History
Development of Intrapartum Surveillance of the Fetus

In the approximately 50 years of clinical use of continuous electronic fetal heart rate (FHR) monitoring, it is a remarkable fact that widespread consensus on interpretation and management of FHR patterns has not yet been reached. In this chapter we examine the role of personalities, politics, and territoriality, which at least partially explains the difficulty in achieving such agreement.

The fetal heart rate was first detected electronically in 1906 by Cremer, but a systematic approach to recording and analyzing the beat-to-beat variation over time was not developed until the late 1950s, by Edward Hon and his collaborators, working at Yale University. Hon recognized and named the average FHR baseline, FHR variability, and he identified three types of decelerations. He also proposed theories for the mechanisms underlying these patterns and carried out various studies that had results supporting the theories. Hon was working with scalp electrodes (originally a metal Michel skin clip that was soldered to a connecting wire) and continuous depiction of FHR patterns on a Gilson Recorder, which was a huge vacuum tube–based device taller than he (Figure 1-1). The original recordings were on a logarithmic vertical scale, which were subsequently changed to an arithmetic scale. The paper speed that he selected was 0.5 mm/sec, hence the origin of today’s conventional paper speed of 3 cm/min.

Hon subsequently began a remarkably fruitful collaboration with E.J. “Ted” Quilligan, Chair of the Department of Obstetrics and Gynecology at Yale University (Figure 1-2). The two men moved to Los Angeles County/University of Southern California Medical Center in the late 1960s.
to carry out intensive studies in FHR with the aid of a research delivery room. The room was equipped fully for physiologic monitoring, processing blood gasses, and archiving all of the data; the approximately 15,000 births per annum that occurred in this institution allowed the data from one woman's labor and birth to be studied intensively each day. An army of obstetric fellows were introduced to research in this venue.

Roberto Caldeyro-Barcia performed additional studies of the mechanisms of FHR characteristics and made further empirical observations of newborn outcomes related to the various FHR patterns.\(^3\) Caldeyro-Barcia, an articulate and urbane Uruguayan, spoke perfect English and was well known in obstetric circles in the United States and Europe. Meanwhile Hammacher and coworkers in Germany were establishing the clinical importance of FHR variability, particularly in the antepartum period.\(^4\)

During this same time period, Erich Saling in Germany was developing the technique for fetal blood gas analysis. The English language edition of Erich Saling’s book *Foetal and Neonatal Hypoxia in Relation to Clinical Obstetric Practice* was published in 1968.\(^5\) The translator, F.E. Loeffler, of St Mary’s Hospital, London, understatedly noted that “...some of the views expressed by Dr Saling ... are rather unorthodox...,” but our interest is drawn to his couple of pages, out of a total of 281, that are devoted to continuous FHR pattern monitoring. Saling illustrated decelerations, which included nomenclature espoused by both Hon and Quilligan\(^2\) and Roberto Caldeyro-Barcia et al.,\(^3\) and commented that “...monitoring of the foetal heart rate will probably not prove sufficiently reliable for accurate assessment of the foetus,” because “…the factors influencing the foetal heart rate are too numerous to allow accurate conclusions. ...” He briefly mentioned his fellow countryman, Hammacher, but omitted Hammacher’s noting the importance of FHR variability, which he called “oscillation.” Hammacher’s work was poorly known in the United States because he wrote only one English-language paper.\(^4\)

Also in 1968, in the United States, Hon published a monograph entitled *An Atlas of Fetal Heart Rate Patterns* (Figure 1-3) that summarized his previous publications and contained theories on the mechanisms from the earliest days of FHR monitoring.\(^2\) It was published by Harty Press, in New Haven, CT. Unfortunately, it is a poorly known work, possibly because it is plastic bound, quarto size, with pages duplicated rather than printed, and was prone to disintegration. Nevertheless, Hon was established as the major figure in FHR monitoring.

