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Integrative Techniques of Cardiotocography

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ABSTRACT

ST-analysis of the fetal electrocardiogram (ECG) (STAN (®)) combined with cardiotocography (CTG) for intrapartum fetal monitoring has been developed following many years of animal research. Changes in the ST-segment of the fetal ECG correlated with fetal hypoxia occurring during labor. In 1993 the first randomized controlled trial (RCT), comparing CTG with CTG + ST-analysis was published. STAN (®) was introduced for daily practice in 2000. To date, six RCTs have been performed, out of which five have been published. Furthermore, there are six published meta-analyses. The meta-analyses showed that CTG + ST-analysis reduced the risks of vaginal operative delivery by about 10% and fetal blood sampling by 40%. There are conflicting results regarding the effect on metabolic acidosis, much because of controversies about which RCTs should be included in a meta-analysis, and because of differences in methodology, execution and quality of the meta-analyses. Several cohort studies have been published, some showing significant decrease of metabolic acidosis after the introduction of ST-analysis. In this review, we discuss not only the scientific evidence from the RCTs and meta-analyses, but also the limitations of these studies. In conclusion, ST-analysis is effective in reducing operative vaginal deliveries and fetal blood sampling but the effect on neonatal metabolic acidosis is still under debate. Further research is needed to determine the place of ST-analysis in the labor ward for daily practice.

Keywords: ST-Analysis; STAN; Cardiotocography; Fetal ECG; Intrapartum Fetal Monitoring.

Electrocardiography and Fetal ST Tract Analysis

During the 20th century the whole of medicine witnessed a considerable development in scientific knowledge and the level of care as well as a consequent enormous technological progress with beneficial influences from both a diagnostic and a therapeutic point of view. Unfortunately, some areas of obstetrics have benefited little from this enormous progress in both scientific knowledge and its practical applications. One area where progress has been slow and difficult, and expectations have often been

disappointed, is the monitoring of fetal well-being in labour.

The purpose of fetal monitoring during labour is the early identification of fetuses at risk of adverse outcomes by trying to understand how the fetus reacts to the stress of labour before its condition is compromised.

The universally used method, electronic fetal monitoring (EFM) or cardiotocography (CTG), has considerably improved our knowledge of the fetal condition during pregnancy and labour. It is currently recommended for fetal surveillance of high-risk pregnancies.

EFM is currently used in at least 75-80% of deliveries but there is evidence that

- in low-risk pregnancies there is no benefit in terms of reducing perinatal mortality and morbidity (1) (although this is mainly due to insufficient numbers of patients studied in the work to demonstrate a reduction in these parameters, which have an extremely low incidence)
- there are increased rates of operative deliveries with the use of EFM;
- there are no substantial changes in the incidence of neonatal metabolic acidosis, hypoxic-ischaemic encephalopathy or cerebral palsy.

Many inauspicious outcomes of EFM-monitored labour are due to:

- lack of ability to interpret CTG recordings and relate them to the clinical picture;
- delay in taking appropriate action;
- poor communication between team members.

In fact, EFM interpretation is based on empirical observations 'after the fact' of many hours of labour recording. There are huge intra- and inter-observer differences in the interpretation of CTG recordings.

Even with reliable interpretations, observations associated with cerebral palsy in EFM such as late decelerations and decreased variability have a false positive rate of 99.8% (2). Moreover, even the sensitivity of the EFM, although very high (85-90%), leaves a margin of uncertainty as to the predictive value of a reassuring CTG (1-3).

Technological development has made a fetal monitoring tool, called STAN, available to us, which allows accurate analysis of the fetal heart rate, ST segment and T/QRS ratio of the fetal electrocardiogram. The analysis of the ST-tract and T/QRS ratio of the fetal electrocardiogram provides us with continuous information about the fetal heart's ability to respond to the stress of labour. During labour, a gold electrode is applied to the fetal scalp to obtain the corresponding electrical signal from the fetal tissues. Electrocardiographic changes are automatically identified and the subsequent clinical action must be in strict accordance with appropriate guidelines, developed for this purpose.

