Until the second half of the 20th century assessment of the fetal condition depended on very limited means: the growth of the uterus and its contents, the movements of the fetus perceived by the mother and the listening of the fetal heart beat with a mono- or binaural stethoscope.

This recurrent dilemma, whether or not the fetus had died in utero, formed the major impulse for the development of cardiotocography (2). Initially fetal abdominal electrocardiography and phonocardiotocography were pursued, but failed, primarily due to technical problems. It was only when the fetal heart beat could be rather easily detected by means of ultrasound (the Doppler-shift) or through the application of direct electrocardiography, that cardiotocography became popular as the method to monitor the condition of the fetus. Currently the majority of obstetric decisions to assist delivery of the baby by artificial means (caesarean section, forceps or vacuum extraction) for reasons of suspected fetal distress, relies on information gathered through the application of cardiotocography.

It is the obstetrician’s reassurance that the fetal heart rate (FHR) pattern is normal and the nearly 100% certainty that the fetus is in a good condition, which has made cardiotocography so attractive and has induced its widespread use. This development is very understandable considering the dependence on indirect signals from the fetus and the problems mentioned in the first paragraph concerning the very limited means to monitor the condition of the fetus prior to the introduction of cardiotocography. However, now cardiotocography is in use for some decades criticism towards the method itself and objections to its widespread application are increasing (table 1). These criticisms and objections will be discussed in more detail and it will be tried to reach a more differentiated opinion.

THE NORMAL AND ABNORMAL FHR PATTERN
The normal fetal heart rate (FHR) pattern is characterised by a baseline frequency between 110 and 150 beats per minute, presence of periodic accelerations, a normal heart rate variability with a bandwidth between 5 and 25 beats per minute and the absence of decelerations (3). In this regard the accentuation of the 120 and 160 frequencies is misleading. It originates from the second half of the 19th century when the normal frequencies by Von Winckel were stated to be between 120 and 160 beats per minute.

The FHR pattern is abnormal when one or more of the following features are observed: a baseline frequency below 110 or above 150 beats per minute, absence of accelerations for more than 45 minutes, decreased or absent FHR variability and the existence of repeated variable or late decelerations. A baseline frequency between 100 and 110 can be considered as normal when the
duration of pregnancy has exceeded 41 weeks.

ARE THE CRITICISMS ON CARDIOTOCOGRAPHY JUSTIFIED?

In recent years cardiotocography has been criticized for a number of reasons. A far from complete summary is given in table 1. The criticisms have a very diverging character. Each of them will be commented on in the following paragraphs.

The FHR pattern is a too indirect signal of the fetal condition

The (patho-)physiologic background of the fetal heart rhythm is extremely complex (4). Blood pressure, cardiovascular regulation, the condition of the autonomic and voluntary central and peripheral nervous system, respiration, temperature regulation, the renin-angiotensin system, the functioning of the adrenals, endocrine mechanisms, the cardiac conduction systems, the condition of the vessel walls and cellular processes, all contribute to the shape of the heart rate pattern recorded on paper or a visual screen. Under normal circumstances the FHR pattern primarily represents the state of the central nervous system, i.e. the 24-hour (circadian) rhythms and the cycling of behavioural states (ultradian rhythms). When the condition of the fetus is being threatened there is a shift to a more likely representation of disturbances in the regulation of the blood pressure and the cardiac performance, and ultimately a direct influence on the fetal heart.

Artificial occlusions of the umbilical cord circulation and the uterine circulation in animal experiments have contributed to a better understanding of the various aspects of the fetal heart rate pattern under pathologic circumstances. The human situation is far more complex though. Successive uterine contractions vary in duration and intensity. The position of the human fetus may change. The amount of amniotic fluid varies from fetus to fetus. Occlusions of the uterine circulation, umbilical vessels and/or placental circulation can be absent, be partial or even be total. The circulation in the umbilical vein and/or one or both umbilical arteries can be affected. These are just a few of the many combinations on the circulatory level that may occur when the fetal condition is threatened. Next there are the many complex variations regarding the biochemical status of the fetus, in particular the state of the acid-base balance. It should be remembered that depth, duration and shape of variable decelerations have no direct relation to the acid-base balance of the fetus at a particular moment (5).

