Signal ambiguity resulting in unexpected outcome with external fetal heart rate monitoring

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Electronic fetal monitors have evolved greatly in the last several decades, allowing accurate recording of the fetal heart rate (FHR) with an external Doppler transducer with much less signal loss than was present in the earlier products. This improved sensitivity has resulted in decreased use of the internal fetal scalp electrode and greater reliance on the external transducers.

In this article, we report a confusing situation which may occur during external fetal monitoring in which the fetal signal is replaced by an alternative signal from the mother or a second fetus without the usual recognizable transition associated with such signal source shifting. This masks the condition of the fetus without the attending staff being alerted to the loss of fetal signal. In approximately 10,000 deliveries, we have encountered 5 examples of unexpected adverse fetal outcome attributable to this signal ambiguity. We have also seen several cases without adverse outcome.

This report consists of 2 cases illustrating the clinical problem, 2 cases illustrating the probable mechanism, and a table summarizing our adverse neonatal outcomes attributable to this process.

Figure 1 illustrates the monitor tracing immediately prior to delivery of a stillborn infant. This neonate had no respiratory efforts or cardiac response to resuscitation efforts, indicating death at least some minutes before the actual delivery, implying that the heart rate tracing in the minutes before birth is entirely maternal, although the staff had interpreted it as fetal. This tracing demonstrates regular persistent heart rate accelerations during second-stage bearing-down efforts. Figures 2-5 show representative tracings from the earlier parts of the labor demonstrating the expected FHR reactivity of a healthy fetus at the start and typical responses to changing conditions during the labor. The transition to the pure maternal tracing at the end of labor (Figure 1) is not evident at any point in the record, although Figure 5 demonstrates a possible point, evidenced by the shifting baseline. The mother was tachycardic during the last several hours of labor, ultimately with a rate between contractions of 120 beats per minute.

Figures 6-11 illustrate a case in which the shift was detected and steps were taken that resulted in a normal fetal outcome. The tracing is from a healthy multipara laboring spontaneously at term. Examples of the tracing are provided for early labor (Figure 6) and late first stage (Figure 7).

In the second stage, a pattern of repetitive heart rate accelerations began to appear (Figure 8) with some brief discontinuity (data loss) at the start of the accelerations, and this pattern became more obvious and sustained shortly thereafter (Figure 9).

Because of maternal tachycardia, a pulse oximeter was applied and its tracing of the maternal heart rate superimposed precisely on the “fetal” tracing, suggesting that the “fetal” record was actually maternal. A scalp electrode was then placed (Figure 10) and demonstrated that the fetus was experiencing deep variable decelerations where the monitor had previously recorded accelerations. Figure 11 shows a magnified part of the paper FHR tracing showing the maternal pulse oximetry record superimposed on the fetal monitor tracing. The pulse oximetry record revealing the maternal pulse rate does not appear on the electronically stored version of the tracing shown in Figure 10. The abnormal fetal pattern persisted, prompting a cesarean section delivery, resulting in a healthy newborn.

Expanded use of maternal pulse oximetry has provided additional insight into this phenomenon, as shown in the next 2 cases (Figures 12-14 and Figures 15-17). These illustrate what may be the transition event in patients in which the fetus was experiencing variable decelerations that later became replaced by accelerations of probable maternal origin, based on the coincidence with the pulse oximetry tracing. Note that the tracing may shift repeatedly between maternal and fetal signal sources in a way that keeps the final readout in or near the expected physiologic range for a healthy fetus.

The display of maternal heart rate on the fetal tracing is relatively common1 and normally presents no problem because it is easily recognizable due to the
FIGURE 1
Tracing immediately prior to delivery of stillborn infant


FIGURE 2
Early labor, reassuring FHR tracing


FIGURE 3
Diminished variability and late decelerations

FIGURE 4
Improved variability 45 minutes later


FIGURE 5
Shifting baseline with accelerations during pushing


FIGURE 6
Active labor, reassuring FHR tracing (11:30 AM)

FIGURE 7
Continued reassuring FHR tracing (12:30 PM)

FIGURE 8
Start of second stage
Beginning acceleration pattern with pushing and suggestion of discontinuity of tracing (arrows) are shown (2:45 PM).

FIGURE 9
Continued acceleration pattern (3:05 PM)
FIGURE 10
Fetal scalp electrode applied midway through the second contraction on this record

This reveals underlying deep deceleration pattern previously masked (3:15 PM).

FIGURE 11
Magnified portion of paper tracing at time of scalp electrode placement (arrow)

This shows the pulse oximetry tracing superimposed on the fetal monitor tracing. The maternal pulse rate from the pulse oximeter shows as a nearly straight line superimposed on the fetal heart rate tracing.

FIGURE 12
Case showing variable decelerations just prior to second stage

Variable decelerations were replaced by confusing pattern with some data loss

Same case as in Figure 12.

This shows replacement of prior variable deceleration pattern with apparent maternal pattern during pushing

Same case with pulse oximeter added.

