

Fetal scalp blood sampling

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Abstract

Sampling capillary blood from the fetal scalp during labour of pregnancy, in order to determine its pH, was introduced to obstetric care in the late 1960s.

Despite current scepticism surrounding its utility, most notably in the US, fetal-scalp blood sampling (FSBS) is still considered a useful fetal monitoring test by expert bodies, and continues to be used in obstetric units around the world.

The intended purpose of this review article is to detail the clinical value of FSBS and explain just why, and under what circumstances, knowledge of the unborn baby's blood pH is useful for management of labour of pregnancy.

The technique and associated risks of sampling blood from the fetal scalp will be discussed. The article will also include consideration of the controversy surrounding the utility of the test.

Finally, there will be brief discussion of the notion that it might be preferable to measure lactate concentration of the fetal-scalp blood sample rather than its pH. The article begins with consideration of the rationale for monitoring fetal heart rate during labour.

This is a good starting point for discussion of FSBS, because FSBS is only performed when and if fetal heart rate monitoring gives cause for concern about the condition of the unborn baby.

Fetal heart monitoring detects possible fetal hypoxia

Fetal well-being depends on an adequate supply of oxygen derived from maternal circulation and delivered to the fetus via the placenta and umbilical-cord vein [1].

Uterine contractions decrease placental blood flow and thereby oxygen delivery, so during labour the fetus is physiologically predisposed to reduced oxygen (hypoxia).

Whilst healthy fetuses normally have the metabolic reserve to tolerate the potential transient hypoxia normally associated with labour, there are a number of conditions related to either the mother, placenta or fetus that can have the effect of further reducing oxygen delivery to fetal organs, causing prolonged or severe intrapartum hypoxia; these conditions are listed in Table I.

If sufficiently severe and prolonged, intrapartum hypoxia can result in asphyxia (i.e. hypoxia in association with metabolic acidosis) and consequent possibility of the hypoxia-mediated brain damage known technically as hypoxic-ischemic encephalopathy (HIE) [2].

The damage may be permanent; cerebral palsy is the outcome for some. If brain damage is particularly severe and widespread, HIE can be fatal; it is one of the more common causes of perinatal death.

The principal objective of fetal heart rate monitoring during labour is to detect hypoxia and impending intrapartum asphyxia so that treatment to improve fetal oxygenation can be implemented, or if necessary, urgent operative birth (cesarean section or instrumental vaginal birth) performed, before hypoxia-mediated damage occurs.

Maternal factors	Utero-placental factors	Fetal factors
Maternal hypoxemia due to: <ul style="list-style-type: none"> respiratory disease hypoventilation seizure, trauma smoking 	Excessive uterine activity: <ul style="list-style-type: none"> hyperstimulation by drugs prolonged spontaneous labor placental abruption 	Umbilical cord compression: <ul style="list-style-type: none"> oligohydramnios cord prolapse or entanglement
Maternal reduced oxygen-carrying capability due to: <ul style="list-style-type: none"> anemia carboxy-hemoglobinemia 	Utero-placental dysfunction: <ul style="list-style-type: none"> placental abruption placental infarction/dysfunction marked by intrauterine growth restriction, oligohydramnios or abnormal Doppler studies chorioamnionitis (infection) 	Decreased fetal oxygen-carrying capability: <ul style="list-style-type: none"> significant anemia due to isoimmunization, maternal fetal bleed or vasa previa carboxy-hemoglobinemia (if mother is a smoker)
Decreased uterine blood flow due to: <ul style="list-style-type: none"> hypotension (e.g. shock, sepsis) regional anesthesia maternal positioning 		
Chronic maternal conditions: <ul style="list-style-type: none"> diabetes chronic hypertension SLE antiphospholipid syndrome 		

TABLE I: Conditions that can affect fetal oxygenation [2]

The rationale for this monitoring is based on the fact that reduced oxygen delivery to the fetus affects heart rate, which is normally in the range of 110-160 beats per minute (bpm), with occasional deceleration – to a rate usually no lower than 100 bpm – during uterine contraction.

Many factors other than hypoxia can affect fetal heart rate during labor so that interpretation of the significance of deviation from normal can be problematic if only intermittent auscultation with stethoscope is used to monitor fetal heart rate.

For pregnancies at higher than normal risk of intrapartum hypoxia (which includes those associated with conditions listed in Table I, as well as those in which auscultation of the fetal heart with stethoscope raises cause for concern), intermittent or continuous electronic fetal monitoring (sometimes called cardiocartography) is used to monitor fetal heart rate during labour.

Electronic fetal monitoring (EFM) involves the noninvasive application (strapping) of two transducers to the abdomen of women in labour [3]. The first transducer is positioned to detect the fetal heart and the other to detect pressure of uterine contractions.

