fetal heart rate (FHR) monitoring has been the subject of controversy. Several recent randomized clinical trials comparing continuous FHR monitoring to intermittent FHR auscultation have failed to demonstrate any major benefit from the former method in relation to perinatal outcome.[1] However, there is a definite increase in operative deliveries including Caesarean sections in women who are continuously monitored. The goals when monitoring the fetus continuously during labour are to prevent intrapartum death and to detect the onset of metabolic acidosis requiring immediate intervention. However, to be clinically useful, a new technique such as continuous electronic FHR monitoring during labour needs to be validated in terms of reliability of interpretation prior to implementation. The purpose of this presentation is to review briefly the role of fetal heart rate monitoring in current practice and its limitations.

FETAL BEHAVIOURAL STATES

It has been recognized that the human fetus near term experiences the organization of behavioural states much like the human neonate as described by Prechtl *et al.*[2] In the human fetus, these states are identified by the linkage of the three variables: body movements, eye movements, and FHR pattern. These states have been referred to by Nijhuis *et al.* as 1F (quiet sleep), 2F (active sleep), 3F (quiet awake), and 4F (active awake).[3] The importance in recognizing the existence of these states in clinical practice is that their organization likely reflects a high degree of central nervous system function which, in turn, may influence the proper interpretation of FHR tracings. It is also possible to make the appropriately grown fetus change behavioural state by the application of vibro-acoustic stimulation (VAS) to the maternal abdomen.[4,5] Similar state changes occur with VAS in the fetus with intra-uterine growth restriction (IUGR), although the amplitude and duration of FHR response are shorter. In addition, the use of FHR response to VAS during labour has been suggested recently to differentiate the acidotic from the non-acidotic fetus.[5]

INTERPRETATION OF FHR TRACINGS

The most widely used definition for a normal FHR tracing includes a baseline oscillation of > five bpm, a baseline FHR between 120 to 160 bpm, absence of periodic FHR decelerations, and the presence of FHR accelerations associated with fetal movements. It is expected that with a normal FHR pattern during labour, the fetus should be born with a good metabolic status. In contrast, an ominous FHR pattern is defined by a decrease in FHR variability, lack of FHR accelerations, loss of rest-activity

cycles, periodic FHR decelerations including late and severe variables, and terminal bradycardia. The ultimate fetal outcome in the presence of an ominous FHR pattern, if no intervention takes place, should be the development of progressive metabolic acidosis, intrapartum death, and possibly neurological sequelae in the survivors.[6]

There have been several attempts to validate and prove the reliability of visual interpretation of the different components of FHR tracings. Unfortunately, they reached the same conclusions. The intra-observer and interobserver agreements of visual interpretations of FHR tracings and their components have been uniformly low.[7-10] With the recent availability of computerized interpretation of FHR tracings, we have tried to compare visual interpretation of FHR tracings to a computer interpretation using the Oxford Sonicaid System 8000.[10] We asked five experts, well-trained in interpretation of FHR tracings, a total of seven questions on three readings of 100 FHR traces each. Judgement-related questions asked were:

1. Is the baseline FHR high, average or low?
2. Is the short-term FHR variability normal or decreased?
3. Should we continue recording? Yes or No?
4. Are you concerned about this tracing? Yes or No?

The accuracy-related questions were:

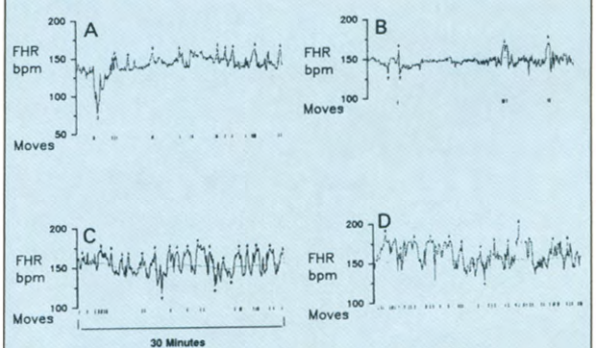
1. How many FHR accelerations of >15 bpm X >15 sec?
2. How many FHR decelerations of >10 bpm X >60 sec?
3. What is the baseline FHR in bpm?

The kappa coefficient was used to assess the reliability of the four judgement-related questions. The intra-observer agreement for the assessment of FHR baseline (range 0.53–0.82) was consistently higher than for FHR variability (range 0.03–0.58). One observer who was relatively consistent in assessing baseline FHR (kappa= 0.76) and FHR variability (kappa=0.58) was inconsistent in deciding whether or not to continue FHR tracing (kappa=0.23) or to be concerned about an FHR trace (kappa=0.23). The interobserver agreement was poor for baseline FHR (kappa=0.44), FHR variability (kappa= 0.18), continue or not? (kappa=0.39), and concerned or not? (kappa=0.26).