Technique for the use of fetal electrocardiography in labour

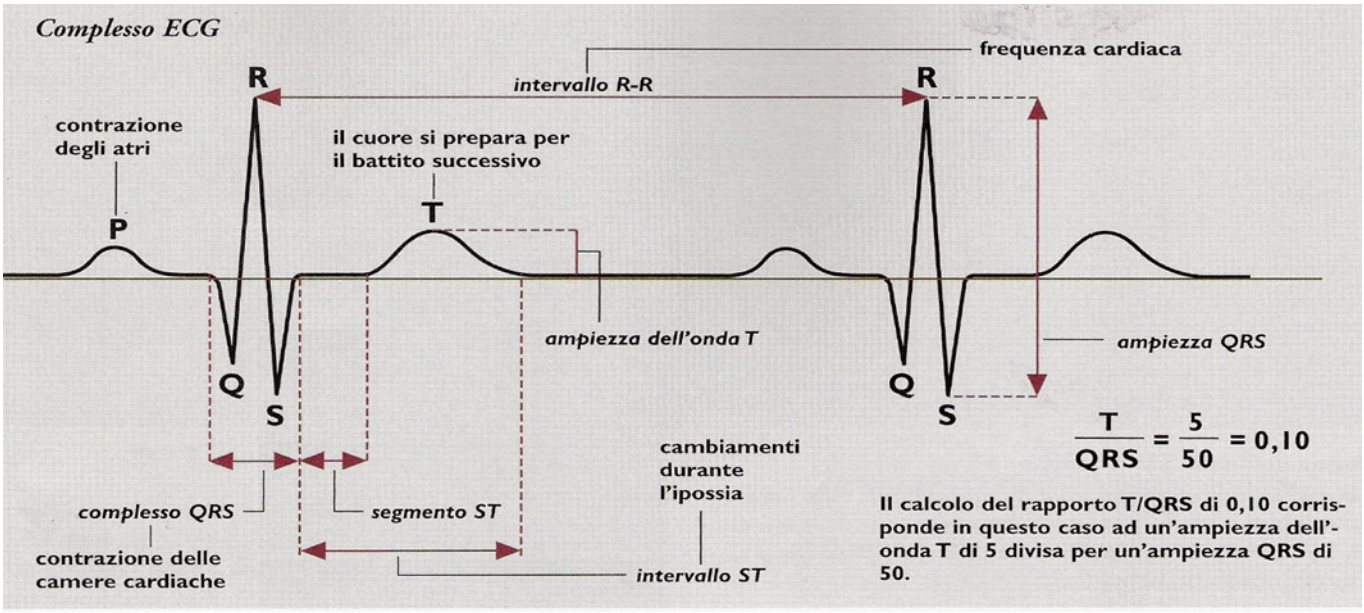
Experimental studies took place in the 1970s and 1980s and were mainly concerned with explaining the pathophysiological mechanisms underlying the changes in the ST wave and the T/QRS ratio of the fetal electrocardiogram.

The fetal electrocardiogram reflects the sum of electrical events within the myocardial cells. The resting state is identified with the diastolic phase, during which in the healthy myocardium the cells are in a state of polarisation characterised by a bal-

anced presence of intracellular positive charges and extracellular negative ions.

When depolarisation occurs, the distribution of positive and negative charges is reversed by a wave that propagates itself from cell to cell. The P and QRS waves of the fetal electrocardiogram represent the electrical activity produced as a result of the propagation of the depolarisation wave. The T wave indicates the time difference between the repolarisation of different parts of the myocardium. The sinoatrial node controls cardiac action and is in turn controlled by the combined and alternating action of the vagus nerve and sympathetic nerves.

Figure 1 - Schematic representation of the fetal ECG.



The P wave of the ECG (figure 1) corresponds to the contraction of the atrium. The next sequence (QRS) corresponds to the contraction of the ventricles. These waves are passively generated, very stable and easily investigated and suitable for measuring the fetal heart rate.

The ratio of the T-wave height to the amplitude of the QRS complex gives us the T/QRS ratio which serves as an accurate measure of changes in T-wave height.

