



Electronic Monitoring of the Fetus*

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Although the fetal electrocardiograph (FECG), was recorded earlier in this century, utilization of the electrical activity of the heart for fetal assessment is really a procedure of approximately the last two decades. This has come about primarily through the work of Dr. Ed Hon in Southern California and Dr. Roberto Caldeyro-Barcia in Montevideo. Early attempts to obtain signals were made from the maternal abdomen, but they were frustrated by problems of noise either from the maternal heart or from the muscles of the abdominal wall. The advantages of working in the vagina—it strikes me as strange that this should take so long to occur to an obstetrician—is an insight of the last decade, resulting in the placement of an electrode on the fetal scalp, rather than on the maternal abdomen, with a vast improvement in the signal-to-noise ratio and reliability. At the present time, the main use of the electrical activity of the heart obtained through such an electrode is to drive a heart rate-sensing device to give the fetal heart rate which is then used to indicate fetal status. Much speculation has been made as to whether or not the FECG is a more sensitive indicator of fetal status than the heart rate, but that question is unresolved, and there is certainly a good deal of evidence to indicate that such is not the case. The fetal electrocardiograph obtained from the maternal abdomen can be used to detect fetal life, multiple pregnancies, and it can be extracted from the background noise by means of computer averaging techniques in order to study the electrical signal itself.

The concept utilized in electronic monitoring of the fetus is that the application of a stress to the organism in question (feto-placental unit) will produce a response which allows assessment of status prior to the production of permanent damage. For-

unately, there is a physiologic situation in which there is stress to the organism—namely labor. The steady-state of exchange across the placenta, which characterizes pregnancy and is adequate to allow not only survival of the fetus but also growth, is normally terminated by labor, a process which deletes part of the time available for exchange. Through the work of Dr. Hon, studies of the implication of fetal heart rate changes observed during labor became much clearer.

It has been pointed out that much of the methodology used in medicine at present is not fully understood. The results are, therefore, not always satisfactory; but the alternative to applying incompletely understood methodology is to deny a patient a modality of diagnosis or therapy which may be of substantial benefit. In the case of electronic monitoring of the fetus, an attempt is made to intercept a pathological process before the more clearly defined end points of irreversible damage occur. That fact in itself raises the need for much sharper criteria of jeopardy at a point of reversibility.

Labor imposes a period of temporary hazard, the main component of which is related to a loss or diminution of exchange across the placenta. (One must also be mindful of the hazard to the fetus which can be imposed by antenatal medication.) Exchange across the placenta is adversely affected by a variety of conditions:

1. *Obstetrical catastrophies* such as abruptio placentae, placenta previa, and uterine rupture which usually cause disruption of the intervillous space and sheering off of a part or all of the placenta.
2. *Hypotension and hypovolemia* whether due to compression of the vena cava, hemorrhage, or epidural anesthesia, reduce the uterine blood flow.
3. *Uterine hypertonus* whether due to oxytocin stimulation, toxemia, or idiopathic

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results in a decreased net perfusion pressure of the placenta and a decreased uterine diastole.

4. *Mechanical interference* with the umbilical cord may occur either as a total event with prolapse or, as is more commonly found, with contractions. Surprisingly, intermittent cord compression may be well tolerated, although it requires close vigilance and preparation for possible operative delivery.
5. *Maternal vascular insufficiency* such as may be encountered with chronic hypertension, long standing diabetes, or toxemia, lowers the uterine blood flow and hence, the availability of oxygen and nutrients to the fetus.

The methodology is as follows. Stress is measured by means of a pressure transducer connected to the amniotic sac by a fluid-filled catheter. The response of the fetus is measured by means of a heart rate meter which is driven by the FECG signal obtained through an electrode attached to the fetal scalp. These two parameters are measured and displayed by a Corometrics[†] fetal monitor which was designed by Dr. Hon. The experience at the Medical College of Virginia has demonstrated this unit's reliability, which is a prime factor in our choice of it. The electronic circuitry is digital so that if the machine is working, it can be expected to give correct answers. Heart rate and intra-amniotic pressure are simultaneously displayed, and the chart patterns are used to predict compromise.