Accuracy of visual assessment for the detection of FHR accelerations, decelerations, and estimated baseline compared with computerized FHR analysis was measured by comparing the first assessment of each observer with that of the computer.[10] When the computer detected < two FHR accelerations (a commonly used definition for an abnormal nonstress test), the observers did not agree with the computer one-third of the time. The five observers were highly accurate in assessing the absence of FHR decelerations. However, when they detected FHR decelerations on their first readings, they agreed with themselves only 58.3 percent of the time. When the computer detected FHR decelerations (35% of FHR tracings), observers saw zero deceleration > 90 percent of the time, indicating that the observers failed to recognize most FHR decelerations detected by the computer.

Figure 1, A through D, represents examples of FHR tracings during which agreement or disagreement between the computer and the observers was present in the detection of FHR decelerations. In one tracing (Figure 1A) , all observers agreed with the computer. In contrast, Figure 1B illustrates a typical example of the 26 FHR tracings (74.3% of tracings with computer-detected FHR decelerations) during which small variables in decelerations occurred usually detected by the computer but not by the observers, causing the major source of disagreement between the computer and the observers. Figure 1C and 1D illustrate two examples during which the computer or observer may have difficulty in establishing the baseline FHR as a result of the absence of low heart rate variation caused by almost continuous fetal activity or a state of wakefulness. As a result, on one occasion the

FIGURE 1



Four examples of 30-minute computer-analysed FHR tracings during which agreement or disagreement between computer and observer was present in detection of FHR decelerations. Upper arrows, FHR accelerations; lower arrows, FHR decelerations; dotted line, basal FHR. Reprinted with permission of Mosby Year Book (Am J Obstet Gynecol 1993;168:842-7).

computer recognized three FHR decelerations, although none of the observers detected them. During interpretation of another FHR tracing (Figure 1D), one observer who identified five decelerations was concerned about the tracing, but the computer recognized only one small FHR deceleration. It is, therefore, becoming evident that the poor level of accuracy in the different components used for interpretation of FHR tracings is responsible for the low interobserver agreement seen in such simple judgement-related questions as the decision to continue or to stop FHR recording. A second conclusion is that fetal behavioural state 4F (active wakefulness), characterized by large and long-lasting FHR accelerations frequently fused into sustained tachycardia, may be interpreted as a markedly abnormal tracing by an observer. We recently reported an erroneous computer interpretation of an FHR tracing as being "flat decelerative" with normal FHR variability due to the same phenomenon of fetal wakefulness.[11]

FETAL REST-ACTIVITY CYCLES

In the term human fetus, gross body movements (GBM) are closely associated with increases in the fetal heart rate (FHR) or accelerations.[12-16] In the premature fetus, the association between FHR accelerations and GBM is not as strong, with a large proportion of accelerations being less than 15 bpm in amplitude. Similarly, in the sheep fetus, 89 percent of FHR accelerations are associated with skeletal muscle activity. The majority of FHR accelerations (~60%) persist after neuromuscular blockade, suggesting that GBM and FHR accelerations occur together as a result of central neuronal output affecting both the cardio-accelerator fibres and the motoneurons simultaneously.

Episodic alternance between high FHR variability and low FHR variability typical of antepartum FHR tracings persists throughout labour. As decreased FHR variability is often quoted as an indication for fetal scalp sampling and is also typical of fetal quietness, it is important to determine how long is enough to wait when the fetus is in a quiet state before starting to be concerned.

Spencer and Johnson[17] using visual assessment of intrapartum FHR tracing, and Dawes *et al.*[18] using computerized FHR analysis reported the longest episode of low FHR variability in healthy fetuses to be 90 minutes. It seems reasonable, therefore, to use this value of 90 minutes as a minimum cut-off point for length of observation of a flat FHR tracing during labour to differentiate between the fetus in a normal state of quietness and one that is possibly in distress and requiring active intervention, for example, fetal scalp sampling.

INTRAPARTUM FHR MONITORING AND PREDICTION OF FETAL ACIDOSIS

Based on animal and human studies, it is usually accepted that by using continuous electronic FHR monitoring, most of the fetuses developing metabolic acidosis during labour would be detected.[19,20] However, the Dublin randomized clinical trial demonstrated that only 15.6 percent of FHR abnormalities were associated with fetal acidosis with continuous FHR monitoring compared to 16.3 percent with intermittent auscultation.[21] These observations demonstrated the poor predictive value of FHR abnormalities for intrapartum fetal asphyxia. Spencer and Johnson,[17] using criteria of reduced FHR variability (baseline oscillation <5 bpm), reported a positive predictive value for the detection of intrapartum acidosis of only 32 percent. Using a more sophisticated computerized FHR analysis, Dawes *et al.*[18] were unable to demonstrate a significant correlation (r=.04) between FHR variability during the last hour of FHR monitoring before delivery and umbilical arterial base deficit.

