Thirty years of electronic intrapartum fetal heart rate monitoring: discussion paper

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The development of electronic intrapartum fetal monitoring

A United Kingdom survey by Gillmer and Combe in 1979[1] confirmed that intrapartum fetal monitoring had by that time become an established part of labour ward routine. The principal mode of monitoring (which remains the same today) was by the continuous measurement and plotting of fetal heart rate, usually with simultaneous measurement and plotting of uterine activity. This method is called cardiotocography, and requires fairly sophisticated electronic machines to perform it. Because these machines became widely available only some 15 years ago, it is sometimes erroneously concluded that intrapartum fetal monitoring is a recent phenomenon. Goodlin, however, in his 'History of fetal monitoring'[2] noted that auscultation of fetal heart tones began early in the 19th century and that in the late 19th century fetal heart rate (FHR) decelerations were noted to be associated with fetal distress. Also, by that time, the mechanisms leading to fetal bradycardia were fairly well understood in terms of our present knowledge. As early as 1893, Winckel had set out clinical criteria for intrapartum fetal distress based on upper and lower limits for basal FHR, 'irregularity' of FHR, and the passage of meconium in vertex presentation; also included was undefined alteration in fetal movements. These clinical criteria have withstood the passage of time and are also accepted as clinical pointers to fetal distress today.

Intermittent auscultation of the fetal heart during labour became widespread and routine practice during the first half of the 20th century. Although many advances were made in the practice of obstetrics, these were mainly concerned with the improvement of maternal morbidity and mortality rather than fetal morbidity and mortality, and the practice of intermittent auscultation of fetal heart tones continued unchanged for the whole of this period.

By the beginning of the second half of the 20th century, medical advances, such as blood transfusion and antibiotics, had simplified the treatment of maternal life-threatening complications and contributed substantially to the continued decline in maternal mortality, and so more interest was taken in fetal outcome. An example of this may be found in one of the widely used textbooks of the times[3] which discussed the results of the Perinatal Mortality Survey of 1958. At that time the perinatal mortality rate was 33.2 per thousand; anoxia during labour accounted for about 31% of all stillbirths, 44% of the mature ones and nearly 9% of the early neonatal deaths. The authors commented: 'Here is a major area for effort and research. Better methods of recognizing fetal distress are badly needed and perhaps a readier recourse to Caesarean section.' It is pertinent to note, however, that the same textbook contains no reference to intrapartum fetal monitoring in the discussion of the management of labour, not even recommendations about auscultation of the fetal heart.

In 1958, Hon[4] proposed that the use of electronic techniques for the continuous evaluation of FHR in labour would permit a more accurate indication of fetal distress than clinical methods (of intermittent auscultation). In a simple assessment of the accuracy of FHR counting by auscultation, he demonstrated that 15 obstetricians had a wide range of counts of a known (simulated) rate with an error rate of up to 30%. Hon suggested that electronic methods would be more accurate and would enable comparison of heart rate changes with uterine activity. A continuously plotted fetal heart rate recording was shown to yield more information than the 30 s average usually obtained by auscultation. By comparing intrapartum FHR patterns with fetal outcome (using Apgar scores), Hon determined the normal FHR pattern, and also attempted to define the significance of both transient and persistent fetal bradycardia. These patterns were summarized in 1963 into a formal 'Classification of fetal heart rate.'[5] The limits of normal baseline FHR were defined, and the pattern of variation (early, late, sporadic, etc.) were categorized, thus laying the foundations for current continuous intrapartum FHR monitoring practice.

The work of Hon, his description of FHR patterns, and his physiological and clinical interpretation of them, became universally accepted. The principles he established govern current practice of fetal heart rate monitoring; his work became accepted for two main reasons: firstly, other workers confirmed his findings and, in particular, correlated them with the biochemical state of the fetus; and secondly, electronic technology advanced sufficiently to permit the mass production of machines which could continuously record fetal heart rate. The term 'fetal monitor' was first used for such machines by Paul and Hon[6] in 1970 and this has now been taken into general use. The availability of fetal monitors on a commercial basis, their ease of use, and apparent clinical benefit, meant that many maternity units had the opportunity of assessing their value in terms of fetal outcome.

