S1-Guideline on the Use of CTG During Pregnancy and Labor

Long version – AWMF Registry No. 015/036

S1-Leitlinie Anwendung des CTG während Schwangerschaft und Geburt

Langfassung – AWMF-Register-Nr. 015/036

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1 Purpose

1.1 Aim, target audience and method

The aim of this consensus paper is to standardize the use of cardiotocograms (CTG) in fetal monitoring using an evidence-based approach. Recommended standards take the impact of disturbances and other influencing variables on the CTG into account, use standard definitions and objective assessment methods, and look at upstream diagnostic procedures and adjunct monitoring methods.

The target audience for this consensus paper are all professionals who use CTG readings to monitor pregnancies and childbirth, most notably gynecologists and midwives.

Method: This guideline was compiled with particular reference to and in consideration of previous recommendations [85], the FIGO guidelines [59, 82], and the guidelines of the Royal College of Obstetricians and Gynaecologists [84], the NICHD [72], the Society of Obstetrics and Gynecologists Canada [110] and the American College of Obstetricians and Gynecologists [4,5] as well as evidence-based data, where available.

The basis for this guideline is the best available "evidence" which was carefully collected and classified by the members of the consensus group. It was not possible in every case to compile recommendations directly from the evidence level provided in the available literature. The recommendations show what is generally considered good clinical practice, so far as this was not queried by the persons involved in the consensus process. With regard to the requirements specified by the AWMF for the compilation of guidelines in terms of a uniform structure for different guideline types (S1, S2e, S2k, S3), the levels of recommendation in this S1 guideline on recommended actions are not stated explicitly but are indicated using the terms "shall", "should" and "can". Transparency is given in the background text, which lists the level of evidence of cited studies.

The level of evidence is as follows (**Table 1**):

Table 1 Evidence level (EL) (from [84]).*

Level	Evidence
Ia	Systematic review with meta-analysis of randomized controlled studies
Ib	At least one randomized controlled trial
IIa	At least one well-designed controlled study without randomization
IIb	At least one other type of well-designed quasi-experimental study
III	Well-designed non-experimental descriptive study, e.g. comparative, correlation and case studies
IV	Expert committee reports or opinions and/or clinical experiences of respected authorities

* The first version of this guideline was compiled in 2003 and published in 2004, in other words, prior to the development of the DELBI and AWMF criteria for defining the level of evidence. The level of evidence was determined in analogy to the evaluation of guidelines issued by foreign professional associations (s. above) and this form of assessment was retained in the revised version of the guidelines.

2 Introduction

2.1 Aim and problems of CTG recordings

The purpose of CTG recordings is to identify when there is concern about fetal well-being to allow interventions to be carried out before the fetus is harmed. The focus is on identifying fetal heart rate (FHR) patterns associated with inadequate oxygen supply to the fetus.

In general, FHR patterns classified as normal are a reliable indication of fetal well-being. Up to 50% of FHR patterns classified as pathological reflect physiological changes and can therefore be classified as false positives (false pathological). This can lead antepartum to increased numbers of induced births and higher numbers of operative deliveries.

The most common causes of false positives are when certain disturbances and influencing variables are disregarded (e.g., fetal behavioral states, age of gestation), failure to use additional complementary evaluation methods, uncertainty of interpretation, and inconsistent threshold values and assessment modalities [15, 23, 26, 37, 61, 68].

2.2 Physiology and pathophysiology

Fetal heart rate and fetal circulation determine fetal supply. Physiologically, this system is regulated by the nervous system, which controls the heart rate. Medullary centers controlled by pressoreceptors and chemoreceptors and local metabolic processes influence regulation. The continuous adjustment of arterial and venous blood pressure, cardiac output and vascular resistance is responsible for maintaining adequate metabolic capacity.

Deviations from this steady state lead to changes in fetal heart rate (FHR) such as accelerations, variability, tachycardia, decelerations and bradycardia. The complexity of the fetal response to various disturbances and influencing variables often results in misinterpretations of the FHR.

2.3 Influencing factors

FHR is affected by the following factors (EL IIa) (**Table 2**):

Table 2 Factors which affect CTG (modified from [44]).

Maternal	Fetoplacental	Fetal	Exogenous
Physical activity	age of gestation	movement	noise
Posture	umbilical cord compression	fetal behavioral states	medication
Uterine activity	placental insufficiency	stimulation to wake the fetus	smoking
Body temperature (fever)	chorio-amnionitis	hypoxemia	drugs
Fluctuations in blood pressure			

Maternal factors include the well-known vena cava syndrome; however, upright posture can also affect uteroplacental perfusion [91]. Uterine perfusion is directly dependent on maternal mean arterial pressure. High diastolic pressure reduces uterine perfusion. Increased uterine tone and/or contractions are always associated with the risk of reducing the supply of oxygen to the fetus. Identifying this early on is particularly important for preterm infants to prevent brain damage.

Similar changes in CTG patterns may also have fetoplacental causes (e.g. placental insufficiency). While temporary umbilical cord compression usually leads to saltatory FHR patterns, placental abruption can result in a phase of tachycardia followed by bradycardia. Chorioamnionitis can lead to an increase in baseline fetal heart rate coupled with decreased variability, even before the rise in maternal temperature is recorded. Particularly in preterm infants, persistent fetal tachycardia over a longer period of time triggered by endotoxins should prompt attendant gynecologists to consider early delivery of the infant as there is a known correlation between fetal brain damage and chorioamnionitis [32].

The most important fetal factors which affect the heart rate curve are “age of gestation” and “fetal behavioral states” [20].