Differences in techniques

For a correct understanding of the FHR pattern as recorded on paper or a screen it is essential to understand the technical procedures involved with the acquisition and processing of the heart beat signal obtained through ultrasound or direct electrocardiography (6). The cardiotocographic equipment has been improved markedly since the introduction of cardiotocography. Nevertheless some technical problems have never been fully resolved: some artificial FHR variability, halving and doubling of heart frequencies, recording of cardiac arrhythmias and recording of the maternal instead of the fetal heart frequency. The major problems, though, occur in clinical practice. There is no uniform opinion regarding the preferred paper speed. Recording speeds vary from 1 to 2 to 3 centimetres per minute, depending on the obstetric unit. A low paper speed facilitates the overview of a recording but has predominant disadvantages: ‘long-term’ FHR variability is artificially accentuated, ‘short-term’ variability is hardly recognisable and the time-relation between uterine contractions and decelerations is more difficult to assess.

The many influences of the FHR pattern

The healthy near-term fetus demonstrates a characteristic FHR pattern with continuous cycling of a ‘reactive’ and a ‘non-reactive’ FHR pattern representing the cycling of the sleep states 2F (REM sleep, active sleep) and 1F (non-REM-sleep, quiet sleep) (7). This cycling is interspersed, in particular around midnight with periods of fetal activity (‘jogging’) accompanied by recurrent accelerations sometimes mimicking fetal tachycardia. The maximum duration of a 1F state is 45 minutes in a healthy fetus.

When pregnancy advances accelerations increase in number, duration and amplitude. Variability increases during the 2F states, but is nearly constant after 26 weeks gestational age in 1F state (8). The variability in the 1F states primarily relates to the absence or presence of clusters of regular mouthing movements (associated with oscillations!) or breathing movements (associated with short term variability!) (9). FHR variability may vary from day to day and week to week in the individual fetus (8).

Interpretation of a cardiotographic tracing is particularly difficult early preterm. Generally the decision to start cardiotocography is determined by a serious obstetric problem such as presence of intrauterine growth retardation, rupture of membranes, vaginal blood loss or pregnancy induced hypertension. Interpretation then is not only more difficult because of the age of the fetus and the presenting obstetric problem, but moreover also because of the use of maternally administered
medication. Betamimetics increase the baseline FHR and are associated with a decrease in FHR variability. Magnesium sulfate causes a decrease in FHR variability. Antihypertensives may cause tachycardia, bradycardia, flattening of the accelerations or a decrease in variability.

Bethamethasone, contrary to dexamethasone, leads to a decrease in the incidence of fetal body and breathing movements and concomitantly a decrease in the number of accelerations and diminished variability (10).

**High intra- and inter-observer variability**

Reading, classification and interpretation should be the successive steps in the assessment of cardiotocographic tracings. Often too easily a conclusion is reached in (vague) terms of a suspicious, pathologic, ominous or terminal FHR pattern.

The high intra- and inter-observer variability concerning the classification and interpretation of FHR patterns has been substantiated in a large number of publications. Assessment of the baseline frequency and the presence or absence of accelerations and decelerations is rather uniform, but lacks any uniformity when FHR variability and deceleration types are concerned (11). Easy, exact guidelines as to how to determine and to interpret FHR variability are lacking. It appears that in daily obstetric practice variable decelerations far too often are classified as early or late decelerations, merely on the basis of the time-relation between the associated uterine contraction and the deceleration. The typical characteristics of the variable decelerations is that they vary in shape, duration and depth and on this basis nearly all decelerations occurring during labour should be classified as being of the variable type (12). The ‘shouldering’, i.e. the increase in FHR prior to and following a variable deceleration, can incorrectly be interpreted as an acceleration. Their monotonous and recurrent character is, though, very different from the irregularly spaced accelerations occurring in association with fetal body movements. Recurrent increases in the fetal heart rate during uterine contractions should raise suspicion that the (umbilical) venous circulation is being obstructed.