In the presence of hypoxia there is a shortening of the PR segment with a concomitant widening of the RR segment; this all relates to the need for the fetal heart to maintain sufficient atrial filling under conditions of decreased blood return to the heart (4 -5).

The ST segment and T wave are related to the repolarisation of myocardial cells in preparation for the next contraction and this repolarisation process involves energy consumption.

Under normal circumstances the amount of oxygen available is always greater than the amount used. The heart adopts an aerobic metabolism, the energy balance is positive and the fetal ECG shows a normal ST waveform, i.e. horizontal ST tract along the baseline and stable T waveform (stable T/QRS ratio).

If there is hypoxia, the amount of oxygen available (dependent on oxygen saturation, haemoglobin concentration in the blood and myocardial blood flow) decreases, but the workload of the heart re-

mains unchanged, so the energy balance becomes negative. The ST segment, in this situation, tilts downwards from the horizontal position. In this situation the foetus activates its defences: there is a release of adrenaline by the foetal adrenals with further activation of the myocardium and further worsening of the energy balance, which becomes even more negative. The hyperincretion of adrenaline causes a β-receptor activation with subsequent activation of the cyclic adenosine monophosphate (AMP) enzyme phosphorylase and glycogenolysis. Simultaneously with the utilisation of glycogen stores, there is a release of potassium ions (K+) (4-5-6) that affect the membrane potential of myocardial cells, causing an increase in T-wave amplitude.

These processes of glycogenolysis and anaerobic glycolysis produce lactic acid and a small amount of energy that is added to the energy from aerobic metabolism, contributing to a (albeit precarious) fetal energy balance. When the energy balance cannot be maintained by vasodilation and anaerobic metabolism, endocardial ischaemia intervenes. Increasing the rate of glycogenolysis increases the amplitude of the T wave.

The downward slope of the ST (biphasic ST) is therefore observed during the initial phase of hypoxia, when the heart has not yet had a chance to respond to hypoxia or when the fetus is unable to respond for various reasons. The biphasic ST is an indicator, therefore, of the direct depressing effect on cardiac function exerted by hypoxia, while the increase in T-wave amplitude is indicative of an adaptation to the activation of fetal defences to hypoxia. Biphasic STs also occur when disorders of heart function are present (infections, malformations).

Thus, a horizontal positive ST segment and a stable T-wave height, which does not increase, signify a normal ST with positive energy balance and aerobic myocardial metabolism, positive balance in the central organs (CNS) and a fetus able to withstand the stress of labour.

An increase in T-wave amplitude corresponds to the fetal defensive reaction to hypoxia with increased adrenaline and anaerobic myocardial metabolism. The metabolic defences of the foetus are intact and the foetus is able to cope with hypoxia: the rate of increase in T-wave amplitude depends on the amount of glycogen the foetus has to use to maintain a balanced energy balance.

The heart of the premature fetus more frequently shows biphasic STs because the ability to defend against hypoxia is reduced with poor adrenaline production and poor ability to utilise glycogen reserves.

A biphasic ST event is significant when several consecutive biphasic ST complexes are present and a shift from first to second and third biphasic STs can be observed with worsening myocardial function.