From the 34th week of gestation on, fetuses show a cyclical change in heart rate patterns associated with changes in fetal behavioral states and fetal movement, shifting between resting (stage 1F, duration 20–30 min) and activity (stage 2F, duration 20–90 min); these changes are the surest sign of fetal well-being during the initial stage of labor and in the expulsive stage of labor. Mature fetuses spend around 80–90% of their time in one of these two defined states of activity. The remaining time they spend in a quiet (stage 3F) or active (Stadium 4F) waking state. Most studies on the physiological development of fetal heart rate patterns are referring to these periods, and the findings of these studies therefore only apply after the 34th week of gestation.

Fetal breathing movements used to be regarded as indications of fetal well-being, but they appear too irregularly to be used as indicators. However, they do increase short-term variability which can indicate fetal respiratory arrhythmia. Fetal hiccups are detectable on fetal heart rate monitoring (spike).

Many medications easily pass the placental barrier to reach the brain and other centers of circulatory regulation at high concentrations [24, 45, 62, 78, 100, 101]. This applies in particular to sedatives, anesthetics (both general and local) and antiepileptic drugs, which reduce heart rate variability and result in flatter curves, something that also occurs with corticosteroids (dexamethasone and betamethasone) and cocaine abuse. Magnesium sulfate has also been associated with reduced FHR variability.

Beta mimetics (e.g. fenoterol, salbutamol) which are used for tocolysis are mostly metabolized prior to the placental barrier, but they can still be effective in minute quantities or as metabolites, leading to an increase in fetal heart rate with a simultaneous reduction of variability and heart rate accelerations. Such CTG patterns are usually reversible after 5–7 days at the latest and do not constitute a concrete fetal risk. Antihypertensives such as beta blockers cross the placental barrier on a 1 : 1 basis and, depending on the dose, can result in complete blockage of the fetal sympathetic nervous system. This leads to flattening of accelerations with pronounced bradycardia or even tachycardia. Beta blockade can also impair fetal circulatory centralization and glucose mobilization, which are important if there is a lack of oxygen.

Acoustic factors (stimuli) also affect FHR patterns and can be used for diagnosis (s. also 6.1.4).

3 Method

3.1 Obtaining the signal

Doppler ultrasound is the most common method used to obtain the fetal heart rate (cardiogram). Parallel recordings or separate manual capture must be done initially to avoid confusion with maternal heart rate. Pulsed ultrasound signals are emitted by a Doppler ultrasound transducer placed on the maternal abdomen and are reflected off the fetal heart back to the ultrasound transducer. Autocorrelation processing is then used to calculate fetal heart rate. A cardiogram does not precisely reflect the fetal heart beat one-to-one. Depending on the algorithm used, around five consecutive heart cycles are usually necessary to reconstruct the actual fetal heart rate after removing noise and interference from the raw Doppler signal [64].

A CTG can only be evaluted if the signal failure rate is less than 15%. At the beginning of monitoring and in cases of doubt the maternal heart rate must be differentiated from that of the fetus. The maternal heart rate, which many CTG units also monitor, can be plotted in parallel on the CTG. In cases of multiple pregnancy, the heart rates of all of the fetuses must be plotted separately. In exceptional cases (when the FHR cannot be assessed with certainty, particularly in the expulsion stage, or in the first fetus in a multiple pregnancy) a scalp electrode can be placed directly on the presenting part of the fetal body (e.g. the head) [61].

Registration of uterine contractions is done using an abdominal pressure transducer which converts the abdominal tension created by the contractions into a written signal, the tocogram, which provides information on both the frequency and the duration of contractions. If an external transducer is used, it will only show the relative strength of the contraction through a comparison of amplitudes, but, overall, this depiction of contraction strength is arbitrary. Intra-amniotic pressure recordings are not necessary. It is generally recommended that the CTG should simultaneously record uterine contractions and FHR.

Units with integrated recognition of low-frequency fetal movement signals extract this data from the same Doppler signals obtained from the FHR transducer but using a different signal recognition technology; this additional information is shown using a third channel (kinetocardiotocogram, KCTG).

3.2 Duration of recording, position, plotting speed

Antepartum and on admission to the labor room (admission CTG) the usual (minimum) duration of recording is 30 minutes. Particularly in the third trimester of pregnancy the CTG should be obtained with the mother placed in a left lateral position to prevent vena cava syndrome.

The plotting speed (paper feed) is usually set to 1 cm/min; however, visual resolution is better at a speed of 2 or 3 cm/min. Every hospital should stipulate its own speed to reduce inter-assessor variability when interpretating the recordings.

3.3 Assessment parameters

Fetal heart rate is classified into

- baseline fetal heart rate (baseline rate),
- accelerations,
- decelerations,
- oscillations,
- oscillation amplitude (range),
- long-term oscillations (oscillation rate).

These long-term, medium-term or short-term characteristics are obtained from the FHR curve. If uterine contractions are also present, decelerations are differentiated into regular early and late decelerations and variable decelerations.

The tocogram records the frequency, duration, form and regularity of uterine contractions; intra-amniotic pressure recordings also show baseline tone and amplitude (mmHg).

4 Clinical Importance

4.1 Antepartum

More than 90% of pregnant women routinely have a CTG, although doing a CTG in a low-risk cohort does not improve perinatal outcomes ([37,61,84]; EL IIa). There are no validated studies on the use of CTG in low-risk cohorts in the early weeks of pregnancy (< 34).