Clinical application of intrapartum fetal monitoring

In a relatively small series of 306 cases, Simmons and Lieberman[7] found no change in overall perinatal mortality when cardiotocography was introduced, but they had already been using fetal scalp blood

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sampling when fetal distress was suspected. They did feel that cardiotocographic patterns changed before significant changes in fetal blood pH occurred, but that fetal blood sampling remained the most accurate denominator of fetal hypoxia. Shenker *et al.*[8] reported the outcome of 2411 labouring patients, of whom 88% had been monitored. They attributed the decrease in intrapartum stillbirths of 1.2/1000 live births over a 4-year period to the increased use of fetal monitoring, and strongly recommended that all patients be monitored in labour. Tutera and Newman[9] monitored 608 cases, of which 96% were considered high risk: a significant rise in caesarean section rate occurred, but they thought that 107 caesarean sections were avoided by the use of fetal monitoring. In addition, there was a dramatic decrease in the perinatal mortality rate in these cases. Again, the use of fetal monitors was recommended for all patients. In 1975 Edington *et al.*[10] also advocated that all patients be monitored. In their review of the first 2 years of intrapartum fetal monitoring, there was a fall of the perinatal mortality rate from 15.8 to 11.7 per 1000 births, and there were no intrapartum stilbirths. The incidence of caesarean section in their review fell from 9.7 to 5.89%. Amato[11] also reviewed the effect of fetal monitoring during a 2 year period. His patients were in two groups, monitored and unmonitored; each group contained both high risk and normal cases. Amato found that fetal monitoring was clearly of value in the normal case, and that definite advantages existed when high risk cases were monitored. Hon *et al.*[12] reviewed not only the obstetric outcome after normal or abnormal FHR patterns, but also related these to neonatal heart rate patterns. It was suggested that when FHR variability was lost, and this loss persisted into the neonatal period, respiratory distress syndrome was much more likely.

The consensus from these early series was, therefore, that continuous FHR monitoring was of great value. It appeared to be the complete answer to be problem of intrapartum morbidity and mortality. Low *et al.*[13,14] looked specifically at the relationship of FHR deceleration patterns to clinical outcome in high risk cases, such as the preterm fetus, the growth retarded fetus, maternal toxaemia and mid-forceps delivery. Where abnormal FHR patterns were marked, these were of particular value in the prediction of intrapartum asphyxia in such cases. The diagnosis of fetal asphyxia was confirmed by acid-base assessment at delivery. Odendall[15] also noted that abnormal FHR patterns were more likely with growth retarded fetuses, which in turn had lower Apgar scores than normal.

It can thus be seen that the initial research work suggested that continuous intrapartum FHR monitoring could predict intrapartum fetal asphyxia, and subsequent trials in clinical practice were associated with a marked reduction in fetal morbidity and mortality. The technique accordingly was received with enthusiasm by most clinicians, if not least because no new concepts were involved - fetal monitors merely automatically noted fetal heart rates that previously had been manually recorded after auscultation. Continuous FHR monitoring in labour came to be thought of as an infallible method of detecting fetal asphyxia, and somehow even the act of attaching a machine to the patient would confer a protective status.

Reappraisal of intrapartum fetal monitoring

Inevitably, disenchantment soon followed as it became apparent that the method did suffer from limitations and was not infallible, and a strong challenge to the efficacy of electronic fetal monitoring was made by Banta and Thacker in 1979[16]. They concluded that it had low predictive value, was of high cost to the individual and society, and had been prematurely diffused into routine clinical practice. In some ways they were probably correct; as the method appeared to be merely an improved method of FHR counting (as had traditionally been carried out by auscultation), too much reliance had been placed on deviations from a normal rate being indicative of fetal jeopardy or even impending demise. The direct effect of this approach to fetal heart rates was an undoubted excessive intervention rate in many labour rooms. When yet another baby had been operatively delivered, because it was thought to be in great danger, and then found to be in perfect health, it was not surprising that the 'monitor' was given the blame.