Despite all this productivity, there were some aspects of Hon’s work that were not universally accepted. His attractive well-known triptych of (1) early decelerations (head compression); (2) late decelerations (uteroplacental insufficiency); and (3) variable decelerations (umbilical cord compression) is a case in point. Hon’s early study that related early decelerations to head compression was performed by pressing a metal pessary against the presenting fetal head. The illustration in the resulting paper depicted what is clearly a variable deceleration, with an onset to nadir of the deceleration of less than 10 seconds (Figure 1-4).\(^6\) However, later illustrations of this work in Hon’s published papers characterized early...
decelerations as smooth, rounded decelerations that looked like late decelerations that had not yet become “late” in timing rather than the variable deceleration that his direct head compression with the pessary actually generated (Figure 1-5). This error has led to a persistent and common misimpression that early decelerations are gradual in onset and rounded, rather than abrupt, and some writers have even endowed them with other properties such as retained FHR variability, nadir being less than 20 bpm below the baseline, and a benign significance. Incidentally, there had been much previous work, particularly from Germany, demonstrating that sufficient compression of the fetal head results in a variable deceleration (Figure 1-6). Nevertheless, it was widely accepted that head compression causes early decelerations, variable decelerations are due to umbilical cord compression, and late decelerations are secondary to uteroplacental insufficiency as a result of insufficient uterine blood flow, resulting in fetal oxygen deprivation. The prevailing beliefs in the United States stressed the hazards of late decelerations without emphasizing the fact that FHR variability is the important FHR characteristic that modifies the adverse significance of late decelerations. At that time the use of ancillary testing was believed to be adequate to weed out the “abnormal” FHR tracings that were falsely positive. The most popular technique was fetal scalp blood sampling for measurement of pH and base excess. This reliance on fetal blood sampling, which never achieved popularity in community hospitals in the United States, lasted until 1985, when Clark and Paul from Los Angeles County/University of Southern California showed that a huge reduction in the use of fetal blood sampling did not result in an increase in newborn infant morbidity in their institution. These authors noted that an obstetrician’s need for fetal blood sampling is in inverse proportion to his or her understanding of FHR pattern interpretation, and that focusing on FHR variability and accelerations is more appropriate.
In 1975, Paul et al. published a most important reanalysis of many of the earlier FHR recordings from Yale. In this publication the authors classified three gradations of late decelerations based on their depth, and dichotomized late decelerations based on whether they had “average” or “reduced” FHR variability. These authors convincingly demonstrated that fetal scalp pH decreases with the depth of decelerations and that this decrease is even more striking if reduced FHR variability is also present (Figure 1-7). The mean pH was $7.09 \pm 0.05$ SD in the presence of severe late decelerations with reduced variability, when the FHR nadir was 45 bpm below baseline or more.
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Figure 1-6 The fetal response to 30 seconds of pressing the fetal head against the sacral promontory is a rapid drop in heart rate. It has a similar appearance to the variable decelerations often seen in the second stage of labor. Reproduced with permission from Rech W. Untersuchungen über die Herzätigkeit des Fetus. III. Die Wirkung des Kopfdruckes auf die Frequenz des fetalen Herzschlages. Arch Gynaecol. 1933;154:47-57. With permission of Springer.

Figure 1-7 Fetal blood pH related to severity of late decelerations and FHR variability. This figure contains unique data from an analysis of FHR tracings, collected before the significance of these patterns was clear. Note that the 28 fetuses with reduced variability and severe late decelerations had a mean pH of 7.09. In this study reduced variability included what is now termed undetectable and minimal FHR variability. Reproduced with permission from Paul RH, Sudar AK, Yeh S, Schifrin BS, Hon EH. Clinical fetal monitoring. VII: the evaluation and significance of intrapartum baseline FHR variability. Am J Obstet Gynecol. 1975;123:206-210.

uniqueness of these data are all the more so because they had 28 fetuses in the group with reduced variability and severe late decelerations. Those studies will never be repeated because it would now be unethical not to intervene when the FHR pattern has reduced variability and recurrent severe late decelerations. It is now accepted that this FHR pattern confers too high a risk of severe fetal acidemia, and if recurrent, will evolve into a worse pattern.
In the 1970s, an attempt was made to reconcile the independent observations of Hon, Hammacher, and Caldero Barcia during a meeting in Europe, which resulted in a degree of standardization. The major unreconciled difference was in the paper speed; 3 cm/min became the standard in the United States, and 1 cm/min became the standard in Europe. When viewed by a practitioner trained with the faster paper speed the slower paper speed exaggerates the apparent FHR variability.

The first randomized controlled trial (RCT) comparing continuous FHR monitoring with intermittent auscultation was published in 1976 by Havercamp et al. The varied interpretation and management of FHR patterns used in the many RCTs following Havercamp's is one of the reasons these studies and their conclusions were controversial and indeterminate. Subsequent RCTs and meta-analyses found that fetal heart rate monitoring did not improve newborn outcomes, with the exception of a decrease in early neonatal seizures, and was associated with a significant increase in cesarean sections.