Four randomized studies [11,27,48,56] showed no decrease in perinatal mortality and morbidity rates, even in high-risk collectives ([3,54,77]; EL Ia). Meta-analysis even showed that perinatal mortality was signficantly increased if a CTG was done in a high-risk cohort without additional diagnostic procedures (EL Ia). This could be due to a iatrogenically induced higher rate of preterm births. The high number of false positives on the CTG with high rates of inter- and intra-observer variability is a contributing factor ([9,14,55,99]; EL IIa).

Combining CTG with Doppler sonography in high-risk cohorts has reduced perinatal mortality by around 30% ([107]; EL Ia); this indicates that if CTG findings are abnormal, fetal status should be additionally assessed with Doppler sonography, particularly in preterm infants.

4.2 Intrapartum

The first prospective randomized studies were carried out many years ago [30,36,38–40,47,49,52,53,57,58,60,69,70,79,86,92,109] and found no improvement in perinatal outcomes with CTG, even in high-risk cohorts, with the exception of lower rates of neonatal convulsions ([97,98]; EL Ia). The ACOG even came to the conclusion that intermittent auscultation done at prescribed intervals was on a par with CTG monitoring [4]. But if CTG monitoring is waived, the necessary auscultation would be time-consuming and would require higher levels of staffing while providing only sketchy documentation from a medical and legal point point of view [75] with no early identification of fetal deterioration.

More recent studies found electronic CTG monitoring to be beneficial [12,15,23,26,61,68,76]. Vintzileos and colleagues found that the use of computerized CTG monitoring resulted in a reduction of hypoxia-related perinatal mortality rates compared to monitoring done by auscultation alone ([92,103,104]; EL Ib) and also noted a significant improvement in identifying different types of fetal acidemia ([93,103,104]; EL Ib). A meta-analysis of nine studies reported a reduction of perinatal mortality of more than 50%, although this decrease in mortality was associated with a rise in the number of operative deliveries by a factor of 2.5 ([94]; EL Ia). Nelson et al. found the incidence of cerebral palsy and neonatal encephalopathy to be significantly correlated with late decelerations on CTG (OR 3.9) and reduced variability (OR 2.7) ([71]; EL IIa). In the study by Gaffney et al., abnormal CTG patterns were associated with significantly higher rates of neonatal encephalopathy and cerebral palsy ([28,29]; EL IIa). Similarly, Spencer and colleagues reported that abnormal CTG

patterns, classified in accordance with FIGO guidelines, were associated with significantly higher rates of neonatal encephalopathy ([93]; EL IIa).
In 2008, a consensus meeting of the National Institute of Child Health and Human Development in the USA undertook a reclassification of CTG patterns, classifying them into I: normal; II: indeterminate; and III: abnormal [61,76]. This was incorporated in the practical recommendations of the ACOG on the nomenclature and interpretation of CTG patterns [4], and the ACOG recommendations on intrapartum management [5], including a subclassification based on the association with neonatal metabolic acidosis [23].
Fetal monitoring using modern monitoring systems can give rise to ambiguous heart rate readings which are caused by the erroneous attribution of maternal heart rate signals to fetal CTG signals [68]. The risk of failing to identify when a fetus is at risk, which is particularly probable during the expulsion stage, prompted the FDA to publish a warning [26]. The proposed solution to clarify ambiguous heart rate patterns was internal CTG monitoring. Simultaneous pulse oximetry recordings of maternal heart rate signals can also ensure that the CTG is monitoring the fetus [15].

5 Recommendations

5.1 Patient safety

There have been no reports of harmful effects resulting from the low ultrasound energy delivered during Doppler investigation to detect FHR and fetal movement.
The use of an electronic transducer attached directly to the fetal scalp has been associated with infections and injuries in up to 1.3% of cases [6].
Although there are no indications that use of CTG poses an increased risk to patients, cardiotocography and monitoring systems which function on similar principles (e.g. KCTG) should only be used when the indications listed under 5.3 and 5.4 are present. If the signal quality is satisfactory, there is no need to use a fetal scalp electrode intrapartum.

5.2 Duration and frequency of CTG monitoring

When using the FIGO score for the assessment of CTG readings, a reading of 30 minutes is necessary. The duration of the reading should be prolonged if the FHR pattern looks suspicious. A reduction of reading times to 10 minutes is possible with certain analysis methods (e.g. Dawes/Redman; Oxford system) if the results are confirmed. The maximum time for an Oxford CTG is 60 minutes.
Monitoring frequency depends on the individual clinical risk confirmed by cardiotocography. It can range from a single reading done on an outpatient basis to several readings per day to continuous monitoring.
If monitoring is done on an outpatient basis and monitoring sessions are more than four days apart, other monitoring systems with longer advance warning times (Doppler sonography, ultrasound evaluation of amniotic fluid volume, KCTG) should be additionally used, particularly to assess patients with any of the diagnoses given in italics and listed under 5.3.