The development of more precise instrumentation for evaluating fetal heart rate patterns has brought with it the necessity of inventing a more precise vocabulary to describe the various aspects demonstrated by the new methodology.

1. *Bradycardia* is a decrease in the baseline of the heart rate.
2. *Tachycardia* is an increase in the baseline heart rate.
3. *Acceleration* is a periodic increase in the fetal heart rate.
4. *Deceleration* is a periodic depression of the heart rate.
5. *Irregularity* is a variation from the baseline heart rate and is characteristic of the fetus who retains homeostatic mechanisms.
6. *Period changes* are the ones which are of

interest in predicting fetal jeopardy. The periodicity is related to the uterine contraction.

Three patterns emerge from the extensive work of Dr. Hon which could be correlated with physiologic events. The first of these is called *early deceleration* and is characterized by a deceleration in the fetal heart rate which occurs with the onset of uterine contraction. The change tends to mirror the uterine pressure curve and may be abolished by the use of atropine. This type of change implies no alteration in the acid-base status and has a good prognosis. It may, however, be quite marked as will be demonstrated in Fig. 1. The second pattern is that of *late deceleration*, and it is associated with utero-placental insufficiency. This type of deceleration has a late onset with respect to the onset of the uterine contraction; in fact, the onset of the deceleration is often at or beyond the acme of the uterine contraction. It is frequently associated with an elevated fetal heart rate and may not fall below 100 beats per minute. This type of deceleration is related to anoxia and is connected with markedly depressed infants in significantly high statistics. The ability to pick up this type of deceleration is one of the distinctive advantages of continuous electronic monitoring. The third type of deceleration pattern is labeled *variable deceleration*, and it is believed to be due to compression of the umbilical cord. It is variable with respect to the onset of the uterine contraction and tends to be variable in shape. It may have either a "fractured" configuration or a deep U-shape. This pattern is the typical one leading to cesarean section for fetal distress. Cord compression, while it may have dire implications, is usually well tolerated, at least in the initial phases. The cord compression pattern appears also to be vagally mediated and is susceptible to marked modification by the use of atropine. At this point I would like to say that when the cord is clamped at birth, physiologic adjustments are required to compensate for that part of the cardiac output which would normally go to the placenta (about 50–60% of the fetal cardiac output). These adjustments which take place about the time of the first breath result in the alteration of the fetal heart from the parallel arrangement to a series configuration. This alteration cuts the cardiac output in half, and incorporates the lung as an organ through which all blood must pass.

Now let us look at some specific illustrations of the various cord patterns and indicated therapy. Figure 1 illustrates some of the problems of moni-

[†] Corometrics Medical Systems, Inc.

