Evidence-based fetal assessment

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Summary
Antepartum cardiotocography (CTG) is the most frequently used method for fetal surveillance during labor. In high-risk pregnancies antepartum fetal heart rate assessment can be used to predict fetal compromise. However, the false-positive rate can be as high as 60% for various reasons. Higher sensitivity might be achieved by longer recording (fetal deep sleep phase) or by adding ultrasound Doppler. Another approach would be to quantify single parameters to determine a score. Extensive knowledge of the physiology and pathophysiology of the fetal cardiovascular regulation is essential for correct interpretation of fetal heart rate patterns. The preliminary warning by CTG for fetal decompensation is with 0–3 days, very short. Therefore, additive methods (Doppler ultrasound, amniotic fluid volume, kineto-CTG) for better preliminary warning should be used for high-risk pregnancies. Continuous electronic fetal heart rate monitoring during labor leads to a significant reduction in perinatal mortality due to fetal hypoxia and neonatal morbidity (neonatal seizures). However, it is also associated with an increase in operative deliveries. Errors of judgement can be reduced by teaching programs for intrapartum fetal monitoring, standardization of the criteria of quantitative design, and defining the need for action by non-reassuring CTG. Using fetal blood analysis (FBA) in labor following non-reassuring CTG may reduce the high false-positive rate of fetal heart rate patterns. The use of CTG in combination with FBA leads to a reduction of avoidable operative deliveries. The development of online-analysis of fetal heart rate patterns with quantification of the parameters by electronic systems leads to a more reproducible interpretation. The implementation of such systems is recommended. The effectiveness of additive methods for fetal monitoring during labor, fetal pulse oximetry with continuous information about oxygen saturation, and ST-waveform analysis of fetal ECG warning in cases of fetal hypoxia and metabolic acidosis, are currently being evaluated in clinical trials.

Introduction
Antepartum cardiotocography (CTG) provides information on the prevailing status of fetal oxygen supply. The monitoring of fetal heart signals, and their electronic processing and recording as fetal heart frequency (cardiogram), were introduced in the middle of the 1960s. The procedure was then enhanced by the recording of uterine contractions (cardiotocogram). The CTG was quickly put to use for surveillance of the unborn child, replacing sporadic auscultation of the fetal heart beat. CTG recording enabled impressive monitoring of alterations in fetal heart frequency (FHR) during contractions and movements of the child, thus providing reliable documentation for the first time. The initial aim was, and still is, to recognize conditions that present a potential risk to the fetus at an early stage, and to take appropriate action before fetal damage occurs. The main target is to recognize heart frequency patterns associated with deficient fetal oxygen supply. The main problem in CTG monitoring with regard to this target is that heart patterns that are very often classified as pathological correspond to physiological alterations. As a result of such false-positive CTG assessments, the numbers of induced births and operative deliveries have increased. The main causes of misinterpretation are insufficient knowledge of the fetal physiological behavioral conditions and influences depending on gestational age, inadequate training in CTG assessment, and the lack of use of additional diagnostics to assess fetal well-being. The accepted advantage of CTG tracing is that if heart frequency patterns are normal, it can be assumed that the fetus is in a good condition. Fetal oxygen supply is controlled, under physiological conditions, via neuronal regulation of the heart, under the superordinate influence of the medullary centers, which are regulated by presso- and chemoreceptors as well as by local metabolic processes. Various disruptive factors and influences, which may be of maternal, fetoplacental, fetal or exogenous origin, cause alterations in the FHR, such as accelerations, decelerations, variability, tachycardia, and bradycardia. Any assessment of these very complex fetal reactions must take all facets of such influences into consideration. Misinterpretation of FHR patterns can only be reduced to a minimum by intensive instruction and training, accompanied by constant reference to the results of fetal monitoring.

CTG methodology
The external method using Doppler ultrasound transducers is used almost exclusively to acquire signals and to record measurements. The recording of fetal cardiovascular action is therefore adequate. However, due to the raw Doppler signal, the autocorrelation function must be used. Instead of the original method of measuring the period between beats and thus calculating the momentary (instantaneous) heart frequency, the autocorrelation process requires up to five heart cycles in succession to reconstruct the actual course of the FHR. Low-frequency signals from

the child’s movements can be extracted from the Doppler signals to register the so-called kineto-cardiotocogram (K-CTG).

If the rate of signal loss (above 15 %) is too high during birth due to recording problems, the fetal heart frequency can no longer be evaluated. In such cases, a scalp electrode may be used to record the fetal electrocardiogram (FECG), thus allowing reliable CTG tracing during birth. Abdominal pressure transducers are normally used to record uterine contractions, so that information can be obtained on the frequency, duration, form, and relative intensity of the contractions. If the quality of the recordings during birth is inadequate, the occurrence of contractions can be only assumed by the lowered heart rate. The measurement of intra-amniotic pressure, which has become neglected, provides information on the basal tonus (reduction of uterine perfusion when pressure increases) and allows excellent form analysis and measurement of absolute pressure values during contractions. The period of CTG tracing during pregnancy and on admission to the labor room is usually about 30 minutes. If the FHR pattern is suspicious, the tracing period is lengthened e. g. to wait for the end of a period of fetal sleep. CTG recording should take place with the patient in a lateral position to avoid vena cava syndrome in pregnant women.