The signal from each transducer is converted for continuous real-time display on a paper roll. The cardiocartograph is thus a paper record of the detail of change in fetal heart rate during and between displayed uterine contractions.

Interpretation of EFM tracing (the cardiocartograph) must take into account the baseline heart rate, its variability, and detail of any periods of acceleration (a signal of fetal well-being), or deceleration in heart rate.

In the case of decelerations, it is important to note how they relate to uterine contractions because this will help to determine if they are benign or pathological.

This quite complex assessment allows EFM tracings to be assigned to one of three categories: normal, atypical (intermediate) and abnormal, devised by experts at a National Institute of Child Health and Development

workshop in 2008 [4]. Table II describes how these three categories were defined.

The rationale for fetal-scalp sampling

Electronic fetal monitoring (EFM) has high sensitivity but low specificity for detecting fetal hypoxia/asphyxia [3]. This means that hypoxia/asphyxia can be reliably excluded if EFM trace is normal (NICDH Category 1); in such cases labor can usually be allowed, so long as the trace remains normal, to progress without intervention to normal vaginal delivery.

However, the low specificity of EFM for detecting fetal hypoxia/asphyxia means a high false positive rate. A falsely positive EFM (that is indication of hypoxia in a normally healthy fetus) could result in unnecessary, potentially harmful interventions such as emergency cesarean section or operative vaginal delivery, because it provides false evidence that the fetus is at risk of not surviving in good condition to normal vaginal delivery.

Whilst introduction of EFM in the 1970s led to a small reduction in the incidence of babies being born with hypoxia-related brain injury, it also had the deleterious effect – due to its low specificity for hypoxia – of greatly increasing the rate of cesarean sections [3].

The clinical value of FSBS is that it addresses the problem of low specificity of EFM for detection of hypoxia/asphyxia, and in so doing provides the means for reducing the number of unnecessary cesarean and operative vaginal deliveries, and allowing more pregnancies to proceed through labor to safer, natural vaginal delivery.

FSBS is only indicated if EFM reveals worrying features of intrapartum hypoxia that are not sufficiently severe to warrant immediate delivery [5], which usually means EFM traces that fall into NICDH Category 2.

Under these circumstances a normal fetal-scalp pH result provides reassuring evidence that the fetus is not at immediate risk of hypoxia-related damage and therefore does not need to be delivered urgently.

	NICDH category 1 Normal EFM trace	NICDH category 2 Atypical EFM trace	NICDH category 3 Abnormal EFM trace
Baseline heart rate	<ul style="list-style-type: none"> • 110-160 bpm 	<ul style="list-style-type: none"> • Mild bradycardia (100-110 bpm) or • Tachycardia >160 bpm for >30 minutes but <80 minutes • Rising baseline 	<ul style="list-style-type: none"> • Moderate/severe bradycardia <100bpm • Tachycardia >160 for >80 minutes • Erratic baseline
Variability in baseline heart rate	<ul style="list-style-type: none"> • 6-25 bpm • ≤5 bpm for <40 minutes 	<ul style="list-style-type: none"> • ≤ 5 bpm for 40-80 minutes 	<ul style="list-style-type: none"> • ≤5 bpm for >80 minutes • ≥25 bpm for >10 minutes
Decelerations in heart rate	<ul style="list-style-type: none"> • None or occasional uncomplicated variables or early decelerations (due to uterine contraction) 	Repetitive (≥3) uncomplicated variable decelerations: <ul style="list-style-type: none"> • Occasional late decelerations • Single prolonged deceleration (>2 minutes but <3 minutes) 	Repetitive (≥3) complicated variables: <ul style="list-style-type: none"> • Deceleration to <70 bpm for >60 seconds • Loss of variability in trough or in baseline • Biphasic decelerations • Overshoots • Slow return to baseline • Baseline lower after deceleration • Baseline tachycardia or bradycardia • Late decelerations for >50 % of contractions • Single prolonged deceleration (>3 minutes)
Accelerations in heart rate	<ul style="list-style-type: none"> • Accelerations (i.e. increase in HR >15 bpm for >15 seconds) occurring spontaneously and after fetal-scalp stimulation (if performed) 	<ul style="list-style-type: none"> • Absence of accelerations, even after stimulation 	<ul style="list-style-type: none"> • Absence of accelerations, even after stimulation

TABLE II: National Institute of Child Health and Development (NICDH) categories for interpretation of EFM trace.

If, however, fetal-scalp pH is found to be reduced, fetal acidosis is confirmed. The combination of fetal (metabolic) acidosis and an EFM suggestive of fetal hypoxia is indicative of intrapartum asphyxia, and consequent justification for immediate delivery.

Asphyxia is reduced tissue oxygen (hypoxia) of sufficient severity and duration to cause metabolic acidosis [6].