5.3 Indications antepartum

The authors are of the opinion that the current catalog of indications of the German Maternity Guidelines, which lists only three initial indications for CTG monitoring (impending preterm birth after the 26th week of gestation, changes in heart tone heard on auscultation, suspicion of premature labor) requires urgent revision and have compiled the following recommendations based on the recommendations of the SOGC:
Indications for antepartum CTG monitoring are

- maternal anemia (hemoglobin < 10 g/dl or ≤ 6 mmol/l),
- fetal arrhythmia (particularly tachyarrhythmias) on ultrasound,
- bleeding during late pregnancy,
- blood group incompatibility,
- *hypertension (≥ 140/90 mmHg),*
- diabetes mellitus type I and II,
- suspicious or pathological fetal Doppler findings (e.g. PI in umbilical artery > 90th percentile),
- drug abuse (e.g. nicotine abuse),
- hydramnios (AFI > 25 cm),
- viral (e.g. parvovirus B19) or bacterial (amniotic infection syndrome) infections,
- decreased fetal movement,
- unstable maternal circulation (orthostatic problems),
- *multiple pregnancy,*
- *oligohydramnios (single pocket < 2 cm),*
- baby overdue > 7 days,
- accident with abdominal trauma or serious maternal injury,
- preterm contractions (tocolysis)/impending preterm birth,
- *fetal growth restriction < 10th percentile [106].*

Doppler investigation should be carried out in addition if any of the indications given in italics are present.

5.4 Indications intrapartum

A 30 minute CTG on admission to primarily exclude fetal risk and verify contractions is considered useful [43].
If the pregnancy is risk-free and the CTG performed during early-stage labor was unremarkable, the interval for electronic fetal surveillance intrapartum can range from once every 30 minutes up to a maximum of every two hours (minimum duration of reading at least 30 minutes); if it is not possible to take a reading, monitoring should be done by auscultation (at least 10 minutes with strict documentation) [41,90]. Continuous CTG monitoring should start late in the first stage of labor and during the expulsion stage. However, in high-risk pregnancies (s. antepartum indications for CTG), if oxytocics are administered during labor, or if complications arise such as fever, bleeding, or green amniotic fluid, continuous CTG monitoring should be done throughout the first stage of labor and the expulsion stage if contractions can be confirmed (ACOG, SOGC, RCOG).
CTG monitoring is also indicated for tocolysis or after the administration of contraction-inducing drugs (oxytocin, prostaglandins) if contractions can be confirmed.
If pathological FHR patterns persist for more than 30 minutes, fetal blood analysis (FBA) should be done on the presenting part of the fetal body to clarify the findings, where technically possible. Determination of lactate concentrations can provide additional information and is considered to be an alternative to blood gas analysis in the ACOG criteria [4]. Exceptions include severe fetal bradycardia, prolonged decelerations > 3 minutes or other highly pathological CTG patterns (e.g. sinusoidal pattern), which require immediate intervention to deliver the baby.

5.5 Classification

5.5.1 FHR parameters and assessment criteria (Table 3)

Table 3 FHR parameters and their definition (modified after ACOG, FIGO, SOGC, RCOG).

Term	Definition
Baseline (bpm)	is mean FHR maintained over at least 10 minutes in the absence of accelerations or decelerations, given in beats per minute (bpm). For immature fetuses, mean FHR was in the upper range of variation. A progressive increase of FHR must be monitored carefully!
▶ normal	normal range: 110–160 bpm*
▶ suspicious	slight bradycardia: 100–109 bpm
	slight tachycardia: 161–180 bpm without simultaneous accelerations
▶ pathological	severe bradycardia: < 100 bpm
	severe tachycardia: > 180 bpm
Range (variability) (bpm)	fluctuations in the fetal baseline rate occur 3–5 times per minute. The range is the difference in bpm between the highest and the lowest fluctuation during the most part of the 30 minute reading monitor strip.
▶ normal	> 5 bpm during the interval when no contractions occur
▶ suspicious	< 5 bpm and > 40 minutes, but < 90 minutes or > 25 bpm
▶ pathological	< 5 bpm and > 90 minutes
Accelerations	increase of FHR > 15 bpm or > ½ range and > 15 seconds**
▶ normal	two accelerations in 20 minutes
▶ suspicious	periodical occurrence with every contraction
▶ pathological	no accelerations > 40 minutes (significance is still unclear, assessment is therefore questionable)
Decelerations	drop in FHR > 15 bpm or > ½ range and > 15 seconds
▶ normal	none
▶ suspicious	early: uniform, periodically recurring drop in FHR is correlated with contractions, decrease in FHR begins at the start of contraction. Return to baseline at the end of the contraction. **Variable decelerations:** variations in form, duration, depth and correlation with contractions, intermittent/periodically recurring decrease in FHR with rapid onset and quick recovery. Can also appear as an isolated phenomenon (associated with fetal movements). **Prolonged decelerations:** abrupt FHR drop below baseline for at least 60–90 seconds < 3 minutes.
▶ pathological	**Late:** uniform, periodically recurring FHR decrease is correlated with contractions and starts between the middle and end of the contraction. Nadir > 20 seconds after contraction has peaked. Return to baseline after contraction has ended. If the range is < 5 bpm, decelerations < 15 bpm may also be pathological.
	Atypical variable: decelerations with one of the following additional characteristics: ▶ loss of primary or secondary FHR rise, ▶ slow return to baseline after the contraction has ended, ▶ longer increased baseline after contraction, ▶ biphasic deceleration, ▶ loss of oscillation during deceleration, ▶ resumption of baseline rate at a lower level.
	Prolonged decelerations: must be considered pathological if they persist for more than two contractions or > 3 minutes.
	Sinusoidal pattern: long-term fluctuation of baseline resembling a sinus waveform. The smooth undulating pattern lasts at least 10 minutes and returns at relatively fixed intervals of 3–5 cycles per minute with an amplitude of 5–15 bpm above and below baseline. No variability of baseline can be established.

* Recent studies found that the physiological range for fetal heart rate at term was probably between 115 (4th percentile) and 160 beats per minute (96th percentile) ([17, 105]; EL II).
** < 32nd week of gestation, rise of FHR > 10 bpm or > ½ range and > 10 seconds. If accelerations are > 10 minutes, this is considered a change in the baseline rate.