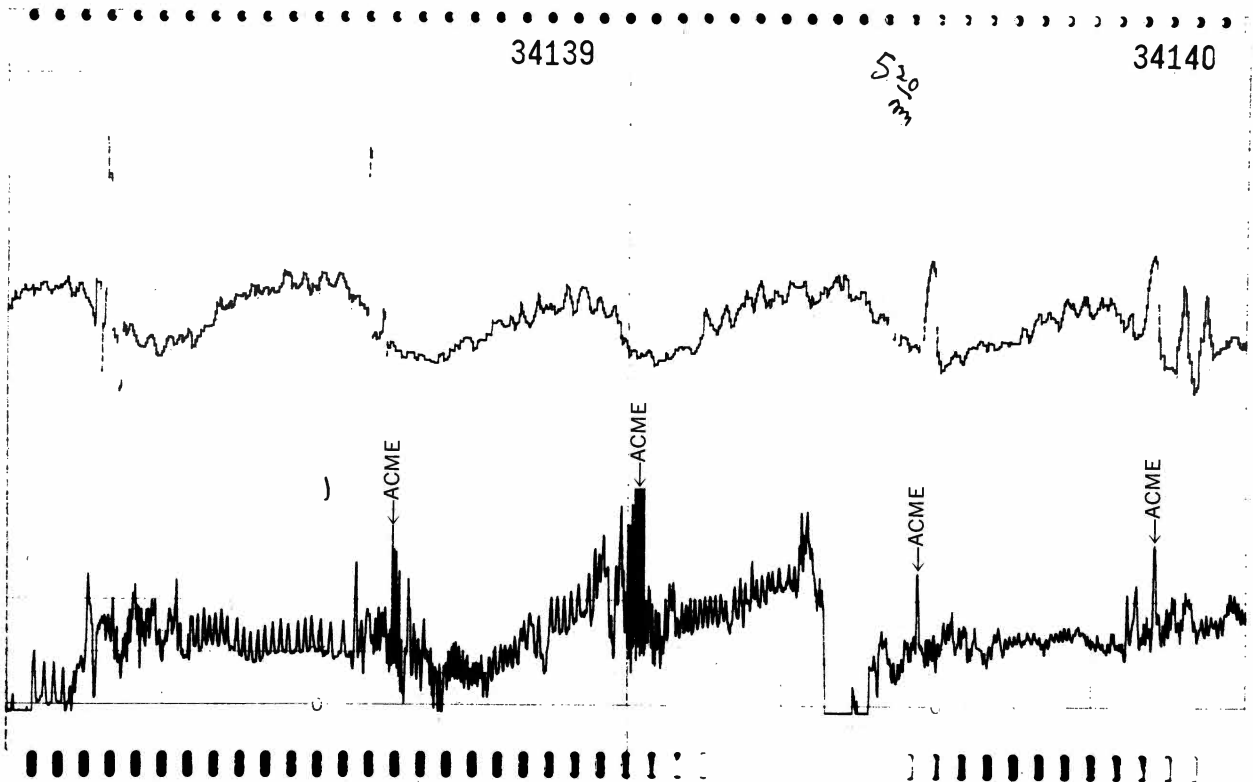


Fig. 1—Fetal heart rate tracing of early deceleration. There was no evidence of depression at birth.

toring the pressure from the abdomen as well as demonstrating marked early deceleration due to compression of the fetal heart. This tracing was recorded with the father present in the labor room. He had expressed a strong interest in having this monitoring equipment used on his wife when she was in labor. After application of the scalp electrode it was noted that there were falls to levels of 80 beats per minute or less with every contraction. However, the acmes of both the deceleration and the uterine contraction occurred approximately simultaneously. The prediction was that the baby would show no evidence of depression, and such was the case.

Figure 2 is that of a patient with Rh disease who went into spontaneous labor at 35 weeks after an amniocentesis. The fetal heart rate tracings show marked deceleration with contractions which are interpreted as the variable type due to cord compression. Since this was a high-risk baby, I would have had to deliver this patient by cesarean section if I had not had the instrumentation to precisely monitor the fetus during her labor. In spite of the fetal heart rate tracings, I was required to watch the patient during a labor lasting several hours,

following which she delivered a baby without evidence of depression. The normal delivery was best for the mother and for the baby, but it was certainly harder on the physician.

Figure 3 shows an instance in which the physicians managing the patient did not understand the significance of fetal heart rate tracing. This episode occurred in our early experience at M.C.V. In addition to marked late deceleration, frequent premature contractions are also noted. This infant died while preparations were being made for cesarean section after the physicians had been watching this pattern for a prolonged period of time.

It should be pointed out that not every fetus will observe the same degree of reserve, so that some infants will exhibit utero-placental insufficiency with relatively mild uterine contractions, whereas other fetuses will exhibit very little response to even marked hypertonus.

Figure 4 is included to show a tracing which was presented in one of our obstetrical conferences. It is typical of the longer tracing which should always be consulted for evidence of progression with passage of time. The pattern is that of variable de-