**The low validity, high false-positive rate**

The low validity of cardiotocography is concluded from a very limited number of earlier performed randomised studies, in which cardiotocography has been compared with intermittent auscultation. These studies suffer from a number of serious drawbacks and inadequacies concerning patient selection, sample size, randomisation procedures, in- and exclusion criteria, the knowledge of the responsible obstetricians how to classify and interpret cardiotocographic tracings and the comparability of the applied intermittent auscultation with daily obstetric practice (dedicated nurses participated in the auscultation groups).

A major problem with these and other studies aiming to assess the validity of cardiotocography and related procedures is the lack of solid endpoints concerning the fetal condition. One of the few hard endpoints is the status of the acid-base balance in arterial and venous cord blood, often applied to assess justification of artificial deliveries for reasons of suspected fetal distress. The primary aim of obstetric interventions in this regard is, though, to prevent fetal distress and as such these measures are not very helpful to assess adequacy of obstetric management in individual cases.

**Cardiotocography increases medico-legal vulnerability**

Sonography and cardiotocography have been named as the ‘minefields of obstetrics’. In contrast to antepartum monitoring it is the intrapartum application of cardiotocography which may lead to litigation. The knowledge that their baby was in a good condition at the start of the birthing process is for parents an unbearable thought when the baby suffers from handicaps in later life which may possibly relate to the occurrence of fetal distress during the process of labour and delivery. The consumers, supported by legal experts, expect from the obstetrician not so much that she/he diagnoses fetal distress, but on the contrary that a serious threat of the fetal condition is being avoided, certainly if it concerns a child with full potentials for later life. The layman wonders why obstetricians do not all apply the same monitoring techniques and cannot understand why fetal heart rate patterns cannot be classified and interpreted uniformly.

The medico-legal vulnerability associated with the application of cardiotocography and other monitoring techniques is a very complex area. Many aspects are involved, such as the time path followed, the standard of care at a certain moment, the preceding training experienced, the chain of commands at a certain moment, the limitations from merely indirect information, uncertainty when damage to the infant occurred, the confusing nomenclature in use and the lack of exact definitions and guidelines. Nearly all cases are discussed ‘in retrospect’ knowing the fatal result of a particular case. Laymen have little understanding of peak loads in clinical care, the time span necessary before conclusions can reasonably be reached and the intensity of communication prior to a secondary caesarean section. The consumers demand optimal care at each moment in order to maximise
future potentials for their child. They exert more and more pressure on decision making and easily push for a caesarean section when the condition of their child might be endangered.

**Cardiotocography leads to an increase in obstetric interventions**

One of the objections towards electronic fetal monitoring is that the widespread application has induced an increase in the number of obstetric interventions, in particular the incidence of caesarean sections. Randomised studies in the seventies and early eighties have demonstrated a higher incidence of artificial deliveries when cardiotocography was compared with (dedicated) intermittent auscultation. This was especially apparent when FHR monitoring was applied in low risk pregnancies. The adding of microblood sampling as a second mode of fetal surveillance, to assess the fetal acid-base status in case of suspicious or abnormal FHR patterns, clearly reduces the number of obstetric interventions if compared with the application of cardiotocography alone.

Following the introduction of cardiotocography, though, obstetrics and maternal-fetal medicine has developed in a different direction. Certain changes in attitudes of the profession and the public have favoured the obstetric intervention through a certain section such as there are: a shift towards a far lower gestational age at which all is done to increase chances for fetal survival and diminished neonatal morbidity, another approach towards the fetus in breech position both preterm and term, an increase in the maternal age for the first pregnancy, an increase in the number of twins and triplets, another look at the pain experienced by the mother during labour and delivery, other criteria for the duration of the birthing process etc. The main line in obstetric policies has moved towards prevention of serious maternal and fetal risks in whatever circumstances. Large randomised studies in high-risk populations and a recent meta-analysis provide evidence of an approximate 60% reduction in perinatal mortality due to fetal distress when electronic fetal monitoring is applied as a routine in high-risk groups (14). These and other studies support earlier recommendations to apply cardiotocography in risk groups. Risks with a potential impact on the condition of the fetus may be identified already previous to pregnancy (hypertension, diabetes), may show up during the course of pregnancy (vaginal blood loss, early preterm rupture of membranes) or may occur during the process of labour and delivery (meconium staining, FHR decelerations). An anticipative attitude of the obstetrician taking care of the pregnant mother should always be warranted.