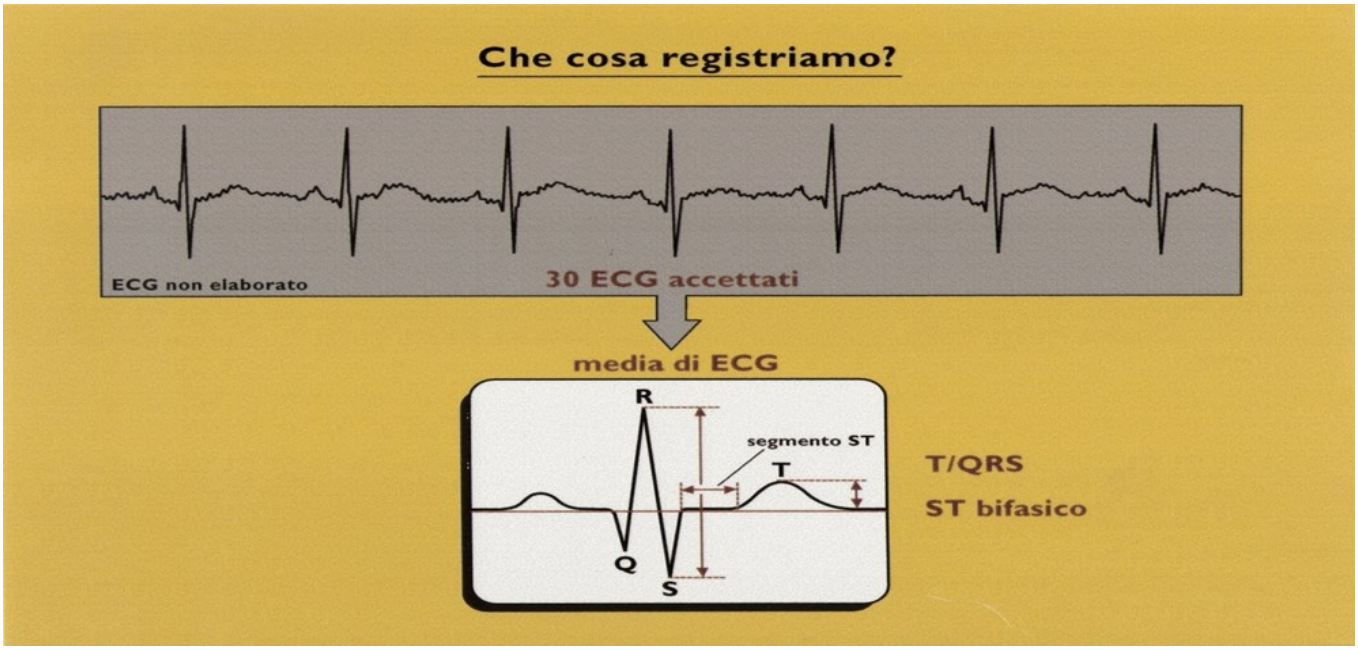
Functional principles of the fetal ECG

A single gold coil fetal electrode is required to record the fetal ECG.

The STAN device accepts and recognises thirty ECG complexes and for every thirty ECG complexes it processes an average ECG and from this calculates the T/QRS complex and ST-segment analysis. With a fetal heart rate between 120 and 160 bpm, there will therefore be four or five aver-

age ECG complexes per minute. The STAN device electronically records all significant fetal electrocardiographic wave modification events in a special register.

Figure 2 - Functional principles of fetal ECG recording



The T/QRS ratio is printed on a scale between -0.125 and 0.50. The T/QRS ratio is identified with a cross. Corresponding to each T/QRS ratio there is also the identification of the biphasic ST which is printed with the numbers 1, 2, 3 according to the different degree of abnormality (7).

Caution:

If recording is started late, when already the hypoxic process has caused the fetal defenses to be

have been exhausted the fetal cardiac metabolism is as reduced to basal levels. In this situation

the T/QRS ratio is stable inducing false reassurance, but in these cases the tracing

CTG above shows a total absence of variability and reactivity (preterminal CTG). Such a situation one should not initiate a combined CTG + ST registration but imposes the

immediate delivery.