In reality, of course, the machine is not a monitor at all. Crawford *et al.*[17] made the point that, in most cases, it is merely a recorder, as a monitor is a machine which observes incoming data and then takes action (e.g. rings an alarm) when appropriate. With a fetal monitor, the monitoring is usually carried out by the attending staff. Moreover, even at the early stage in the introduction of the technique to clinical practice, the evidence about its limitations had been put forward, and yet it seems the evidence was overlooked by many clinicians then, and possibly by some today. As early as 1971, Beard *et al.*[18] warned that generalizations had to be made in the interpretation of FHR patterns, and that, even in the worst case situation of baseline tachycardia, loss of FHR variability, and late decelerations, only half of the babies were actually acidotic. Saldana *et al.*[19] found that variable decelerations were frequently seen (nearly 50% incidence) in FHR patterns, and these did not necessarily indicate fetal asphyxia. This incidence was far greater than the incidence of detected cord entanglement, though variable decelerations were traditionally held to be due to cord compression. Late decelerations were related to low Apgar scores, and a highly significant relationship was found between poor neonatal outcome and fetal acidosis. However, there was no correlation between FHR patterns and fetal acidosis. It was concluded that FHR patterns were 'best used as an alarm system of fetal difficulty than as an absolute measure of fetal distress'. Tejani *et al.*[20] correlated FHR patterns with fetal outcome and found, in 200 cases, that ominous FHR patterns were associated with depressed one minute Apgar score in only 37% of cases, whereas a fetal scalp blood pH of 7.20 or less gave an accurate prediction of neonatal depression in 88% of cases. They concluded that ominous FHR patterns gave a false positive prediction of fetal acidosis and neonatal depression in 50% of cases. It was considered that fetal blood sampling with pH measurement provided the most objective evidence of fetal hypoxia and expected neonatal condition. Liu and Blackwell[21] found that although FHR patterns could indicate fetal hypoxia, they could not reliably indicate fetal reserve to stress. They also recommended fetal blood sampling to used as the final arbiter of fetal welfare.

There was also a suggestion that the apparent benefits from introducing FHR monitoring to a

hospital population may have been purely due to enthusiasm of those undertaking the research. In 1978 Johnstone *et al.*[22] examined this possibility in a non-research population (Aberdeen). In the two years preceding fetal monitoring, the labour-related fetal death rate was higher than in the two years following its introduction. However, the fall in deaths due to asphyxia was not statistically significant. There was a decline in low one-minute Apgar scores over the same period, but the five minute scores remained the same. It was concluded that morbidity may have been reduced by the introduction of fetal monitoring, but that the number of babies saved from death because of monitoring was small - perhaps one in 1000 deliveries. Nevertheless, in their opinion, this figure still justified the use of fetal monitoring.

Controlled trials of fetal monitoring

In 1978, Wood[23] discussed the difficulties of assessing FHR monitoring even when using controlled trials. He reviewed two such published trials, one of which found a clear advantage for FHR monitoring, and the other no difference, when comparing monitored and non-monitored groups. Wood suggested that FHR monitoring may be advantageous only in the high risk situation, but advocated further controlled trials. Kelso *et al.*[24] undertook a prospective randomized study of 504 low-risk patients. Each was assigned to a monitored or non-monitored group; no beneficial or deleterious effect of continuous FHR monitoring was shown and both groups delivered babies with symptoms of asphyxia. Mueller-Heuback *et al.*[25] suggested that very large numbers of patients are necessary to compare monitored and non-monitored groups. They found, in their large series, when corrected for variables such as changes in obstetric practices, that the incidence of stillbirths and intrapartum asphyxia was lower in the monitored patients of 1977 than the non-monitored patients of 1970.