The authors recommend classifying CTG readings into normal/suspicious/pathological (NSP classification) (**Tables 4** and **5**):

Table 4 Evaluation of individual FHR parameters (modified after ACOG, FIGO, SOGC, RCOG).

Parameter	Baseline rate (bpm)	Range (bpm)	Decelerations	Accelerations
Normal	110–160	≥ 5	none[1]	present, sporadic[2]
Suspicious	100–109 161–180	< 5 ≥ 40 minutes > 25	early/variable dec. individual prolonged dec. up to 3 minutes	present, periodical occurrence (with every contraction)
Pathological	< 100 > 180 sinusoidal[3]	< 5 > 90 minutes	atypical variable dec. late dec. isolated prolonged dec. > 3 minutes	absent > 40 minutes (significance still unclear, evaluation questionable)

[1] FHR deceleration amplitude ≥ 15 bpm, duration ≥ 15 seconds
[2] FHR acceleration amplitude ≥ 15 bpm, duration ≥ 15 seconds
[3] sinusoidal FHR: ≥ 10 bpm, duration ≥ 10 minutes

Table 5 FHR classification into normal, suspicious, pathological including need for action (based on FIGO).

Category	Definition
Normal	All four assessment criteria are normal (no action required)
Suspicious	At least one assessment criterion is suspicious and all others are normal (need for action: conservative)
Pathological	At least one assessment criterion is pathological* or two or more are suspicious (need for action: conservative and invasive)

* does not apply to accelerations

Intrapartum, the CTG reading must be constantly classified. The 30 minute segment with the highest number of suspicious or pathological FHR parameters must be analyzed (if present). If the patterns are unremarkable, an entry on the CTG printout or in the file with an identifiable signature (s. Documentation) every two hours (e.g. N for normal) is sufficient. The analysis is done by the midwife or physician.

If an assessment is classed as "suspicious", a repeat assessment should be done after 30 minutes and the number of suspicious parameters must be recorded (e.g. S1 for "1 suspicious parameter"). A number of conservative measures can be taken to clarify or improve the patterns (e.g. change of position, infusion).

If the reading is classified as "pathological", assessment must be continuous and recorded every 10 minutes including information on the number of suspicious parameters (e.g. S2 or P4 for 4 pathological parameters). In addition to various conservative measures (e.g. tocolysis, attempts to wake the fetus, change of position, infusion, O_2 administration), fetal blood analysis (FBA) should be done, if possible or useful (exception: at the end of the expulsion stage). If no improvement in the CTG pattern can be achieved for one of the three important parameters or FBA shows pathological values (**Table 6**), rapid delivery of the fetus is indicated.

5.5.2 FIGO guidelines

The FIGO guidelines can be used both antepartum and intrapartum. The moment one of the specified criteria is defined as suspicious or pathological, the entire CTG is considered suspicious or pathological. The CTG reading is also classified as pathological if two supicious criteria coincide (s. **Table 5**). The FIGO score is currently the only score which enjoys widespread consensus. The assessment of a CTG reading using a score forces the evaluator to consider the CTG reading very carefully and offers an opportunity to create a more objective record of progress [34]. However, the more complex the score, the more difficult it is to reproduce it. Assessment mechanisms based on categorizing CTG criteria into "no action required" and "action required" have been found to offer the best reproducibility. Postnatal morbidity was found to be higher when the FIGO score was pathological [93]. However, it is important to point out that the evidence provided by the above-listed CTG criteria has only been verified for the time after 34th week of gestation. Below the 34th week of gestation, other criteria apply, s. **Accelerations [4].

5.5.3 Electronic online assessment

Studies on inter- and intra-observer variability have shown that the introduction of computer-assisted classifications of CTG readings has resulted in a more reliable categorization of CTG patterns overall [37,46]. The benefit of "online" CTG analysis is that asssessment can be done almost in realtime. All methods currently used for online assessment (e.g. Dawes/Redman, DMW-FIGO, [89]) are reliable and can be recommended for use. The Monica system (AN24) uses 5 electrodes placed on the maternal abdomen and records the electronic readings of fetal heart beat and uterine contractions over time and has been approved for use both antepartum and intrapartum. Uterine activity is shown on an electrohysterogram with results comparable to those obtained with tocography [35].

However, there are as yet no evidence-based studies showing the impact of long-term recordings with these systems on perinatal mortality and morbidity [51].

Automatic computerized CTG analysis has improved intra- and inter-individual reproducibility [88,89]. Care must be taken to ensure that suitable training is available to teach the necessary basic understanding of the physiology and pathophysiology of the fetal circulation required to adequately assess CTG readings.

6 Additional Diagnostic Tests and Their Significance

6.1 Antepartum

6.1.1 Non-stress test

The term used internationally to refer to a CTG examination carried out at rest is non-stress test (NST).

Physiological principles: The NST is based on the assumption that a well fetus modulates its heart rate through the autonomic effects of the sympathetic and parasympathetic nervous system. Heart rate regulation in the non-distressed fetus responds to fetal movement by an acceleration of the heart rate (this applies from the 34th week of gestation).

Assessment of the NST: The NST is based on a cardiotocogram without induced contractions. The accelerations of fetal heart rate which occur with fetal movement are assessed. A reactive pattern is present if NST is carried out over a period of 20 minutes with two FHR accelerations associated with fetal movement. A decrease in or complete lack of accelerations (fetal movements) can indicate fetal lack of oxygen.