Metabolic acidosis develops in the context of hypoxia because when tissue cells are severely depleted of oxygen, aerobic metabolism of glucose is compromised, and cells must depend for their function and survival on less effective anaerobic pathways that result in reduced ATP (energy) production and accumulation of metabolic acids (principally lactic acid) [7].

Normal buffering mechanisms are overwhelmed by this acid influx, and pH falls below normal limits.

Interpretation of fetal-scalp blood pH result

Since it would be unethical to perform fetal-scalp sampling on healthy fetuses, a formal study to determine a reference (normal) range for fetal-scalp blood pH has never been conducted.

Instead, interpretation of FSBS results is based on the original data and advice of the German study group, who pioneered fetal-scalp blood sampling in the 1960s [8]. This group devised the fetal-scalp pH cut-off values that define “normal”, “pre-acidosis” and “acidosis” listed in Table III below.

Sampling blood from fetal scalp – the technique [11]

Sampling of fetal-scalp blood depends on visual access and can therefore only be performed during labour after rupture of the membranes and dilatation of the

cervical os to greater than 3 cm. The procedure can be performed with the patient in either the lithotomy or left lateral position.

A specialized cone-shaped tube containing a light source (called an amnioscope) is passed via the vagina and lip of the cervix to the fetal head with the narrow end of the amnioscope “cone” resting against the presenting part of the scalp to be sampled. A sponge passed via the amnioscope with the aid of forceps is used to clean the illuminated scalp surface.

A spray of ethyl chloride to the scalp is sometimes used to enhance blood flow, and silicon grease is applied directly to the scalp to contain blood flow into a droplet. A specialized fetal-scalp blade approximately 2 mm in length is used to make a quick stab-like clean incision of the scalp, and blood is collected from the resulting formed droplet into a 100 µL heparinized capillary tube; blood flows naturally into the tube by capillary action.

It is important that the blood is collected from the centre of droplets to prevent air contamination of the sample. (The presence of air bubbles within the sample

Fetal scalp blood pH	Interpretation	Recommended action [9, 10]
≥7.25	Normal	Continue EFM monitoring: <ul style="list-style-type: none"> Repeat FSBS in 1 hour if EFM abnormality that prompted FSBS persists Repeat FSBS sooner if EFM trace worsens If EFM reverts to normal pattern, then no repeat FSBS is necessary
7.21-7.24	Pre-acidosis	Continue EFM monitoring: <ul style="list-style-type: none"> Repeat FSBS within 30 minutes Urgent delivery should be considered if a trend of pH reduction is evident, or EFM trace worsens
≤7.20	Acidosis	<ul style="list-style-type: none"> Fetus should be delivered immediately by either instrumental vaginal delivery or urgent cesarean section

TABLE III: How to interpret FSBS result

represents a source of in vitro analytical error for pH measurement).

Depending on blood flow it may be possible to fill more than one capillary, but a half-filled capillary (blood volume 50 μ L) would be ample for the determination of pH using most modern blood gas analyzers.

The collected capillary sample needs to be passed to an assistant immediately after sampling so that the capillary can be sealed and the contained blood mixed with a magnetic “flea”.

This ensures maximal heparin anticoagulation, and avoidance of microclots that could block the sample path of the analyzer and thereby prevent analysis. It is obviously vital for clinical effectiveness of FSBS that the sample be analyzed immediately.

To arrest scalp bleeding after sampling, pressure should be applied with a sponge to the scalp wound and maintained through two uterine contractions. Before withdrawal of the amnioscope, the wound should be observed for signs of bleeding for a further two contractions; occasionally further pressure on the wound is required.

Sources of error leading to either falsely increased pH (masking possible acidosis) or falsely decreased pH (possible false diagnosis of acidosis) are:

- Contamination of blood sample with air (falsely increased pH)
- Contamination of blood sample with amniotic fluid (falsely increased pH) [12]
- Sampling blood from an area of scalp affected by edema – “caput” (falsely decreased pH) [13]

Study of fetal-scalp blood sampling

Anecdotally, FSBS is sometimes reported to be a procedure that is difficult to perform and painful. These issues were formally addressed by two studies [14, 15].

The main finding of the most recent [14] was that FSBS is generally well tolerated by women who have received epidural analgesia but may be painful for those who have not.

Obstetricians do not generally find the procedure difficult to perform according to this study. Women are more likely to feel pain and obstetricians more likely to find the procedure difficult if the cervix is minimally dilated (<7 cm) and/or the fetal head has not yet descended to the ischial spine.

From a study of 100 consecutive attempts to obtain a fetal-scalp sample by “middle-grade doctors”, Tufnell *et al* [15] determined that the median time from decision to perform the test to receipt of result was 18 minutes (interquartile range 12-25 minutes).

In 9 % of cases the time interval was more than 30 minutes. The extent of cervical dilatation was found to be a determinant of this time interval; the test took longer for women whose cervix was minimally dilated compared with those who were close to being fully dilated.