The standardized printing speed of 1 cm/min should be maintained to avoid confusion when interpreting the results. The monitoring frequency depends on the risks established in the clinical, Doppler sonographic, and cardiotocographic findings. For the more frequent indications (e. g. delivery date is a week overdue) repetition of the CTG two days after the first test is considered sufficient if the amount of amniotic fluid is normal. Additional diagnostic procedures with longer warning times (Doppler sonography, amniotic fluid volume rate, K-CTG) for which the use of antepartum cardiotocography are recommended, are shown in Table 4, pp. 138 f, in the indications (in italics) of the Guideline of the German Society of Gynecology and Obstetrics (DGGG 2007).

Evaluation parameters and clinical significance

Long-term (baseline heart rate), mid-term (accelerations, decelerations) and short-term (oscillation amplitude and frequency) alterations in heart rate are assessed. In the FIGO criteria, the frequency ranges for the baseline heart rate were altered for bradycardia and tachycardia (Rooth et al. 1987), without establishing adequate normal values. Studies carried out by Daumer et al. (2007) and Roemer and Walden (2006) showed threshold values for the number of cycles, the definition is consistent with that of Hammacher, and also with regard to the action required (RCOG 2001).

Cardiotocography for antepartum fetal assessment

Assessment of the antepartum CTG is based predominantly on short-term alterations (minor fluctuations) in baseline FHR and accelerations associated with fetal movement (fetal reactivity). Short-term variations in the FHR are an expression of autonomous influences of the sympathetic and parasympathetic nervous systems, influenced by the superordinate medullary centers. Apart from a loss of acceleration, a decrease in short-term alterations, particularly in the FHR, to the extent that the fine rhythms are lost, can point to a deficiency in the fetal oxygen supply. According to the FIGO criteria, only the oscillation amplitude (baseline variability) should be taken into consideration when evaluating an antepartum CTG.

Evidence-based medicine (EBM): according to Nelson et al. (1996, Evidence Level (EL) Ila according to RCOG 2001), a baseline variability of ≤5 bpm for a period of > 90 minutes is associated with increased perinatal morbidity.

The oscillation frequency is not taken into consideration in the FIGO evaluation criteria, possibly for simplification. After years of experience with this method, Hammacher (1977) described the variation in oscillation frequency of two to six cycles per minute as the most important information on the fetal condition that can be gained from the cardiotocogram. With the electronic recording of the reversal points, this parameter is integrated as the oscillation (OSZ) into the evaluation score of the quantitative analysis of the CTG (Q-CTG) (Roemer and Walden 2006). Under physiological conditions, there is a high rate of change at the reversal points of the cycles and inversion of the direction takes place. A rounding-off of the reversal points and a decrease in the number of cycles point to a worsening condition in the fetus. Sinusoidal rounding-off and a permanent decrease in cycles to under two per minute, or a complete lack thereof (linear recording), are signs of high-degree intrauterine risk that require prompt action (Hammacher 1977). According to Young et al. (1980), a sinusoidal pattern shows long-term fluctuations in the basal frequency (like sinus waves) and a smooth, undulating pattern lasting at least 10 minutes, with relatively fast repetition of three to five cycles per minute. Apart from the number of cycles, the definition is consistent with that of Hammacher, and also with regard to the action required (RCOG 2001).
The Fischer Score (Fischer 1981) is currently the preferred method for assessment of antepartum CTGs in Germany. The score incorporates the five evaluation criteria described by Hammacher (Table 1). The CTG is assessed according to systematic analysis and is classified in the following groups according to the number of points scored (Table 2):

- normal (8-10),
- suspect (5-7) and
- pathological (≤ 4).

Table 1: Fischer Score for semi-quantitative evaluation of the antepartum CTG (altered according to FIGO in 1988)

<table>
<thead>
<tr>
<th>Points</th>
<th>0</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>baseline (bpm)</td>
<td>&lt; 100 or &gt; 170</td>
<td>100-110 or 150-170</td>
<td>110-150</td>
</tr>
<tr>
<td>bandwidth (bpm)</td>
<td>&gt; 5</td>
<td>5-10 or &gt; 25</td>
<td>10-25</td>
</tr>
<tr>
<td>zero-crossings/min accelerations</td>
<td>&lt; 2</td>
<td>2-6</td>
<td>&gt; 6</td>
</tr>
<tr>
<td>late, variable accelerations with unfavorable additional criteria</td>
<td>none, variable</td>
<td>sporadic</td>
<td></td>
</tr>
</tbody>
</table>

Hage (1985) postulates a good reproducibility of the CTG assessment (non-stress test). This can be achieved by combining the classification according to Fischer with a statement of need to action (Table 2). It does not appear advantageous to carry out evaluations according to the FIGO classification rather than the simply structured, routinely used and very trusted Fischer Score for antepartum CTG monitoring.

**Fetal movements**

Reduced periods of fetal movement are considered as early signs of reduced fetal oxygen supply and an altered fetal behavior (Gnirs 1995). They are early warning parameters of fetal risk (on average about 12-14 days previously) that can be detected by simultaneous electronic recording of the child’s movement by K-CTG. Low-frequency signals from the child’s movements are extracted from the external derivation of the Doppler signals and are processed using a suitable algorithm. The number and duration of the child’s movements are shown in the third channel of the cardiocograph; the latter are depicted by bars of various lengths. Shortened periods of activity below the 5th percentile of the reference curve for normal pregnancies is considered pathological (Gnirs et al. 1998). A reduction in the number of fetal movements usually occurs at a late stage and is a late warning signal, as are pathological alterations shown in the CTG (0-3 days before decompensation). FHR accelerations associated with movement can be safely classified if the physician has knowledge of fetal movement.