Subsequent observations by Pello *et al.*[22] failed to demonstrate a difference in baseline FHR, the number of FHR accelerations, the number of FHR decelerations with or without slow recovery, the area under the curve of FHR decelerations as recorded during the last hour of FHR tracing in fetuses born with either a normal pH, mild acidaemia, or moderate/severe acidosis. In only one out of 12 women delivered by Caesarean section for fetal distress, the umbilical artery base deficit was greater than 11 mmol/L, so the clinical diagnosis of fetal distress was not associated with severe acidaemia. Late FHR decelerations were of poor value (~30% positive predictive value) in predicting fetal acidaemia. There were no typical FHR patterns that could help to differentiate the acidotic from the non-acidotic fetus. However, gestational age and other physiological variables that could influence FHR reactivity were not taken into account.

ALTERATIONS IN BEHAVIOURAL STATES

In order to obviate the difficulties caused by the behavioural states and the alternance between episodes of rest and activity of the healthy fetus on FHR monitoring,

OTC SHOWCASE

several unsuccessful external stimuli to alter fetal behavioural states and FHR variability have been tried, including an external source of light, external manipulation of the fetus, and maternal ingestion of glucose. However, significant and reproducible alterations in fetal behaviour have been reported following vibro-acoustic stimulation (VAS).[23] Usually, an increase in FHR occurs following external VAS. This FHR response increases with advancing gestational age and with increasing intra-uterine sound pressure levels reached during stimulus. In contrast, during the progression of labour, after rupture of membranes, and in the presence of intra-uterine growth restriction, FHR response to VAS is reduced. In addition, the amplitude of FHR response to VAS is inversely related to the pre-stimulus baseline and is, therefore, of limited value in the presence of fetal tachycardia.

During labour, four different patterns of FHR response to VAS have been described,[23] including:

1. a prolonged period of acceleration (s) of >15 bpm for > three min;
2. one or more FHR accelerations of >15 seconds' duration;
3. a biphasic response with acceleration(s) followed by a prolonged FHR deceleration;
4. no FHR response or an FHR deceleration.

The overall positive predictive value of an abnormal FHR response for fetal distress during labour was <50 percent if the previous FHR pattern was not taken into account.

Intrapartum studies evaluating the relationship between FHR response to acoustic stimulation and fetal scalp pH used similar stimulus and the same criteria to define an adequate FHR response. Currently available data suggest the following.

1. The presence of an FHR acceleration following VAS during labour is associated with a fetal scalp pH >7.20 approximately 98 percent of the time. Occasionally, a normal FHR response can be seen in a fetus with significant metabolic acidosis.
2. The absence of an FHR acceleration following VAS during labour is a poor predictor of fetal metabolic acidosis, and should be followed by fetal scalp sampling to confirm the metabolic status of the fetus. If fetal scalp sampling cannot be done, the usual criteria of fetal distress using FHR patterns should be used to decide if immediate delivery is indicated or not.

CONCLUSIONS

It is becoming increasingly evident that one of the major causes of misinterpretation of FHR tracings is the spontaneous change in fetal behavioural state that is a normal feature of a healthy human fetus. Growth-restricted fetuses also have an inherently low FHR variability when compared to normally-grown human fetuses which would make the interpretation more difficult, in addition to the changes seen with gestational age.[4,24] Visual interpretation of FHR tracings has been clearly shown to be unreliable. It is, therefore, possible that all the randomized clinical trials assessing the value of FHR monitoring in predicting the fetal metabolic status were doomed to fail due to the unreliability of visual interpretation. In order to use electronic FHR monitoring, it is becoming necessary for the clinician to start learning the physiology of the fetus, its changing evolution with advancing gestation, and the various ways that these are represented in FHR tracings under stress or distress. With the development of computerized FHR analysis that virtually eliminates inter-observer and intra-observer variation in interpretation, and the knowledge of the factors influencing FHR, it is now possible and timely to conduct a properly designed large-scale randomized clinical trial to demonstrate whether or not both antenatal and intrapartum FHR monitoring can ultimately become useful tools in obstetrical practice.