Despite all this activity and dissection of FHR patterns, agreements about interpretation of the FHR tracing (i.e., the relationship between an FHR pattern and fetal or newborn acidemia), and management recommendations (i.e., how to manage the woman's labor based on the FHR pattern to avoid newborn acidemia) were slow in coming. Efforts were made by the International Federation of Gynecology and Obstetrics, the Royal College of Obstetricians and Gynaecologists, the Society of Obstetricians and Gynaecologists of Canada, the Royal Australian and New Zealand College of Obstetricians and Gynaecologists, and others, but none achieved widespread international consensus.

In the mid 1990s the U.S. National Institute of Child Health and Human Development (NICHD) began a series of meetings with 18 experts to gain consensus on FHR monitoring. One of the aims of the first NICHD Research Planning Workshop was to develop a consensus for FHR pattern management. The effort failed because of the inability of the 18 participants to reach agreement about the specifics of management. However, the group did successfully define and assign nomenclature for the various FHR patterns and established a terminology for each FHR characteristic, which has been widely accepted in the United States and elsewhere.

The final NICHD document ended with a “Clinical Statement,” which defined the normal FHR as a baseline rate of 110 to 160 bpm, FHR variability of amplitude 6 to 25 bpm, and absent decelerations. The group concluded that fetuses with this FHR pattern were not at risk for damaging acidemia. The document also defined an FHR pattern in which the fetus is at high risk of potentially damaging acidemia, which included absent FHR variability in the presence of decelerations or bradycardia. All other patterns between these were relegated to a zone of “no consensus.”

In 2008 the NICHD reconvened an expert panel to revise the 1997 recommendations. The 1997 nomenclature was reconfirmed, terminology for uterine activity was included, and the three interpretative groupings of the 1997 document became the three categories (I, II and III), with category II being termed “indeterminate.” One might surmise that no progress had been made in subcategorizing the FHR patterns that are most frequently observed, those in category II, in the previous 11 years.

In 2005 and 2009, American College of Obstetricians and Gynecologists (ACOG) published Practice Bulletins and accepted the FHR nomenclature of the 1997 NICHD workshop and the three interpretive categories of the 2008 NICHD meeting. The reaction of clinicians including perinatologists, obstetricians, midwives, and nurses to the three categories of the 2008 NICHD publication has been substantial, and not necessarily supportive. The excessive heterogeneity of category II has been noted by many authors, and the impossibility of using this category for management recommendations has been problematic.
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A number of authors have compared outcomes following use of the 3-category system or a 5-tier system that is based on the relationship between specific FHR patterns and the risk of acidaemia. The 5-tier system also includes the risk that a pattern will evolve to one with a higher risk of acidaemia as labor progresses. It is well recognized that the FHR undergoes a recognizable evolution as acidaemia develops.

Meanwhile, in the midst of the reaction to the NICHD categories, ACOG put out a further Practice Bulletin in 2010, which presents an algorithm that ends in eight separate interpretative/management categories based on FHR variability, presence or absence of accelerations, and the type of deceleration present. This Practice Bulletin clearly has the makings of recommendations for management, and in each of the categories it notes that the presence of normal FHR variability modifies one’s management of the pattern. However, this latest ACOG schema does not appear to be a major step in simplification of management for the physician, midwife, or nurse on the front line.

Meanwhile, under the encouragement of the Japan Society of Obstetrics and Gynecology, the 5-tier color-coded FHR interpretation and management system was enthusiastically accepted in Japan. It has penetrated widely to many Japanese birth units, and data on effectiveness are being established. One small study showed a seven-fold reduction in the incidence of metabolic acidaemia (pH < 7.1 and base excess of umbilical arterial blood at birth ≤ –12 mEq/L) with no significant change in cesarean or vacuum extractor delivery rates. Subsequent analysis showed that this reduced metabolic acidaemia was due to a reduction in the number of fetuses who had variable, prolonged, and late decelerations and bradycardias. This implies that the 5-tier system with its rigid emphasis on standardized nomenclature and classification allowed better selection of those patients who needed intervention for fetal indications.

Further support for the effectiveness of the 5-tier system of interpretation and intervention is seen in an analysis of almost 2500 newborn infants with variable outcomes. The incidence of metabolic acidaemia and encephalopathy at birth were related to both the degree and duration of FHR-tracing abnormality, as described in the 5-tier system. Another study that compared the analysis of five FHR experts who used strict rules for the interpretation of the 5-tier color-coded system showed remarkable agreement amongst the experts in examination of the last 3 hours before birth of 30 fetuses. Further support for the need for a greater expansion, or reclassification of category II will be found in Chapter 9.

The current remarkable activity on the part of many organizations and individuals in the field of fetal heart rate monitoring, interpretation, and management suggests that we are finally within reach of achieving consensus on management algorithms in the coming years. This will be a highly desirable first step towards testing these approaches for effectiveness.

References