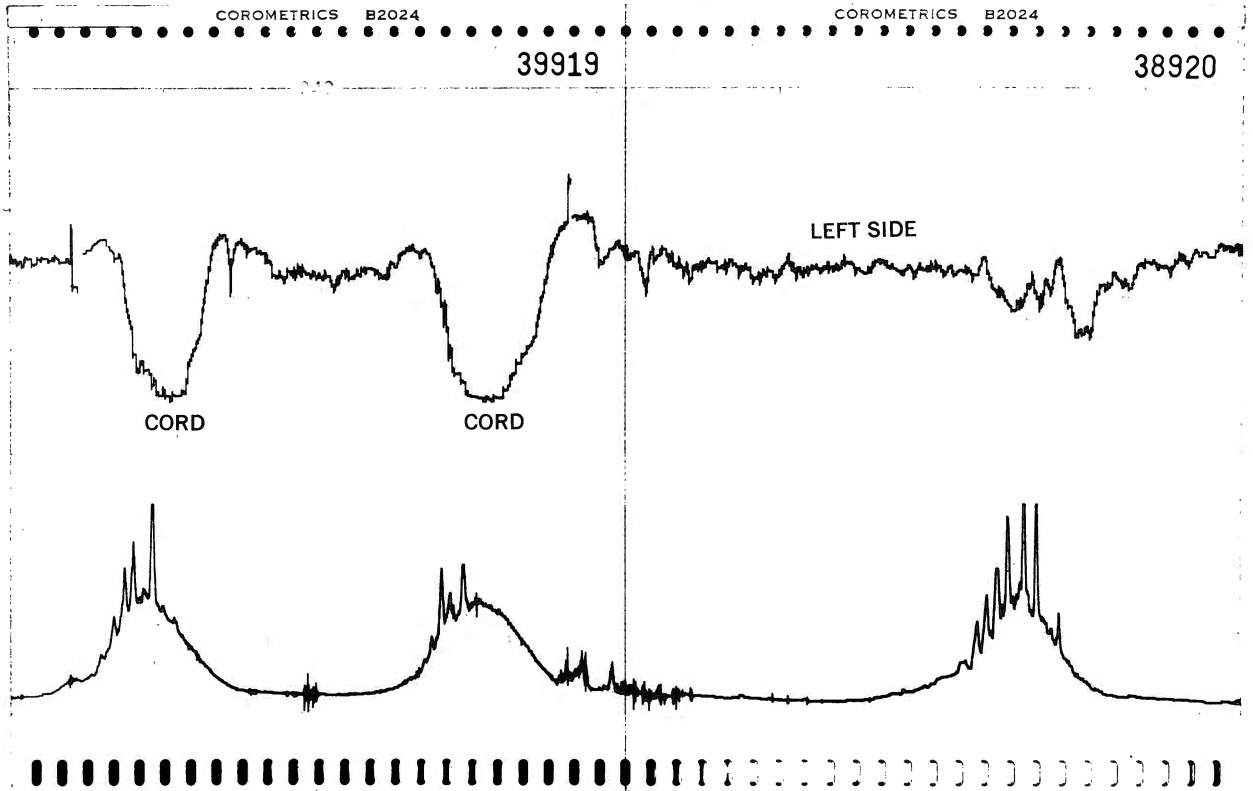


Fig. 2—Fetal heart rate tracing of mild variable deceleration. There was no evidence of depression at birth.