Failure to obtain a fetal-scalp sample, despite repeated attempts, occurred in 11 (11 %) cases; a median time of 26 minutes elapsed before the test was eventually abandoned in these 11 cases.

Risks/contraindications of fetal-scalp sampling

Although fetal-scalp sampling is considered a generally safe procedure [16], it is invasive and associated with low risk of haemorrhage [17] and transmission of maternal infection to the fetus.

According to guidelines [2, 9] FSBS is contraindicated if:

- there is a family history of haemophilia or other bleeding disorder
- there is a suspected fetal bleeding disorder (e.g. fetal thrombocytopenia)
- there is maternal infection (HIV, viral hepatitis,

- herpes simplex, intrauterine sepsis)
- the fetus is premature (< 34 weeks of gestation)
- there is clear EFM evidence of possible severe hypoxia (e.g. prolonged, severe bradycardia). Under such circumstance immediate delivery is warranted, and delay, caused by performing FSBS, poses a higher than acceptable risk of prenatal hypoxia-mediated brain damage (HIE)

Variable applicability of FSBS

The extent to which obstetric units routinely use FSBS as an adjunct to EFM varies around the world, reflecting a level of controversy about its utility.

Although its use is recommended in current UK, Canadian, Australian and New Zealand national guidelines for intrapartum fetal monitoring [9, 2, 18], the equivalent US guideline [19] does not recommend its use, stating that “the scalp stimulation test, which is less invasive, provides similar information about the likelihood of fetal acidemia as does scalp pH.”

Although there has been a significant decline in the use of FSBS in the US [20], that is not the case in Europe. A recent survey [21], for example, revealed that 100 % of obstetric units in Sweden have a policy of performing FSBS when EFM trace is non-reassuring, compared with 84 % of obstetric units 10 years previously. According to this survey FSBS is now used in up to 14 % of deliveries in Swedish obstetric units.

Two recently published opinion papers [22, 23] highlight the controversy surrounding the use of FSBS; each is a critique of FSBS testing, in essence arguing that for a number of reasons the test should now be abandoned.

One important strand of their argument is that it has never been proven in adequately powered randomized controlled trials that FSBS testing has the desired effect of reducing the number of unnecessary urgent interventions (caesarean sections and operative vaginal deliveries).

Such a notion is challenged by a recent combined analysis of 32 previously conducted trials [16]. The results of this analysis allow the conclusion that FSBS testing does indeed have the desired effect, and in this sense provides valuable evidence in favour of FSBS testing and weakens the argument of those who believe the test should be abandoned.

In discussion of this study [16], the Danish authors report that their experience of frequent and daily use of FSBS over more than 25 years is that it has prevented unnecessary emergency caesarean section, despite non-reassuring EFM trace.

They observe that most of the few reports of serious complications date back many years to the time when longer and potentially more hazardous scalpel blades were used, and the sample volume required for pH measurement was much larger. Over the past 10 years they have experienced no serious complications of FSBS at any of their obstetric units.

For these experts, the evidence suggests that FSBS is a safe, effective and clinically useful test.

Lactate – an attractive alternative to pH measurement

Techniques for rapid and convenient measurement of lactate concentration on very small blood volumes (< 5 µL) became available around 20 years ago, allowing the feasibility of fetal-scalp blood lactate measurement as an alternative to pH measurement [24].

Lactic acid is the principal metabolic acid responsible for the fall in fetal-scalp blood pH associated with intrapartum asphyxia [24]. It follows, theoretically at least, that fetal-scalp blood lactate concentration should be as reliable an indicator of intrapartum asphyxia as fetal-scalp pH.

A number of studies [25-28] have established that fetal-scalp lactate concentration correlates well (inversely) with fetal-scalp pH, and that measurement of lactate concentration is at least as reliable as

measurement of pH in identifying fetuses with asphyxia [27].

Suggested [27] lactate concentration cut-off values corresponding to pH values in Table III are:

- <4.2 mmol/L (normal)
- 4.2-4.8 mmol/L (pre-acidosis)
- >4.8 mmol/L (acidosis)

These studies have confirmed two important practical advantages of lactate measurement:

- lower sample volume required (5 μ L vs. 35-50 μ L), and therefore significantly lower failure rate
- more speedy analysis and therefore less delay in urgent delivery of asphyxia-affected fetus

An additional advantage of lactate measurement is that lactate remains normal in the case of respiratory acidosis, whereas pH is abnormal in both respiratory and metabolic acidosis. Lactate is thus more specific for intrapartum asphyxia than pH.

Further study is required to fully validate the suggested cut-off lactate values above but fetal-scalp lactate measurement is a promising alternative to fetal-scalp pH that is recommended in at least one national guideline [18] and is already being routinely used in some obstetric units [21].

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