**The future of cardiotocography**

Cardiotocography was initially introduced merely on an empirical basis. At the start little was understood of the (patho-)physiology at the basis of the FHR pattern, the many factors influencing the shape of the FHR pattern and the clinical implications to be drawn from ‘abnormal’ FHR patterns. A classic example is the pseudo-sinusoidal pattern related to fetal sucking which for long was not distinguished from the truly sinusoidal pattern associated with serious fetal anaemia or severe fetal acidosis. The simultaneous introduction of guidelines how to classify and interpret FHR patterns by outstanding obstetricians living at different continents (Caldeyro Barcia, Hammacher, Hon, Maeda, Wood) has further contributed to the confusion in nomenclature and definitions, a problem which has not been resolved in world-wide terms until today.

In spite of many efforts, improvements in the quality of the instrumentation, better understanding of the FHR patterns and improved recognition of the position of cardiotocography among the full arsenal of fetal surveillance techniques, the current status of cardiotocography is at the awkward age. It certainly has not reached full maturity yet. The major weaknesses are formed by its application. Differences in paperspeed, lack of uniform and exact definitions, uncertainties regarding how, when and whom to monitor, problems with storage of cardiotocographic tracings, uncertainty if and when fetal microblood sampling should be applied, the generally very limited training of them who are directly involved with fetal monitoring and the lack of guidelines how to handle in the great variety of (often complex) clinical circumstances are just a few of the problems which have weakened the position of cardiotocography as a monitoring technique. Another aspect is the department’s organisation regarding responsibilities at various locations, i.e. the outpatient clinics, the antenatal clinics and the labour and delivery unit? Are there solid and uniform arrangements and can one trust that they are continuously followed by each and any member of the department?

A computerised system permitting digital processing and storage of all fetal heart rate data has a number of potential advantages: the availability of quantified information including analysis of trends, easy retrieval of relevant cardiotocographic traces for education purposes, decreased medico-legal vulnerability concerning lost CTG traces etc. The currently available integration of a number of fetal (heart rhythm, oxygen saturation) and maternal (heart rhythm, electrocardiogram, oxygen saturation, blood pressure) variables in one monitor offers more possibilities for fetal monitoring in future, in particular studies of the effects of changes in the maternal cardiovascular status on the condition of the fetus. There are initial experiences with management supporting
systems in which clinical, biophysical and biochemical data of the mother and the fetus are integrated. These systems still have a long way to go, but certainly deserve further study. Cardiotocography in itself is a useful and indispensable adjunct to monitor the condition of the (endangered) fetus. In this regard the continuous debate concerning its usefulness compared with intermittent auscultation is meaningless. Both methods in principle provide similar information. However, cardiotocography in comparison with intermittent auscultation results in continuous versus spot-like, and objective versus subjective data.

### TABLE 1: CRITICISMS TOWARDS CARDIOTOCOGRAPHY

- insufficient understanding of the (patho-)physiologic background
- a too indirect signal of the fetal condition
- a number of technical pitfalls
- differences in recording techniques
- primarily qualitative information (pattern recognition)
- lack of uniform classification systems
- confusion due to the many influences on the fetal heart rhythm
- substantial intra- and inter-observer variation regarding the interpretation
- low validity, high incidence of false-positive findings
- primarily screening method, too often applied as a diagnostic
- leads to an increase in artificial deliveries
- lack of agreement on how, when, and whom to monitor
- contributes to medico-legal vulnerability

### TABLE 2: IMPROVEMENTS IN CARDIOTOCOGRAPHY

- a further understanding of (patho-)physiology
- knowledge of technical pitfalls
- uniform paper speed, vertical scaling
- knowledge of the many factors influencing FHR patterns
- knowledge of all relevant clinical data
- discipline in reading, classification and interpretation of FHR patterns
- recognition that cardiotocography is an indirect parameter of fetal condition
- recognition that cardiotocography is only one parameter of fetal condition
- recognition that cardiotocography is only a screening technique
- disposition of maximal possible information (microblood sampling)
- availability of protocols how, when and whom to monitor
- availability of quantified, objective FHR analyses
- digital storage of fetal heart rate data
- systematic pre- and postgraduate training

**Disclosures:**

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