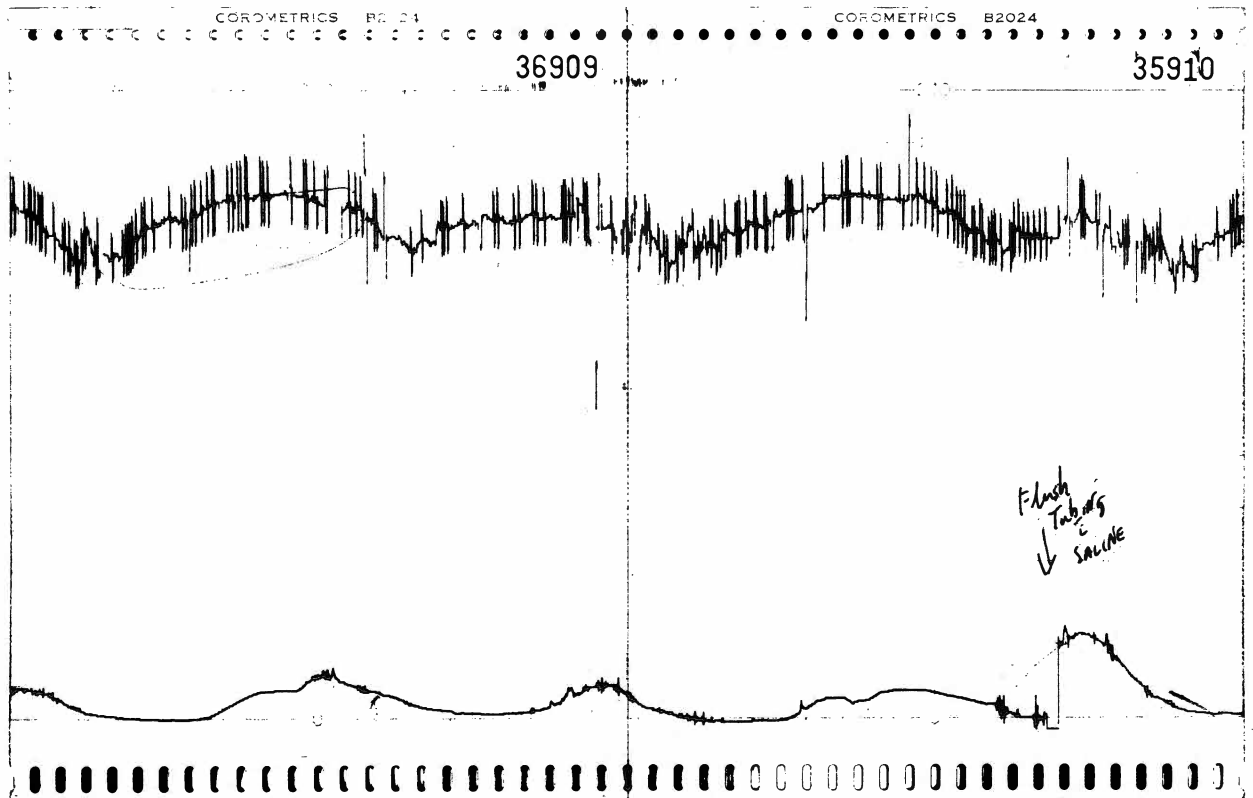


Fig. 3—Fetal heart rate tracing of severe late deceleration. The fetus died in labor.