More recently, several large scale prospective randomized controlled trials of continuous electronic intrapartum fetal monitoring, versus intermittent auscultation, have been carried out. The two largest, (the Dublin trial[26], and the Dallas trial[27]) both contain groups of several thousand patients. These trials, and the other smaller ones, have been comprehensively reviewed by Prentice and Lind[28], who noted that only 2 of the 8 trials concluded that continuous electronic FHR monitoring was more beneficial than intermittent auscultation. In all the trials operative deliveries were higher in the continuously monitored group, but no improvement was demonstrated in the usual measures of outcome including cord pH values and five minute Apgar score. With this evidence, Prentice and Lind had little option but to endorse earlier calls[16,23] to return to traditional methods of monitoring (by auscultation), at least in low risk cases. Thacker[30] also carried out an assessment of the trials and applied rigorous statistical criteria to them. Only one, the Dublin trial, was evaluated to be of a high standard, but pooling of the data from the smaller studies did not demonstrate any significant change in their individual results. Apart from the Dublin trial indicating that the use of electronic fetal monitoring decreases the incidence of neonatal seizures, (and this finding was analysed in depth), Thacker concluded that the trials did not demonstrate that continuous electronic FHR monitoring is a useful screening procedure for all women in labour.

Discussion

The main problem with electronic intrapartum FHR monitoring, of course, is that the technique is not sufficiently robust to alert labour attendants to poor fetal condition or otherwise. In departments where there is a strong research interest, it is possible to achieve reasonable levels of sensitivity and specificity for moderate and severe acidosis[30], but, unfortunately, even in well run prestigious units it is all too easy for results to be less good. In Oxford, Sykes *et al.*[31] found that the diagnosis of fetal distress by continuous FHR monitoring usually was not associated with severe acidosis or low Apgar scores, yet continous FHR monitoring 'did little to improve the precision in predicting which infants would be borne in an adverse condition'. Similar results have also been recently published by Van den Berg *et al.*[32].

In the face of all the evidence, the judgement could be that continuous electronic fetal monitoring should be abandoned altogether. Even if this became the established view, there might be severe medico-legal problems in so doing, for it is here that obstetricians and midwives face the greatest irony of all. Continuous FHR monitoring, as argued above, has severe limitations in the prediction of fetal condition; the work of Sykes and Van den Berg have shown that the outcome is often the opposite of that which has been deduced from the FHR tracing. Because the limitations have not been sufficiently publicized, however, the lawyers are now able, with the power of hindsight, to pillory anyone on the basis of fetal heart rate patterns which in another case may have been associated with good fetal condition. Because of the omnipresent medico-legal threat, it is hardly surprising that the slightest aberration in the FHR tracing is often seen as a reason for operative intervention, even though the fetus may be in good condition.

Should the recommendation to monitor only high risk cases, leaving low risk cases to intermittent auscultation, then now be followed? Despite the many strong views put forward in support of this, it may nonetheless not be correct. Two arguments may be ranged against it. The Dublin study found a decrease in neonatal seizures in their monitored babies, compared with the non-monitored babies. Whilst it is true that the long-term significance of seizures in the neonate is not known, common sense suggests that they are probably best avoided. However, Thacker (a strong advocate of selective monitoring) advises caution in the interpretation of the Dublin results because clinical practice in Dublin may be very different from that in the United States. This is unfair; a large survey of all the randomized trials of FHR monitoring must take all of the outcome findings into account irrespective of where they were carried out, and, in addition, the Dublin trial was said to be the best designed of all those studied. The other large trial, in Dallas, did not show any differences between monitored and unmonitored babies, but closer inspection of the trial does show some differences in method. Firstly, no fetal blood sampling was performed, yet there has always been clear evidence that interpretation of FHR tracings is extremely unreliable without it[20,21]. Secondly, in the non-monitored group, auscultation was not carried out by Pinard's stethoscope, but by a hand-held Doppler unit. The latter has considerable advantages in the evaluation of fetal heart rate when compared to the traditional method of auscultation, particularly during

a contraction, and therefore cases of fetal distress could have been detected which otherwise might not have been.

The second argument against a policy of selective monitoring is that the arguments in favour contain a certain amount of illogicality. What is effectively being said is that continuous electronic fetal monitoring has limitations, that FHR pattern are subject to misinterpretation, and that the predictive value of the technique as applied in most labour rooms is less than desirable - in short, that electronic fetal monitoring is not very good, and therefore should not be applied to cases where the baby is likely to be born in a healthy condition. If this argument (for selective monitoring) is followed to the logical conclusion, it then turns upon itself; if electronic fetal monitoring is sufficiently poor not to be applied to low-risk cases, how can the technique possibly be justified in high risk cases where there is much more at stake?