Another case showing variable deceleration pattern prior to second stage with some data loss

Maternal pulse oximeter was placed.
FIGURE 16
Pulse oximetry tracing shows apparent transition to maternal pattern during pushing

Same case as above approximately 45 minutes later.


FIGURE 17
Continuation of same case showing more complete transition to maternal pulse with some data loss


TABLE
Case summaries for unexpected adverse outcomes

<table>
<thead>
<tr>
<th>Case</th>
<th>Clinical setting</th>
<th>EFM findings</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Term twins Induction of labor</td>
<td>Alternated between fetuses during late first stage, remaining in normal range until bradycardia recognized in 1 fetus</td>
<td>Emergency cesarean section. One normal newborn and 1 severely acidotic fetus with neonatal death</td>
</tr>
<tr>
<td>2</td>
<td>Postdate induction (case presented in text)</td>
<td>Shifting baseline in early second stage with appearance of fetal heart rate accelerations during pushing</td>
<td>Stillborn, no response to resuscitation</td>
</tr>
<tr>
<td>3</td>
<td>Term, normal pregnancy with spontaneous labor</td>
<td>Fetal heart rate accelerations during contractions appeared during long second stage</td>
<td>Spontaneous delivery Apgar scores 2, 6, 6, 7 pH 6.9 Did well in neonatal intensive care unit</td>
</tr>
<tr>
<td>4</td>
<td>Term, elective induction labor</td>
<td>Gradual transition from fetal heart rate decelerations in second stage to fetal heart rate accelerations</td>
<td>Spontaneous delivery Apgar scores 2, 6, 7 Did well in neonatal intensive care unit</td>
</tr>
<tr>
<td>5</td>
<td>Term, spontaneous labor, planning VBAC</td>
<td>Early second-stage bradycardia transitioned to accelerations during contractions</td>
<td>Spontaneous delivery Apgar scores 2, 6, 8 pH 7.1 Cerebral edema with signs of CNS injury</td>
</tr>
</tbody>
</table>

CNS, central nervous system; EFM, electronic fetal monitor; VBAC, vaginal birth after cesarean.

very different rate and the usual loss of data preceding the transition. However, in these and the other cases we have encountered, transition from the fetal to the maternal signal occurred imperceptibly, in some cases probably several times with minimal to no data interruption. Experienced obstetricians reviewing these cases have been unable to determine the transition points. Therefore, the staff is not alerted to the possibility of misleading data, and the potential for unrecognized fetal distress occurs.

In singleton pregnancies, the most characteristic indication of this problem is the pattern of repeated heart rate accelerations during second stage (Table). Sherman et al\(^2\) have published an analysis of maternal and fetal heart rate patterns in labor and report that mothers typically show accelerations in heart rate while pushing and do not show decelerations. In contrast, fetuses commonly show decelerations with pushing, and almost never show repeated accelerations. Thus, the pattern of repeated accelerations demonstrated by our cases will usually be maternal.

The conditions under which this phenomenon occurs are maternal tachycardia with excursions into the fetal range and simultaneous fetal bradycardia or tachycardia outside the normal fetal range. It appears that when the maternal rate meets typical fetal characteristics and the fetal rate is not typical, the switch may occur. This could be a consequence of the evolution of fetal monitoring transducers, which are now highly sensitive and capable of picking up signals from both mother and fetus simultaneously. Internal discrimination circuitry (logic) determines which signal is displayed as fetal, and when the mother looks more like a fetus than the fetus, the logic may cause a switch in the display.

Sensitivity to these conditions and recognition of the characteristic pattern of recurring heart rate accelerations during second-stage bearing-down efforts are the key factors that should lead to suspicion of this situation, and fetal scalp electrode placement will resolve the question. In twin (or higher-order) pregnancies, the monitor has not only the maternal rate to discriminate but also signals from another fetus. Thus, we believe that fetal scalp electrode placement on the leading twin should be considered to minimize this potential confusion.

Maternal pulse oximetry, especially in second stage, should help eliminate the risk of this confusion, but the pulse rate printout from the pulse oximeter is affected by maternal movement and other factors, limiting its reliability for this purpose. A more precise way to differentiate the recording of maternal heart rate (MHR) from FHR would be to compare the MHR obtained from maternal electrocardiogram (ECG), which is available on some monitors. Ideally, a modification of current monitors would be to obtain the maternal ECG from electrodes mounted on the Doppler and toco transducers. Ongoing comparison could be made electronically as is available on some twin monitors, which alarm when the same twin is being monitored twice. The maternal and fetal signals could then be compared using the same process as is on the twin monitors, and appropriate alarms could indicate when the MHR is being recorded on the fetal tracing.

This problem is not confined to a single manufacturer or model and can be expected from any of the fetal monitors currently being used in hospital settings. We have discussed this with manufacturers and have notified the Food and Drug Administration of this problem. However, until a better technical solution appears, the scalp electrode is the most accurate way to assess the fetal status.

REFERENCES