EBM: The basal heart rate can be precisely determined in the case of suspect FHR patterns, thereby lowering the false-positive rate by up to 50%. Significant shortening of periods of activity (< 5th percentile) is an early warning parameter of fetal risk, particularly if there is fetal growth retardation (12-14 days) (Gnirs et al. 1998, EL IIA).

**Fetal behavioral states**

Close to delivery date, four different periodically recurring behavioral states are found in 80% of all fetuses (Nijhuis and van de Pas 1992, EL IIA). The fetus spends about 4% of the day in a state of rest, of which 25-35% is deep sleep with an FHR pattern similar to that observed in fetal hypoxia (narrow to silent oscillation amplitudes, no accelerations, and occasional body movement). To avoid misinterpretation, the tracing period should be lengthened to over 40 minutes, to wait for the end of a sleeping phase.

EBM: Waking methods such as vibroacoustic stimulation can aid the clarification of abnormal FHR patterns during periods of deep sleep and thus increase the specificity of CTG interpretation (Tan and Smyth 2001, EL IIa); however, an evidence-based improvement in perinatal results has not been demonstrated.

**Non-stress test (NST)**

According to Freeman et al. (1982), 20 minutes are sufficient to diagnose fetal well-being using the antepartum CTG, if a reactive FHR with two accelerations associated with fetal movement is observed during this period. Due to its simplicity, and for reasons of time and cost, this test is widely used to assess fetal well-being (ACOG 1994).

EBM: Four prospective randomized studies found no recognizable advantage of using the non-stress test (Pattison and McCowan 2000, EL Ia). Therefore, routine use of the NST – proof of a reactive FHR – is not recommended. There has been increasingly critical appraisal of the meta-analysis, given that the studies began shortly after introduction of the test, and due to the lack of experience of the trial participants in interpreting the CTG findings and the consequences of these results (Bruce and Young 2008).
Biophysical profile
In the biophysical profile, fetal breathing and body movements, muscle tone, the amount of amniotic fluid (ultrasound), and fetal reactivity (CTG) are assessed synoptically as a score, instead of the evaluation of individual criteria. When various fetal regulatory and adaptive mechanisms were appraised, a high rate of negative prediction was found when test results were negative (Miller et al. 1996).

EBM: The meta-analysis of randomized studies showed no improvement in perinatal results (Alfirevic and Neilson 2000, EL Ia).

Doppler sonography
Doppler sonography (DS) using the envelope curve function and evaluation provides better reproducibility of the systolic–diastolic variability than the CTG and all CTG-based tests. Examination of the umbilical artery in cases of fetal growth retardation (24th–37th week of pregnancy) provides the most distinct advance warning, in comparison to all other monitoring procedures, of pathological test results three weeks before delivery (Gnirs 1995). If the DS results are pathological (circulatory centralization, end-diastolic flow loss or flow reversal), repeated K-CTG tracing at short intervals has the advantage that fetal risk is recognized at an early stage due to a decrease in fetal activity (duration of fetal movement) (Hopp et al. 1994, EL Ia). The specificity of FHR monitoring increases significantly in preselected patient cohorts, and when based on regular check-ups during pregnancy before the 37th week of pregnancy (danger of iatrogenic premature birth) it enables more exact determination of the delivery date.

EBM: The use of Doppler sonography in combination with CTG tracing in groups of high-risk pregnancy patients in prospective randomized studies led to a significant reduction in perinatal mortality (Westergaard et al. 2001, EL Ia).

Contraction stress test
Fetal heart frequency is evaluated during spontaneous or induced contractions (oxytocin stress test). If the fetal oxygen supply is marginal under resting conditions, uterine contractions may lead to decelerations of the FHR due to short-term reductions in uteroplacental circulation. The contraction test is:
• negative, if no late decelerations occur;
• positive, if late or variable decelerations with unfavorable additional criteria are observed during several contractions.

Polysystoles and continuous contractions accompanied by fetal bradycardia can develop as undesirable side effects of induced contractions.

EBM: With a false-positive rate of up to 60% and a false-negative rate of 15% (Staisch et al. 1980, Thacker and Berkelman 1986, EL Ila), recognition of fetal compromise is inadequate.

Computer analysis – Dawes-Redman criteria
Computer analysis of antepartum FHR (Oxford CTG) is performed by taking the week of pregnancy into consideration. The imported CTG is compared with a database of over 48000 recordings, and a preliminary analysis of the most important parameters is available within 10 minutes (Fig. 1). Fulfillment of the Dawes-Redman criteria offers good reassurance that there is no fetal risk (Dawes et al. 1992).

Figure 1: Printout of a computerized CTG analysis (Dawes-Redman Criteria)

Short-term variation (STV) provided by computer analysis is particularly valuable for making an up-to-date diagnosis in cases of severe deficiency in placental supply. A decrease in STV observed at regular check-ups may point to increasing fetal compromise. The variation in the average absolute time difference between consecutive heartbeats is measured. Short-term variation is a parameter that is independent of the week of pregnancy but correlates closely with fetal outcome (Table 3). Exact measurement is problematic as the quality is greatly influenced by Doppler raw signals, and an autocorrelation process is necessary to determine the heart frequency.