Fetal ECG changes

- Episodic increase in T/QRS ratio

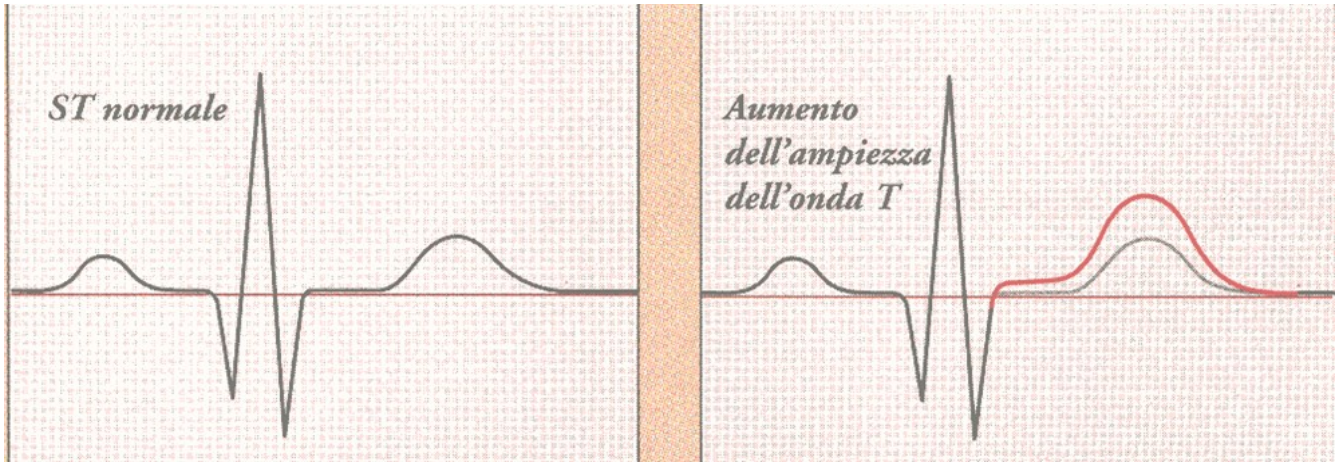
An episodic increase means that the T/QRS ratio increases and returns to previous values within 10 minutes. The magnitude of the increase is proportional to the fetal stress. The increase is significant if it exceeds a value of 0.10 and is automatically recorded on the device and event log as an ST EVENT.

When the CTG is intermediate, we can accept a magnitude of the increase in the T/QRS ratio >0.15. An abnormal CTG is a significant event if the elevation exceeds 0.10.

- Baseline increase in the T/QRS ratio

A baseline increase means that the increase in the T/QRS ratio exceeds the duration of 10 minutes and is considered significant when it exceeds 0.05 (with abnormal CTG) and 0.10 (with intermediate CTG). In these cases, persistent stress is present and there is no chance of recovery (Figure 3).