A further aspect to the debate between those advocating selective monitoring and those advocating 'monitoring for all' lies in the analysis of what is really being said by both sides, for both agree that counting fetal heart rate during labour can give the observer a guide to fetal condition. However, both electronic fetal monitoring and intermittent auscultation are methods of counting fetal heart rate. As discussed above, there is no difference in what is being done except that the electronic machine automatically measures FHR and then records it, whereas in intermittent auscultation, the counting and recording are done manually. Moreover, a fetal monitor will continuously record the heart rate; in any given time, more heart rate counts are available. In other words, continuous electronic fetal monitoring will give much more information about fetal heart rate than intermittent auscultation. If counting fetal heart rate is a useful method of monitoring fetal condition then, accordingly, a method which gives the most information must be superior and should logically be offered in all cases, not just high risk. Of course, some patients may prefer not to be monitored electronically. That should be their choice, but in the light of the above arguments, obstetricians and midwives should not delude themselves, or their patients, that intermittent auscultation is a superior method of deriving fetal heart rate data, for it never can be. The problem of electronic fetal heart rate monitoring in labour to date is that obstetricians and midwives have been thoroughly inept at using the increased FHR information given for the benefit of the patient and the fetus.

Perhaps too much is being asked of fetal heart rate counting. At best, and by whatever method derived, it lacks the precision to differentiate between the normal and the hypoxic fetus that is so desirable in the modern labour room setting. Because of this, many research groups have been exploring alternative methods of fetal monitoring; these have been reviewed elsewhere[33] and they may be divided into biochemical methods and biophysical methods. The biochemical methods include continuous measurement of pH, P_{O_2} or P_{CO_2}. These methods all have the disadvantage of measuring the fetal condition at its periphery and through the skin: because skin blood flow may vary due to factors other than overall fetal condition, the results so far have been conflicting. Biophysical methods evaluate central events in the fetus in the hope that these will reflect fetal condition. Fetal heart rate monitoring is a biophysical method, as is the measurement of fetal cardiac electromechanical intervals, fetal electroencephalography, and fetal electrocardiography. Of these, (apart from FHR monitoring), the latter is the easiest to perform, provided the correct equipment is available, since the fetal ECG is available from any standard fetal electrode. The conventional view of fetal electrocardiography, established over 20 years ago[34] is that it is of little value in assessing fetal well-being. However, subsequent work with animals[35] and humans[36] has challenged this. Symonds[37] has proposed that fetal electrocardiography, using a real-time computer of advanced design, may offer a new direction in fetal monitoring. Shortening of the PR interval, and an inversion of the normal positive relationship between the PR and RR intervals, have been found to be early indicators of fetal stress, with ST segment and T-wave changes being later indications of fetal asphyxia. Continuing work in fetal electrocardiography has shown that the subject is worthy of much further evaluation and is now proceeding in several centres.

Conclusion

Electronic fetal monitors were introduced in an attempt to improve the evaluation of fetal condition in labour. Unfortunately, the results of their use have been disappointing, and because clinicians have been unable to interpret recordings in an unbiased fashion, there have been many calls to limit their use to high-risk cases. This, however, is illogical. Electronic fetal monitors give more information about fetal heart rate than intermittent auscultation, but clearly much more work is needed to improve our understanding of fetal heart rate patterns and their significance.

It is important that there is not an over-reaction to the failure of electronic monitoring to attain the results initially expected of it. Unfortunately, the failure has convinced some obstetricians, midwives, and patients, that technology should be banished from the labour room completely, but this would surely be a retrograde step. The failure of the technique should not close our minds to other monitoring methods which may be superior. These should be evaluated and accepted if proved to be so; a new and better method is desperately needed. In the meantime, our use of continuous electronic fetal heart rate monitoring in labour may be considerably improved if the guidelines, published by the International Federation of Gynaecology and Obstetrics (FIGO)[38], were strictly followed.

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