Table 3: Relationship between short-term variation (STV) and frequency of metabolic acidosis and intrauterine premature death (IUFD)

<table>
<thead>
<tr>
<th>STV (ms)</th>
<th>Metabolic acidosis (%)</th>
<th>IUFD (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 2.6</td>
<td>2.6-3.0</td>
<td>&gt; 3.0</td>
</tr>
<tr>
<td>10.3</td>
<td>4.3</td>
<td>2.7</td>
</tr>
<tr>
<td>24.1</td>
<td>4.3</td>
<td>0</td>
</tr>
</tbody>
</table>
Indications and clinical evaluation during pregnancy

The DGGG (2007) guideline on the use of CTG during pregnancy and birth recommends the expansion and more detailed definition of the catalogue of indications (Table 4). Independent of the previous catalogue of indications laid out in the German maternity guidelines (“Mutterschaftsrichtlinien”), which only included three indications for CTG tracing from the 26th week of pregnancy onwards (threatening premature birth from the 28th week of pregnancy onwards, alterations in heart tones established by auscultation, suspected premature contractions), CTGs were recorded for over 90% of all pregnant women. This high frequency shows that CTG tracing is now mainly performed in low-risk patients, although it is accepted that this procedure does not lead to an improvement in perinatal data (RCOG 2001).

Table 4: Indications for antepartum CTG tracing (Recommendations of the DGGG 2007 guideline)

- maternal anaemia (haemoglobin ≤ 10 g/dl or ≤ 6 mmol/l), premature arrhythmia (especially tachyarrhythmia) in ultrasound studies of pregnancy, bleeding during pregnancy
- thrombophilia and collagenoses
- diabetes mellitus
- blood group incompatibility
- premature contractions (tocolysis)/premature birth threatens
- suspicious or pathological Doppler findings
- infection (e.g. PI in the arteria umbilicalis > 90th percentile)
- drug abuse (e.g. nicotine abuse)
- oligohydramnios (AFI ≤ 25 cm)
- maternal circulatory instability
- multiple pregnancy
- oligohydramnios (< single-pocket < 2 cm)
- maternal circulatory instability
- accident with abdominal trauma or severe maternal injuries
  - premature contractions (tocolysis)/premature birth threatens
  - growth restrictions < 10th percentile

In the early, opening phase of low-risk pregnancies and if the previous CTG was normal, the DGGG guideline (2007) recommends intermittent electronic subpartum monitoring every 30 minutes, with up to a maximum interval of 2 hours (for at least 30 minutes). If tracing is impossible, examination should be performed by auscultation. In the active phase of labor, intermittent auscultation should occur after a contraction, for a minimum of 60 seconds, and at least every 15 minutes in the first stage and every 5 minutes in the second stage, with stringent documentation. The CTG should be traced continually during the later first and second phases of birth. In high-risk pregnancies (see Table 4) continuous electronic fetal monitoring may be necessary during the whole of the first and second phases.

CTG tracing is also indicated for tocolysis or where oxytocin is being used for induction or augmentation of labor if there is evidence of contractions. If pathological FHR patterns persist for more than 30 minutes, they should be clarified by an FBA at the precedent fetal pole. This does not apply in cases of serious fetal bradycardia or highly pathological CTG patterns, which require immediate intervention and delivery (DGGG 2007).

Subpartum clinical evaluation

The introduction of electronic fetal surveillance during birth brought about dramatic changes for obstetricians and obstetrical decision-making. Young obstetricians greeted CTG monitoring with enthusiasm and quickly learned to interpret its results (Hammacher 1977; Hon 1968; Kubil and Rüttgers 1969). In the 1970s, a work group in Rostock began to use the CTG to interpret circulatory disruptions, rather than using a purely descriptive evaluation (Heinrich and Seidenschnur 1988). Details on subpartum tolerance and recommendations of the measures to be taken have been compiled for the FHR patterns thus evaluated, and these have been grouped together according to clinical findings (see Table 5). Excellent results have been obtained after years of clinical practice as a result of efficient training and continued instruction and this has led to...
a very low frequency of acidosis (umbilical artery pH values < 7.10; 0.4%) without an increase in the rate of Cesarean sections (about 4%), and to a perinatal mortality rate of 0.6% (Heinrich and Seidenschnur 1988). In view of these results, it is not clear how the first randomised studies (Haverkamp et al. 1976; Haverkamp et al. 1979; Kelso et al. 1978; Langendoerfer et al. 1980) reached the conclusion that perinatal outcome cannot be improved by the use of electronic fetal surveillance. At this point, the high inter- and intraobserver variability (Bernardes et al. 1997; Cibils 1996) should be mentioned, and in view of the problems in interpreting results, the value of these randomised studies should be questioned.

Table 5: Clinical classification of FHR findings

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Baseline (bpm)</th>
<th>Variability (bpm)</th>
<th>Decelerations</th>
<th>Accelerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reassuring</td>
<td>110-150</td>
<td>≥ 5</td>
<td>none*</td>
<td>present, sporadic**</td>
</tr>
<tr>
<td>Non-reassuring</td>
<td>100-109</td>
<td>&lt; 5 and ≥ 40 min</td>
<td>early/variable</td>
<td>present, periodic (with each contraction)</td>
</tr>
<tr>
<td></td>
<td>151-170</td>
<td>&gt; 25</td>
<td>individually prolonged up to 3 min</td>
<td></td>
</tr>
<tr>
<td>Abnormal</td>
<td>&lt; 100</td>
<td>&lt; 5 and ≥ 90 min</td>
<td>atypically variable</td>
<td>lacking for &gt; 40 min (meaning still unclear)</td>
</tr>
<tr>
<td></td>
<td>&gt; 170</td>
<td>sinusoidal***</td>
<td>late individually prolonged &gt; 3 min</td>
<td></td>
</tr>
</tbody>
</table>