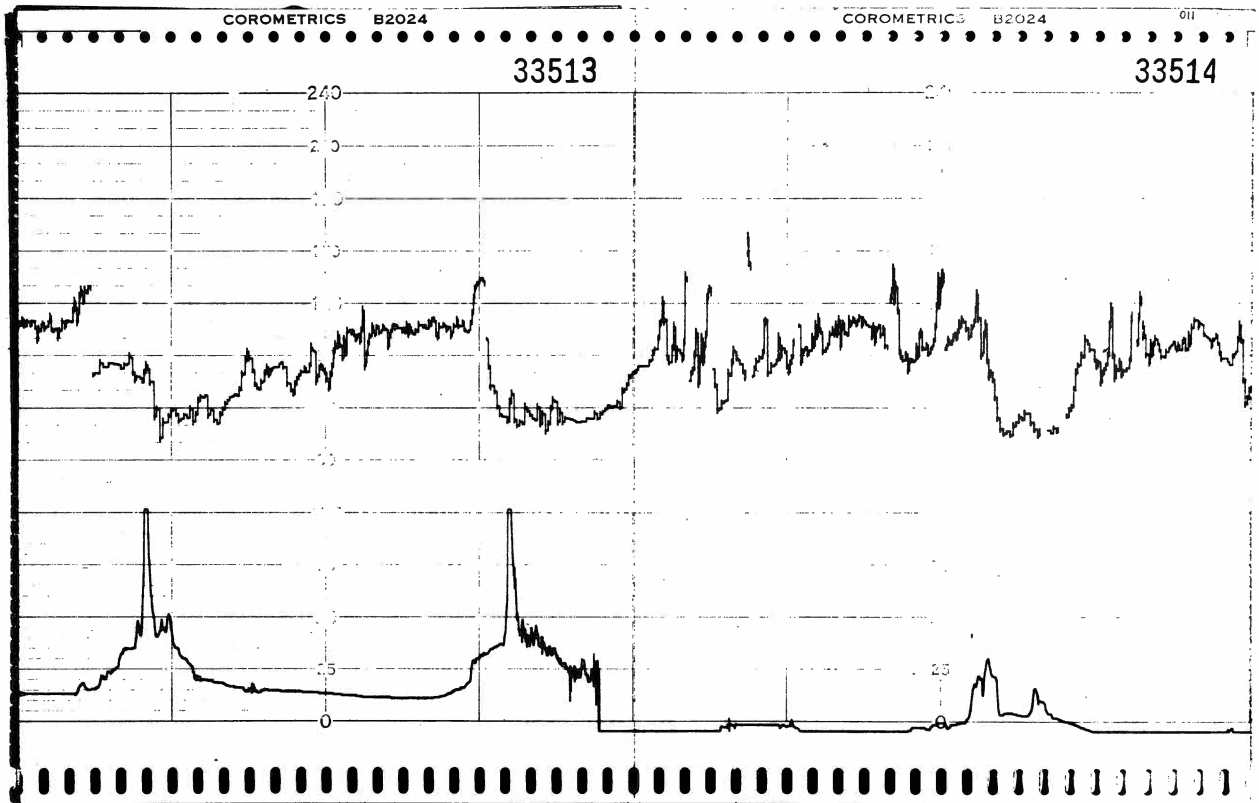


Fig. 4—Fetal heart rate tracing of variable deceleration from tight umbilical cord. There was no evidence of depression at birth.

celeration with a rounding off of the shoulder of the recovery phase. By following this pattern, we saw that there was a prolongation of recovery most consistent with a progressive cord problem. The infant delivered before evidence of anoxia appeared in the chart, without evidence of depression. There was as predicted, a tight cord around the neck.

While I feel that the technology required for electronic monitoring of the fetus has reached a degree of development adequate for clinical use, a few words of caution seem to be in order.

1. The emotions of the obstetrician are treated much more roughly than previously since he is committed to a vigilance which may last several hours in contrast to simply performing a cesarean section which might or might not be of benefit to the mother and fetus.
2. The instruments are only slightly more fool-proof than the obstetricians using them and do have weak links; for example, an integral part of the units utilized at M.C.V. is a Statham® strain

gauge. Over a period of 6 weeks, about twelve hundred dollars' worth of these strain gauges were rendered inoperable by improper technique—an occurrence that has not been unique to M.C.V.

3. Reading the tracings requires an active interest and practice which appears to make it difficult to establish the technique in a new hospital unless someone is there to instruct the obstetricians in the technique and to act as a back-up consultant.
4. External monitors and accessories to convert present monitoring units to external monitoring are beginning to appear which will increase acceptability of electronic monitoring. These instruments generally work on the Doppler principle which is utilized in most well-known instruments such as the Doptone® to detect the fetal heart. Though this type of instrumentation has been demonstrated here, we have not seen any which we

consider sufficiently reliable to consider abandoning the use of the scalp electrode. Probably, reliable external monitoring equipment will become generally available in the next two years.

5. The insertion of the amniotic catheter is troublesome and requires some practice. The catheter usually can be inserted and does give accurate measurements of the labor. Monitoring the labor from the abdomen is not as satisfactory. It gives only a rough estimate of intensity and no indications of changes in baseline pressure.
6. The present reliable instrumentation requires rupture of the membranes, which may not always be acceptable. Dilatation of 3–4 cm is also required for easy application and insertion.

What are the benefits?

1. Treatment is made on a more exact diagnosis. It is very true that at this stage the information extracted is relatively crude and that the mechanisms of the changes and their implications for long-term survival and function are only incompletely understood. But the presence of compromise in labor is more accurately

predicted than by other methods of assessment. Most of us will see this method of evaluating the fetus become routine for both high-risk and routine labors.

2. The use of electronic monitoring encourages the obstetrician to consider the implications of labor to both the mother and the fetus, rather than just as a period of time which must be passed before an attempt is made to deliver a baby, at whose condition we can only guess.

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