In addition to decreased accelerations it is also important to note variations in fetal heart rate. A decreased oscillatory pattern with a range of < 5 beats/min over a longer period (> 90 min) is associated with increased perinatal morbidity [71].

Evidence base for the use of NST: The analysis of four prospective randomized studies [11,27,48,56] on the use of non-stress CTG recordings antepartum showed no discernable benefits ([77]; EL Ia). This means that, after consideration of the evidence base, routine use of NST *cannot be recommended*.

6.1.2 Stress test

In a contraction stress test, fetal heart rate is assessed during uterine contractions. The contraction stress test is carried out during either spontaneous or induced contractions (administration of oxytocin for oxytocin challenge test = OCT). The physiological principle behind contraction tests is a brief restriction of uterine perfusion during the contraction. FHR deceleration may occur at "borderline" oxygenation.

The use of OCT has also *not been found to yield any evidence-based clinical benefits* ([94,97]; EL IIa). The reported false-positive rate is as high as 50%. Undesirable side-effects of OCT can include polysystole and continuous contractions with fetal bradycardia.

6.1.3 Doppler sonography

Ultrasound echo envelope analysis and analysis of systolic-diastolic variability means that Doppler sonography (DS) findings can be reproduced better than the results of CTG and all CTG-based tests including OCT. Use of DS antepartum in high-risk cohorts (see German Maternity Guidelines) in prospective randomized studies showed that DS was the only method which led to a significant decease in perinatal morbidity of approximately 30% without increasing the rate of operative interventions ([107]; EL Ia). Umbilical artery velocimetry was also found to provide the best advance warning, even prior to the occurrence of pathological CTG patterns (approx. three weeks between the 24th and the 37th week of gestation) compared to all other monitoring methods.

As one of the indications for the use of antenatal DS listed in the German Maternity Guidelines is "suspicious" fetal FHR readings, this method should *always be used* in pregnancies in the period prior to the due date (< 37 + 0 week) and when FHR is pathological to prevent a iatrogenic preterm birth.

When DS findings are pathological (particularly in cases with circulatory centralization or end-diastolic zero and reverse flow in arteries and veins), FHR readings should be recorded as part of continuous monitoring; the specificity of FHR readings increases significantly in preselected cohorts.

The venous compartment will not necessarily become pathological in all cases with increasing decompensation ([25]; EL IIa). The are currently no long-term studies on the benefits of using venous Doppler in compromised fetuses.

6.1.4 Fetal stimulation

Fetal stimulation (digital, acoustic, photo-optical, and, most sucessfully, vibroacoustic) can be used to clarify reduced or non-reactive FHR patterns associated with fetal deep sleep phases. The incidence of these patterns can be reduced by 48% by these method, increasing the specificity of the CTG ([96]; EL IIa).

Only one or a maximum of two short (1 s) pulses should be administered, for example using a modified electrolarynx, as risks to the fetus have been reported for more intensive applications. However, the potential impact on fetal hearing has not yet been sufficiently studied.

As the current evidence base has not found any improvement in perinatal outcomes, a better – but not quicker – alternative consists of prolonging the duration of CTG readings (> 40 min) until the end of the sleep phase.

6.1.5 Fetal behavioral states

In the last weeks of pregnancy, around 80% of fetuses show periodically recurring behavioral states which can also occur intrapartum. Four different behavioral states have been classified ([73]; EL IIa). Fetal deep sleep phases are characterized by a reduced or almost silent range of variability, which can be misinterpreted as suspicious for hypoxia. Prolonging the duration of the reading > 40 minutes or using stimuli to wake the fetus (e.g. vibroacoustic stimulation, s. above) can help to differentiate the diagnosis. This is particularly important in view of the fact that the fetus spends around 40% of the day in a resting state, and 25–35% of that time in a state of deep sleep. Failure to differentiate leads to a high number of false-positive CTG findings ([73]; EL IIa).

6.1.6 Biophysical profile

The biophysical profile consists of a synoptic examination of fetal breathing and body movements, muscle tone, amniotic volume (using ultrasound) and fetal reactivity (in CTG at rest) with findings compiled into a score. The aim of this method, which is used predominantly in the USA and the UK to monitor high-risk pregnancies, is to improve the prediction of fetal risk compared to predictions based on conventional monitoring of individual criteria. Although numerous studies have reported a high negative predictive value, particularly when results were negative, meta-analysis of randomized studies in the Cochrane Database of Systemic Reviews found no benefits in terms of perinatal outcomes ([2,63]; EL Ia).

6.1.7 Fetal movement

Insufficient oxygen or nutrient delivery will result in the fetus economizing its energy requirements, among other things by reducing the intensity of its movements. A reduction in the duration of fetal movement is an early indication (by approximately 12–14 days) of imminent fetal risk. Continuous electronic recording of fetal movement is done using a kinetocardiotocogram (KCTG). The KCTG records fetal movements in a third channel in addition to CTG recordings; the number and duration of movements are depicted using columns of various lengths. An algorithm based on the Doppler principle records low-frequency signals of the extremities and body movements. Signal acquisition of movement was found to have a sensitivity of 81% and a specificity of 98% and is far superior to maternal perception of movement. A reduction in the duration of fetal movement below the 5th percentile of published standard curves is considered pathological ([33]; EL IIa). The number of fetal movements, recorded at the same time, only decrease quite late, which means that it is not a useful parameter for fetal monitoring. As FHR accelerations can be matched to fetal movements, the baseline can be defined precisely in suspicious FHR patterns, reducing the rate of false positives by up to 50% ([33]; EL IIa).