* FHR deceleration amplitude: ≥ 15 bpm, duration: ≥ 15 s
** FHR acceleration amplitude: ≥ 15 bpm, duration: ≥ 15 s
*** Sinusoidal FHR: undulating pattern with an amplitude of 5-15 bpm (sine wave), duration: ≥ 10 min

Table 6: Categorisation of FHR traces and action required (according to FIGO, DGGG 2007 guidelines)

<table>
<thead>
<tr>
<th>Category</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>All four evaluation criteria are reassuring (no need to act)</td>
</tr>
<tr>
<td>Suspicious</td>
<td>At least one of the evaluation criteria is non-reassuring and all others are reassuring (need for conservative action)</td>
</tr>
<tr>
<td>Pathological</td>
<td>At least one of the evaluation criteria is abnormal or two or more are non-reassuring (need for conservative and invasive action)</td>
</tr>
</tbody>
</table>

EBM: The meta-analysis of randomized studies on the use of cardiotocography during birth showed a reduction in the rate of cramps in newborns, and an increase in the number of Cesarean sections and instrumental deliveries (Alfirevic et al. 2006, EL Ia). The more recent evaluation of the studies by Vintzileos et al. (1993, EL Ib), which showed that electronic fetal monitoring reduces perinatal mortality caused by hypoxia and that the various forms of acidosis during birth are significantly better recognized, was not taken into consideration (Vintzileos et al. 1995a, EL Ib). The meta-analysis by Vintzileos et al. (1995b, EL Ia) showed a reduction in perinatal mortality of over 50% as a result of the use of electronic fetal monitoring; however, the rate of operative deliveries increased by a factor of 2.5.

The importance of a reliable evaluation of the CTG to assess this monitoring method has been shown in several studies: Nelson et al. (1996, EL Iia) – significant association of the occurrence of cerebral palsy and neonatal encephalopathy with late decelerations in the CTG (odds ratio, OR: 3.9) and reduced baseline variability (OR: 2.7); Gaffney et al. (1994a, 1994b, EL Ia) – significantly higher rates of neonatal encephalopathy and cerebral palsy found with abnormal CTG patterns; and Spencer et al. (1997, EL Ila) – an abnormal CTG pattern, classified according to FIGO criteria, accompanies a significant increase in the rate of encephalopathy.

FIGO criteria and the NSP classification

The introduction of CTG evaluation during birth, according to FIGO criteria (Table 6) and the NSP classification (normal, suspicious, pathological), including the recommendations on measures required in the case of suspicious or pathological findings (Table 7), is meaningful and logical.

Table 7: “NSP” Categorisation of FHR traces and action required (according to FIGO, DGGG 2007 guidelines)
The CTG must be evaluated continually during birth by analyzing a 30-minute phase with the highest density of suspicious or pathological FHR parameters (EL IV).

Even if the CTG is normal, a signed entry must be made on the recording strip every two hours. In the DGGG guideline (2007), the following procedure is recommended when using the CTG during birth:

- If FHR classification are suspicious, the evaluation must be repeated 30 minutes later and the number of non-reassuring parameters noted (S1 for “1 non-reassuring parameter”). Measures to be taken: clarification or improvement of the situation by conservative means (e.g. change of position, attempt to wake the fetus, infusion, oxygen administration). It should be noted that in the event of oligohydramnios and severely varying decelerations, amnioinfusion via the intraamnial catheter leads to a decrease in circulation disruption in the umbilical vessels (Hofmeyr 2000, EL Ia), and in many cases (up to 50 %, according to the authors’ own experience) operative delivery can be avoided.

- In the event of pathological FHR classification, the CTG must be assessed continually, and the assessment must be documented every 10 minutes, together with specification of the number of non-reassuring/abnormal parameters (S2 or P4 for “4 abnormal parameters”). Measures to be taken: improvement of the situation by taking conservative measures (e.g. changing position, tocolysis, attempt to wake the fetus, infusion, administration of oxygen). Clarify by performing an FBA. If the FBA results are pathological or if the FHR pathology cannot be improved, delivery should take place rapidly.

### Fetal blood gas analysis

Discontinuous fetal blood sampling for gas analysis (FBA) can be used for reliable diagnosis of the acid-base metabolism during birth (Saling 1966). The FHR pattern indicates the necessity of an FBA (see measures to be taken), which should be carried out directly after conservative measures are taken to improve the situation if there are signs of hypoxemia. The current pH value is the decisive fetal blood parameter used when diagnosing hypoxemia (Table 8). The clinical consequences of a physiological decrease in fetal pH values during birth must be taken into consideration. In deliveries close to the delivery date, the 10th percentile for the fetal pH value is 7.20 on completion of delivery. For a differentiated evaluation, apart from measuring acidity, the lactate concentrations, and pO₂ and pCO₂ should be measured and the base-excess (BE) calculated (Dudenhausen et al. 1997). If FHR patterns are non-reassuring or abnormal, combined birth surveillance, including the determination of acid-base metabolism parameters, provides the necessary diagnostic reliability. As yet, the FBA cannot be replaced by additive monitoring procedures; at best, the frequency of the test may be reduced.