REFERENCES

1. Thaker SB. The efficacy of intrapartum electronic fetal monitoring. Am J Obstet Gynecol 1987;156: 24-30.
2. Prechtl HFR, Akiyama Y, Zinkin P, *et al.* Polygraphic studies of the full-term newborn. I. Technical aspects and qualitative analysis, London, Heinemann. In: Ban MCO, MacKeith RC (Eds). Studies in Infancy (ed. 6). Clin Dev Med 1968;27:10-21.
3. Nijhuis JG, Prechtl HFR, Martin Jr. CB, *et al.* Are there behavioural states in the human fetus? Early Hum Dev 1982;6:177-95.
4. Gagnon R, Hunse C, Fellows F, *et al.* Fetal heart rate and activity patterns in growth-retarded fetuses: changes after vibratory acoustic stimulation. Am J Obstet Gynecol 1988;158:265-71.
5. Smith CV, Nguyen ITN, Phelan JP, *et al.* Intrapartum assessment of fetal well-being: a comparison of fetal acoustic stimulation with acid-base determinations. Am J Obstet Gynecol 1986;155:726-8.

6. Low JA, McGrath MJ, Marshall SJ, *et al.* The relationship between antepartum fetal heart rate, intrapartum fetal heart rate, and fetal acid-base status. Am J Obstet Gynecol 1986;154:769-76.
7. Borgatta L, Shrout PE, Divon MY. Reliability and reproducibility of nonstress test readings. Am J Obstet Gynecol 1988;159:554-8.
8. Lotgering FK, Wallenburg HSC, Schouten HJA. Interobserver and intraobserver variation in the assessment of antepartum cardiotocograms. Am J Obstet Gynecol 1982;144:701-5.
9. Hage ML. Interpretation of nonstress tests. Am J Obstet Gynecol 1985;153:490-5.
10. Gagnon R, Campbell K, Hunse C. A comparison between visual and computer analysis of antepartum fetal heart rate tracings. Am J Obstet Gynecol 1993;168:842-7.
11. Gagnon R, Bocking AD, Richardson BS, McLean P. A flat decelerative fetal heart rate tracing with normal fetal heart rate variability. Am J Obstet Gynecol 1994; 171:1379-81.
12. Patrick J, Campbell K, Carmichael L, Natale R, Richardson B. Patterns of human fetal breathing during the last 10 weeks of pregnancy. Obstet Gynecol 1980;56:24-30.
13. Richardson B, Natale R, Patrick J. Human fetal breathing during the last 10 weeks of pregnancy. Obstet Gynecol 1979;133:247.
14. Patrick J, Campbell K, Carmichael L, Natale R, Richardson B. Patterns of gross fetal body movements over 24-hour observation intervals during the last 10 weeks of pregnancy. Am J Obstet Gynecol 1982;142:363-71.
15. Natale R, Nasello C, Turliuk R. The relationship between movements and accelerations in fetal heart rate at 24 to 32 weeks' gestation. Am J Obstet Gynecol 1984;148:591-5.
16. Bocking AD, Harding R, Wickham PJD. Relationships between accelerations and decelerations in heart rate and skeletal muscle activity in fetal sheep. J Dev Physiol 1985;7:47-54.
17. Spencer JAD, Johnson P. Fetal heart rate variability changes and fetal behavioural cycles during labour. Br J Obstet Gynaecol 1986;93:314-21.
18. Dawes GS, Rosevear SK, Pello LC, *et al.* Computerized analysis of episodic changes in fetal heart rate variation in early labor. Am J Obstet Gynecol 1991;165:618-24.
19. Murata Y, Martin CV, Ikenoue T, *et al.* Fetal heart rate accelerations and late decelerations during the course of intrauterine death in chronically catheterized rhesus monkeys. Am J Obstet Gynecol 1982;144:218-22.
20. Low JA, Cox MJ, Karchmar EJ, *et al.* The prediction of intrapartum fetal metabolic acidosis by fetal heart rate monitoring. Am J Obstet Gynecol 1981;139:299.
21. MacDonald D, Grant A, Sheridan-Pereira M, *et al.* The Dublin randomized controlled trial of intrapartum fetal heart rate monitoring. Am J Obstet Gynecol 1985;152:524-39.
22. Pello LC, Rosevear SR, Dawes GS, *et al.* Computerized fetal heart rate analysis in labor. Obstet Gynecol 1991;78:602-10.
23. Gagnon R. Stimulation of human fetuses with sound and vibration. Semin Perinatol 1989;13:393-402.
24. Murotsuki J, Bocking AD, Gagnon R. Fetal heart rate patterns in growth-restricted fetal sheep induced by chronic fetal placental embolization. Am J Obstet Gynecol 1997;176:282-90.