6.2 Intrapartum

6.2.1 Fetal blood analysis intrapartum

Discontinuous fetal blood analysis (FBA) using the Saling technique [87] provides a reliable way of monitoring the fetal acid-base status which is largely independent of any effects caused by medication.

The indication for FBA using blood from the fetal scalp is based on heart rate patterns: FBA should be done if the CTG pattern is pathological; the exception is prolonged deceleration > 3 minutes, where preparations should be made to deliver the infant quickly (**Table 6**).

Table 6 pH values, PCO_2 und base excess (BE) obtained from fetal blood analysis (FBA) and recommended procedures (modified after FIGO).

Fetal blood analysis (FBA)*	Recommended procedure
pH ≥ 7.25	If FHR abnormality persists, FBA should be repeated after an interval of 30 minutes.
pH 7.21–7.24	FBA should be repeated after an interval of 30 minutes or rapid delivery of the fetus should be considered (if pH value has dropped quickly since the last measurement).
pH ≤ 7.20 PCO_2 > 65 mmHg (acidosis) BE > −9.8 (e.g. −15) mmol/l (metabolic acidosis)	Quick delivery of the fetus is indicated, particularly if metabolic acidosis is present.

* All measurements of fetal blood should be interpreted to take account of the initial pH value, the metabolism, the progress of labor and other clinical findings of the fetus and mother.

Contraindications and barriers to FBA include (modified after RCOG)

- maternal infection (e.g. HIV; hepatitis A, C; herpes simplex virus),
- fetal clotting disorders (e.g. hemophilia),
- preterm birth (< 34th week of gestation),
- closed or insufficiently dilated cervix,
- non-presenting fetus in a multiple pregnancy,
- end of expulsion phase (the focus should be on delivering the fetus quickly).

Current pH is the most important fetal blood parameter for a diagnosis of hypoxemia. Maternogenic fetal acidosis and a physiological decrease of fetal pH in fetal blood analysis may have clinical consequences. The 10th percentile for pH values of fetal blood at the end of labor in term infants is 7.20. In addition to measuring acidosis, determination of pO_2 and pCO_2 and calculation of the base excess are useful to diagnose fetal status. Determination of lactate concentration in fetal blood is less prone to errors [1, 21, 81].

The value of FBA lies in its combination with CTG to monitor labor. In cases where FHR patterns cannot be interpreted or are abnormal, determining the parameters of the acid-base metabolism will provides the required diagnostic information.

The use of FBA leads to a significant reduction of avoidable operative deliveries and to a reduction of neonatal convulsions ([12, 40, 102–104, 111, 112]; EL II).

7 Obligation to Record and Store Information

The CTG readings must always be assessed by a midwife or a physician and the readings must be signed off using an identifiable signature. Every CTG must be labeled to include the most important personal particulars of the pregnant woman, the week of gestation and (if not automatically included) the date and time of the recording. Depending on the professional regulations in the individual federal states in Germany, medical records (CTG and patient files) must be stored for at least ten years (in some federal states in Germany up to 30 years). If electronic storage devices are used, it is important to ensure that they cannot be overwritten or erased and that they comply with the regulations specifying the duration of data storage [19, 90].

8 Education and Training

Evidence-based data has shown that regular CTG training improves fetal outcomes. Attendance at and participation in such training should therefore be encouraged ([7, 65]; EL II a). The use of electronic systems with integrated signal analysis (unremarkable, suspicious, pathological) is useful for education and training as the success of the training can be measured objectively before and after training (EL I a).

9 Other Developments

9.1 Antepartum diagnosis

9.1.1 Automatic CTG assessment

The Dawes/Redman criteria are exclusively used to describe fetal status antepartum using a computerized analysis of fetal heart rate variability with the aim of obtaining an objective assessment in the shortest possible time (minimum 10 min). The data obtained was correlated with outcome criteria and it was shown that achieving the Dawes/Redman criteria was a significant indicator that the fetus was not at risk ([16, 95]; EL II a).

Criteria indicating that the fetus is not at risk include:

- short-term variation (short-term variation, STV) > 4 ms (STV measures variations in the mean absolute difference in time between consecutive heart beats; this data can only be obtained from computer readings),
- no sinusoidal rhythms,
- at least one episode of higher FHR variation,
- no deep or repeated FHR decelerations,
- FHR accelerations and/or fetal movements,
- normocardia.

A decrease in STV detected during serial observations can be an indication of increasing compromise of the fetus between the 25th and 38th week of gestation (EL II a), **Table 7**, caused by a disturbance in the interaction between the sympathetic and parasympathetic autonomic nervous system.

Table 7 Association between short-term variation, metabolic acidosis and intrauterine fetal death (IUFD).

STV (ms)	< 2.6	2.6–3.0	> 3.0
Metabolic acidosis	10.3 %	4.3 %	2.7 %
IUFD	24.1 %	4.3 %	0 %

However, there is currently no data from prospective randomized studies confirming the benefits of this method. The data from such studies is still being evaluated (Oxford study, TRUFFLE study).

9.1.2 Other approaches

Another method has focused on the electronic quantification of relevant heart rate patterns and their correlation with perinatal data (Q-CTG) ([80]; EL II b).

Another approach consists of “online” analysis of fetal heart rate based on the FIGO score and using “traffic light” labeling (green = no findings, yellow = suspicious, red = pathological [88; II b]). The system with its visual analysis was tested by CTG experts and resulted in a significant improvement of reproducibility. A panel of experts has also favored use of a 3-step system [61]. More recently, STV based on the Dawes/Redman criteria can also be calculated online independent of the device used and combined with the FIGO score [88].