#### Table 8: Recommended procedure following fetal blood gas analysis (DGGG 2007 guideline)

<table>
<thead>
<tr>
<th>Fetal blood gas analysis (FBA)*</th>
<th>Conclusions</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH ≥ 7.25</td>
<td>Repetition of the FBA within 30 minutes, if the FHR abnormality persists.</td>
</tr>
<tr>
<td>pH = 7.21-7.24</td>
<td>Repetition of the FBA within 30 minutes, or delivery should be considered (if there has been a rapid fall in pH values since the last measurement).</td>
</tr>
<tr>
<td>pH ≤ 7.20</td>
<td>Prompt delivery is particularly indicated in the case of metabolic acidosis.</td>
</tr>
<tr>
<td>pO₂ &gt; 65 mmHg (respiratory acidosis)</td>
<td></td>
</tr>
<tr>
<td>BE &gt; −9.8 (e.g. −15) (metabolic acidosis)</td>
<td></td>
</tr>
</tbody>
</table>

* All fetal blood measurements should be interpreted with reference to the initial pH value, metabolism, progress of delivery, and other fetal and maternal clinical findings.

EBM: Combined monitoring of birth reduces neonatal convulsions and decreases the number of avoidable operative deliveries (Haverkamp et al. 1979; Vintzileos et al. 1995b, EL Ia).

### Electronic online CTG evaluation

A more reliable grouping of FHR patterns in trials on inter- and intraobserver variability was made possible by the introduction of computerized CTG classification (Keith et al. 1995, EL IIa). With the use of online CTG evaluation and its improved reproducibility, electronic documentation systems can now be recommended that do not interfere with medical decisions and therapeutic sovereignty (DGGG 2007).

### Computerized FIGO classification (Schindler 2002, EL IIb)

CTGs are analyzed through a computer algorithm by TRIUM, calculating the FIGO criteria and using a color ranking system in which

- green indicates normal,
- yellow indicates suspicious and
- red indicates pathological.
Compared with visual CTG analysis by experts, CTG online® by TRIUM showed a significant improvement in reproducibility (Schiermeier et al. 2006).

Q-CTG (Roemer 2003, EL IIb)

Online analysis of the CTG quantifies relevant FHR parameters and correlates them with perinatal data. Microfluctuations "OSZ", the level of frequency "FRQ", and the dip area "DEC" are used as evaluation parameters in the CTG score, each being given up to six points (Fig. 2). The vector reversal points are determined electronically to evaluate microfluctuation, thereby integrating the oscillation frequency into the analysis.

Thirty minutes after commencement of CTG tracing, the calculated score is shown together with the current pH value on an additional channel in the CTG monitoring system ARGUS (from NEXUS/GMT). The display may also be hidden. Previously, FHR online analysis required direct recording of the FECG via a scalp electrode. In order to allow for the almost exclusive use of external recording of measurements during birth, the procedure will be altered to permit analysis of externally recorded FHR. Single parameter values can be recognized by the use of different colors to represent the total score (Fig. 3). The last 30 minutes of the CTG before each score output are used in the evaluation. For this reason, it is difficult to precisely assign single FHR events to a particular score. The results of an almost year-long evaluation show good conformity with neonatal outcome. Differences in the calculated (lower) pH values and those measured in the umbilical artery are noted in the event of severe decelerations. According to Roemer (2007), this is due in part to the large influence of maternal hyperventilation on the fetal acid-base status during birth. The authors combine online analysis with fetal pulse oximetry and ST waveform analysis (STAN) of the direct fetal ECG for further evaluation of the Q-CTG, and examine the correlation of the various monitoring parameters.

Additional monitoring procedures during birth

Fetal pulse oximetry

Fetal pulse oximetry (FPO) allows the measurement of arterial oxygen saturation (FSpO2) during birth. Using the fetal Sat-System (see Fig. 4) reliable FSpO2 data are assessed in over 90% of the recording period (Knitza 2007). This means that one of the main problems of FPO recording has been overcome: the poor application stability and high signal loss of the now discontinued FS 14 fetal sensor (Nellcor System). Thus the signal was only of limited usefulness (only 75% of the signals, according to the authors’ own research). When recorded simultaneously with the CTG, the FPO can improve the possibility of verifying alterations in FHR, especially those associated with fetal hypoxemia (see Fig. 5). Animal experiments and clinical trials show that if values fall below the threshold of 30%, the number of cases of fetal hypoxemia increases significantly. Our own studies on normal values during birth showed significantly lower mean FSpO2 values in cases of deficient placental supply with fetal growth retardation. With the same FHR patterns there were frequent critical decreases in FSpO2 below 30% (Fig. 6) in cases of fetal growth retardation. Seelbach-Göbel and Riedl (2005, EL IIb) demonstrated that, in cases of non-reassuring CTG, the threshold value analysis "FSpO2 ≤ 30% for at least 10 minutes"
(Kühnert et al. 1998) was able to detect (sensitivity) or exclude (negative predictive value) an umbilical artery pH below 7.1 with 100% and base-excess values ≤ 12 mmol/l with 75%.

It is highly probable that a significant drop in pH values of 0.1 pH units could be excluded by repetition of the FBA (negative predictive value of 98%). With a specificity of about 60% and low positive predictive values, persisting low FSpO2 values alone do not indicate operative delivery; the fetal condition should be assessed by an FBA if the CTG does not signal acute fetal risk. The safety of pulse oximetric monitoring is influenced by the rate of signal loss and by individual fetal factors such as a fetal infection (development of metabolic acidosis), or fetal anemia (lack of oxygen supply despite normal FSpO2 values). To avoid misinterpretation, and if there is a preexisting suspect CTG, it is recommended that an FBA is performed at the beginning of simultaneous pulse oximetric surveillance. In the course of monitoring, the plausibility of saturation measurements should be questioned and, if in doubt, even if FSpO2 values are normal, the FBA should be repeated. When combined with a CTG, fetal pulse oximetry improves recognition of fetal hypoxemia and, if influential and disruptive factors are taken into consideration, permits a reduction in fetal blood gas analyses when persisting FSpO2 values are above 30%.