Studies on and experience with the use of mobile CTG devices used for telemedical home monitoring have consistently shown that the technique is safe and use of mobile CTG devices is associated with high patient satisfaction.

The introduction of electronic documentation systems is generally recommended (online assessment with a high degree of reproducibility) (EL IV [35, 42, 76]). But all systems which interfere with the physician’s ultimate authority to take decisions and decide on the appropriate therapy and which would have consequences in terms of the physician’s liability for damages should be firmly rejected.

At present it is still not clear whether such analyses will lead to detailed or binding recommendations for action.

9.2 Intrapartum

9.2.1 ST segment analysis (STAN)** with direct fetal ECG

An increase in T-wave amplitude is the result of increased glycogen depletion in fetal myocardial cells during metabolic acidosis. The T/QRS ratio increases as fetal hypoxia increases with consequent metabolic acidosis during labor. The method can be used for intrapartum monitoring after the 36th week of gestation (contraindications for STAN with its use of a fetal scalp electrode are the same as those listed for FBA).

FHR must be analyzed together with any ST events to draw clinical conclusions.

Studies have shown a reduction in the rate of operative deliveries and fewer neonates with metabolic acidosis. Under certain conditions (30 minutes recording time, initial analysis of fetal acid-base balance), the continuous availability of information on metabolic parameters can reduce the need for FBA with the Saling technique while offering the same level of monitoring ([18, 67, 74, 108]; EL IIa).

But when signals are pathological, fetal hypoxemia/hypoxia is often far advanced, leaving little room for maneuver.

The method was summarized in a Cochrane review published in 2006 [8, 67]: four studies investigating around 10 000 women in labor compared fetal monitoring using CTG with or without the use of ST waveform analysis as an adjunct to CTG (EL Ia). Significantly fewer neonates with severe acidosis or neonatal encephalopathy were born in the group monitored using STAN, and there were fewer operative deliveries and lower rates of fetal scalp blood sampling. The reduced incidence of acidosis in the group additionally monitored with STAN was attributed less to the lower sensitivity of CTG; it could be ascribed to the fact that STAN provided additional indications when the fetus was at risk [83]. The negative aspect of STAN for fetal monitoring is the requirement for internal fetal scalp electrodes.

The main problem of evaluating the STAN method for fetal monitoring is that no study has yet attempted to avoid the "treatment paradox" [66]. This refers to the fact that under certain circumstances a test may appear to be poorly predictive because during the assessment stage the physician is aware of the findings and provides effective treatment for cases with abnormal findings. The physician then associates abnormal findings with good outcomes. The reverse can also be true.

Until such a study is available, the method cannot be broadly recommended.

9.2.2 Pulse oximetry

Fetal pulse oximetry measures fetal oxygen saturation ($FSpO_2$) intrapartum by placing a sensor on the fetal cheek or scalp (using a spiral electrode). Animal studies and clinical studies have shown that when $FSpO_2$ was less than 30%, the number of cases with fetal hypoxemia was significantly higher [50].

In a Cochrane review published in 2004 only one study met the strict requirements ([13, 22]; EL Ib). Although the cesarean section rate for imminent hypoxia was lower in the pulse oximetry group, the overall rate remained unchanged. A study published in 2006 [10] compared more than 5000 women in labor. In one group, pulse oximetry data were displayed to the clinician during labor while the pulse oximetry data for the other group were hidden. Knowledge of pulse oximetry data was not associated with a reduction in cesarean section rates or in a reduction in the rates of neonatal acidosis.

Pulse oximetry appears to have a lower sensitivity for registering non-reassuring fetal status compared to CTG [31]. This applies particularly in cases with fetal anemia where oxygen saturation is good but oxygen supply to the body can be poor.

Even though the technical problem of a loss of signal due to inadequate probe fixation has largely been solved through the use of invasive scalp electrodes, based on the currently available data, pulse oximetry as an adjunct to CTG monitoring during labor *cannot be recommended.*

10 Summary of Recommendations

Use of CTG monitoring antepartum in high-risk pregnancies which are determined based on the patient's previous history or suspicious findings (s. Indications) provides indications of immiment fetal risk. However, the advance warning time for decompensation provided by CTG ranges between one and four days. For pregnancies at chronic risk, it is prudent to use additional monitoring methods with longer advance warning times, such as Doppler sonography, ultrasound evaluation of amniotic fluid volume, or KCTG to measure fetal movement. The high false-positive rate of up to 60% reported for CTG caused by numerous sources of disturbance and other influencing factors can be reduced by the additional use of Doppler sonography, longer FHR recording times, or fetal stimulation (waking the fetus).

Analysis of hypoxia-induced morbidity shows that use of CTG monitoring intrapartum significantly reduces both perinatal mortality and neonatal morbidity (reducing the incidence of convulsions in the neonatal period and the incidence of cerebral palsy). The high false-positive rate for CTG monitoring intrapartum which could potentially lead to increased rates of operative deliveries can be reduced through the additional use of fetal blood analysis. Other adjunct methods such as ST segment analysis improve the specificity of the CTG and reduce the need for fetal scalp blood analysis.

Fetal status should be evaluated both antepartum and intrapartum using assessment criteria which should be as objective as possible. The FIGO score, which quantifies the CTG parameters, is particularly suitable, as are various electronic methods currently being developed, which analyze CTG findings "online".

A good understanding of the physiology and pathophysiology of fetal cardiac and circulatory regulation is essential for a competent interpretation of fetal heart rate patterns.

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