EBM: In a randomized controlled multicenter study, the Cesarean deliveries in cases of abnormal CTG were reduced by about 50% in the FPO group; however, the overall rate of Cesarean deliveries was unaltered. In cases of operative intervention for non-reassuring fetal status, a higher sensitivity and specificity for secondary endpoints of fetal monitoring – metabolic acidosis and reanimation of neonates – was found in the FPO group (Garite et al. 2000, EL Ib). In another controlled study with over 5000 monitored births, knowledge of the pulse oximetry data did not lead to decreased rates of Cesarean section and acidosis (Bloom et al. 2006, EL Ib). In one study FBA was routinely applied for combined intrapartum monitoring in cases with non-reassuring FHR patterns. The use of FPO in such cases reduced the rate of operative deliveries and the frequency of FBA by 50% (Kühnert and Schmidt 2004, EL Ib). The FOREMOST study showed a significant reduction in operative interventions in the FPO group, but no difference in neonatal outcome (East et al. 2006, EL Ib).
ST waveform analysis of the fetal ECG (STAN)

Persisting oxygen deficiency causes anaerobic glycolysis in the myocardium and release of potassium ions, leading to alterations in membrane potential in the repolarization phase and thus also to the ST segment and the T waves. The T/QRS ratio rises as hypoxia and metabolic acidosis increase, so that a disruption in the oxygen supply can be deduced by analysis of the FECG. Equipment from Neoventa Medical (STAN S21 and S31) can be used for continuous ST analysis after attachment of a fetal scalp electrode. A significant rise in the T/QRS ratio is described as an »ST event« that is documented using the absolute values, which are registered continuously (T/QRS base line).

Episodic and persisting elevations in the T/QRS baseline, as well as biphasic ST waveforms (figures from 1-3 below the T/QRS values) may indicate disruption in oxygen supply (Fig. 7). In principle, interpretation of the CTG serves as a basis for evaluation of STAN alterations, i.e. clinical decisions should not be made solely on the basis of evaluation of ST waveform alterations. In a large Swedish study, it was shown that when CTG is coupled with STAN a lower rate of metabolic acidosis and operative deliveries can be achieved (Amer-Wahlin et al. 2001, EL Ib).

In a European multicenter study involving 7000 patients, it was found that in comparison with intermittent FBS monitoring, fetal surveillance using CTG plus STAN provides adequate timely information on intrapartum acidosis (Luttkus et al. 2004, EL Ib).

The continuous information provided on a metabolic parameter and the good correlations with fetal acidosis were grounds for the assumption that the present problems regarding CTG interpretation and the high false-positive rate of the CTG can be reduced without risk to the fetus. This obvious advantage of combined use of the CTG and STAN, particularly when used by initially externally recorded non-reassuring CTG, was only partly confirmed in several observational studies due to a high false-negative rate of STAN (no ST waveform alterations in the event of metabolic acidoses). In a Dutch observational study by Kwee et al. (2004), a high false-negative rate was shown for this method. With umbilical artery pH values from 7.00 to 7.04, no ST alterations were found during the course of birth in six out of 13 newborns: only when umbilical artery pH values fell below 7.00 did significant ST events develop 18 to 31 minutes before birth. The authors’ own experience with the combined used of CTG, STAN and FPO confirms the false-negative results of STAN with pathological CTGs and in cases in which the FPO shows signs of fetal hypoxemia. In the case of a woman giving birth for the third time, where the total surveillance time was 53 minutes and the FHR pattern was pathological with FSpO2 values < 30 %, neither T/QRS elevations nor biphasic ST segments were found during the last 16 minutes of birth (Fig. 8). Doria et al. (2007) also mention metabolic acidoses in seven out of 23 children that were not identified by STAN. Westerhuis et al. (2007) observed three cases of severe metabolic acidoses (umbilical artery pH < 7.00) with highly pathological CTGs, without registration of ST events. When these cases were analyzed, the reasons for these results were the bad signal quality, poor interpretation of the CTG, and an interruption in STAN recording. In this context it should be pointed out that the recommendations of a consensus paper on the use of STAN, which were revised in January 2007 by a group of experts, should be strictly adhered to (Amer-Wahlin et al. 2007).
It should be a requirement that monitoring by STAN is only carried out by adequately trained personnel with experience in the method. The aim should be to commence ST recording at an earlier stage (preferably, when the CTG is still reassuring), as in advanced metabolic acidosis there is the danger that the ST waveform will show no alteration in comparison to the initial ST findings. If the quality of the signal is bad and the heart frequency pattern is abnormal, without ST events, the method should be supplemented by the FBA in order to limit the false-negative rate – avoidable advanced acidoses. In ST waveform analysis, fetal hypoxia and metabolic acidosis are often only identified after the development of serious alterations, leaving only limited scope for action.

EBM: In a Cochrane review, 8872 patients were evaluated in three studies in which continuous CTG monitoring was compared with CTG combined with STAN. The use of adjunctive ST waveform analysis was associated with fewer babies with severe metabolic acidosis at birth, fewer babies with neonatal encephalopathy, fewer FBAs and fewer operative vaginal deliveries. There were no statistically significant differences in Cesarean section, Apgar score less than seven points at five minutes, or admission to the special care unit. Thus, in conclusion, the available data show “some support” for the use of fetal ST waveform analysis when a decision has been made to undertake continuous fetal rate monitoring during labor (Neilson 2008, EL Ib).

Summary

Evidenz based fetal assessment
Cardiotocography (CTG) is the most frequently used method for fetal surveillance during labour. In high-risk pregnancies antepartum fetal heart rate assessment will predict fetal compromise. However, the false positive rate might be as high as 60 % due to various factors. A higher sensitivity might be achieved either by a longer registration (fetal deep sleep phase) or by adding Ultrasound Doppler studies. Another method would be the quantification of the single parameters in a Score. Premise for a correct interpretation of fetal heart patterns is extensive knowledge of physiology and pathophysiology of the fetal cardiovascular regulation. To detect fetal decompensation by CTG is with 0–3 days very short, so that additive methods (Doppler ultrasound, amniotic fluid volume, KinetocG) should be used for high-risk pregnancies. Continuous electronic fetal heart rate monitoring during labour leads to a significant reduction of perinatal mortality and neonatal morbidity (neonatal seizures). However, this is also associated with an increase in operative deliveries. Errors of judgement can be reduced by teaching programs for intra-partum fetal monitoring and standardisation of the criteria of quantitative design and the definition of the need for action by nonreassuring CTG. Using fetal blood sampling (FBS) in labour for nonreassuring CTG, can reduce the high false positive rate of fetal heart rate patterns. The use of CTG in combination with FBS leads to a reduction of neonatal seizures and also to a reduction of avoidable operative deliveries. The development of online-analysis of fetal heart rate patterns with a quantification of the parameters by electronical systems leads to more reproducible interpretation. Their implementation can be recommended.

Effectiveness of additive methods for fetal monitoring during labour, fetal pulsoxymetry with continuously informations of oxygen saturation and ST-waveform analysis of fetal ECG warning in case of fetal hypoxia and metabolic acidosis, are being evaluated in clinical trials.


Keywords
Antepartum fetal assessment, electronic fetal monitoring, fetal pulse oximetry, STAN, computerised cardiotocography

References
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Question 1
Which of the following is the chosen method for recording measurements during CTG tracing?
- a. The scalp electrode (FECG).
- b. Recordings of the heart tone (phonocardiography).
- c. The Doppler signal of cardiac activity.
- d. The indirect FECG (measurement via the maternal abdominal wall).
- e. b and d are correct.

Question 2
Which statement is incorrect?
Antepartum CTG evaluation according to Fischer is based on the assessment of the following parameters:
- a. Fetal movement.
- b. Accelerations.
- c. Decelerations.
- d. Oscillation amplitude.
- e. Oscillation frequency.

Question 3
A pathological antepartum CTG with high fetal risk can be recognized by which of the following:
- a. accelerations during movements of the child,
- b. baseline variability (oscillation amplitude) < 5 bpm for over 90 minutes,
- c. an oscillation frequency of 2–6 cycles per minute,
- d. sporadic slight decelerations,
- e. a basal frequency of around 110 bpm with normal oscillation.

Question 4
Perinatal data have improved as a result of antepartum cardiotocography in which of the following:
- a. status post treatment for sterility,
- b. status post stillbirth,
- c. high-risk patients,
- d. only in combination with Doppler sonography in high-risk patients,
- e. status post Cesarean section.

Question 5
Which antepartum test has the longest warning time with regard to fetal decompensation due to intrauterine growth retardation?
- a. Fetal heart rate.
- b. Amniotic fluid volume rate.
- c. Number of fetal movements.
- d. Duration of fetal movement.
- e. Doppler sonography.

Question 6
Which statement is correct?
CTG monitoring during labor makes
- a. a reduction in the number of operative interventions possible,
- b. fetal blood gas analysis unnecessary,
- c. safe prediction of the pH value in the umbilical artery possible,
- d. a reduction in perinatal mortality caused by hypoxia possible,
- e. it possible to shorten the length of delivery time.

Question 7
Which monitoring procedures can be combined to assure reliable assessment of fetal oxygen supply during birth?
- b. Intermittent CTG tracing and ultrasound examination of the child’s position.
- c. Continuous CTG surveillance and indicated fetal blood gas analysis (FBA).
- d. Fetal pulse oximetry without fetal blood gas analysis.
- e. Maternal pulse oximetry plus ST analysis.

Question 8
Which answer is correct?
Fetal pulse oximetry makes it possible
- a. to make a reliable prediction of the pH values of the umbilical artery > 7.20 with a non-reassuring CTG and FSpO2 values > 30%,
- b. to exclude umbilical pH values of < 7.10 with plausible FSpO2 values > 30%,
- c. to indicate operative delivery if FSpO2 values are above < 30%,
- d. to exclude disruptions in fetal oxygenation if FSpO2 values are above > 30%,
- e. to omit performing an FBA if FSpO2 values are over > 30%, without ascertainment of the acid-base status at the beginning of the FPO.
**Question 9**
Which statement is correct?

ST analysis in fetal surveillance
a. can be performed during external recording of fetal cardiac activity,
b. permits a longer period for taking action in the case of ST events and pathological CTG,
c. replaces the FBA during birth,
d. always excludes fetal acidosis if T/QRS values are normal,
e. enables continuous registration of fetal metabolic parameters.

**Question 10**
Which statement is incorrect?

Electronic online CTG analysis
a. quantifies the relevant parameters of the FHR,
b. improves the reproducibility of CTG evaluation,
c. indicates the need for immediate operative intervention during birth,
d. indicates a possible worsening of the fetal condition at an early stage,
e. does not, as yet, permit reliable assessment of the fetal acid-base status.