Figure 3 - Changes in fetal ECG

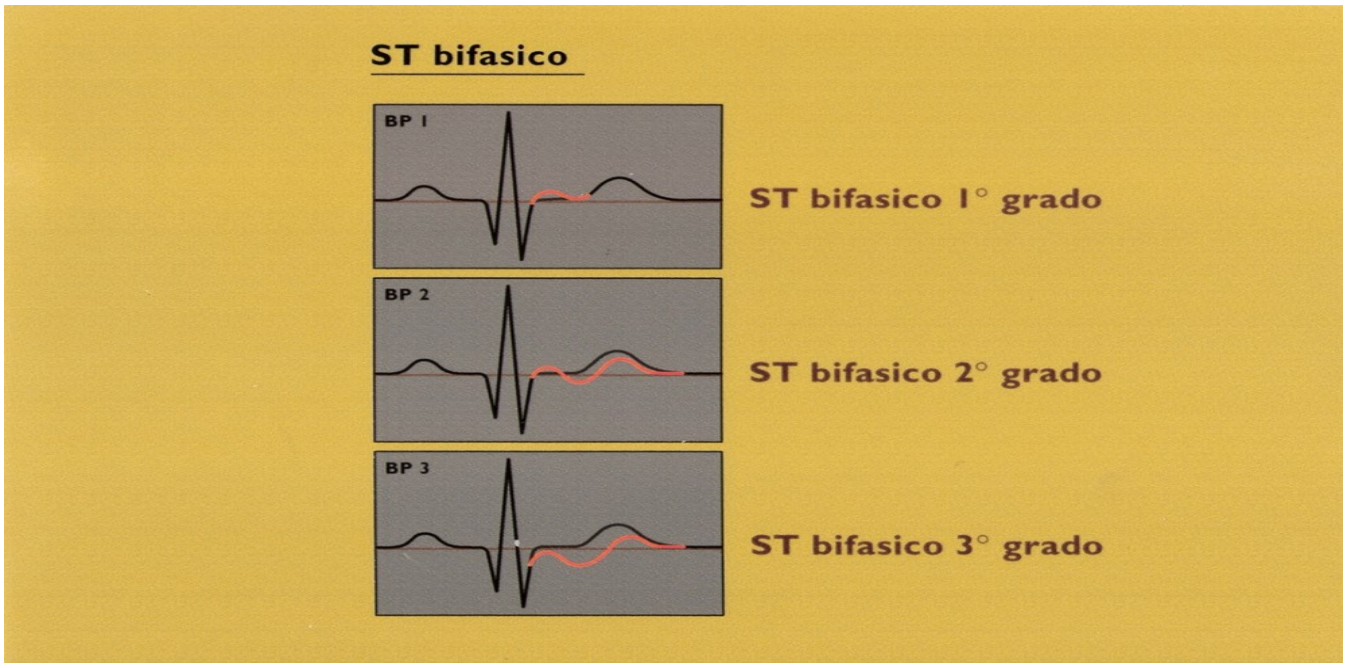


Biphasic ST

Biphasic STs can be divided into three different categories:

- 1st degree corresponds to a ST segment tilted downwards all above the baseline;
- 2nd degree: an ST segment that goes beyond the baseline and then back above.
- 3rd degree: the entire ST segment is below the baseline.

Figure no. 4 - Degrees of biphasic ST



The second and third degrees indicate an abnormality and if there are more than two STs (with abnormal CTG) or three biphasic STs (with intermediate CTG), action must be taken. The event log indicates in all these cases the time at which the event occurred (7).

Special ECG

N.B.: The shape of the middle ECG must always be checked at the beginning of the recording.

If the electrode is placed on the fetal podium (fetus in breech presentation), the ECG is recorded upside down and a negative P wave and ST segment are observed.

If the electrode is placed on the maternal cervix or a dead foetus, the maternal ECG can be recorded with the QRS complex coinciding with the maternal pulse.

SIGNAL QUALITY.

The STAN is a Pentium-class Personal Computer with signal amplification and data conversion from analogue to digital at 500 Hz. Signal analysis and data presentation are performed on a screen using dedicated software running a real-time operating system.

As already mentioned, the system calculates the T/QRS ratio on an average ECG after accepting and recognising thirty ECG complexes. So, every thirty ECG complexes you have an average ECG and a T/QRS ratio printed as a cross on the bottom of the screen. A computerised algorithm, ST log, is used to identify quantitative changes in the ST waveform (Figure 2).

The ST event log automatically identifies, and shows on the screen and on paper, significant changes in association with an abnormal CTG.

Signal quality is determined by the percentage of available ECG complexes used for fetal heart rate and ST wave analysis.

Automatic computerised ST event log determination occurs when signal quality is greater than 75%. In cases with lower quality, a warning appears for operators.

The FDA (US Food and Drug Administration) and a consensus conference have defined that an interruption of the recording or an interval in the presentation of ST report data due to poor signal quality for more than 4 minutes may result in failure to detect the presence of ST events: in these cases, clinical decisions should be based on the CTG trace and the clinical situation (7).

The words 'poor signal quality' appear when the signal quality (for automatic ST event log processing)

exceeds 90 seconds.

At the beginning of the recording, the T/QRS baseline is calculated from the mean T/QRS value recorded during the last ten minutes and from that point on an episodic increase is identified with an increase in the T/QRS sequence above the 3rd median.

It is necessary for there to be a sequence of two T/QRS ratios showing a change before this is reported, thus preventing erroneous data from being interpreted as significant (7-8).

Biphasic ST occurs when there is an imbalance between the endocardium and myocardium. The perfusion of the endocardium is always minimal, as is the mechanical force. Therefore, if there is myocardial activation (β-receptor activation and increased Frank - Starling relationship) there is no alteration, otherwise any decrease in performance causes a biphasic ST. The cause of a biphasic ST is not only hypoxia (as a sign of maladaptation) but also all factors that cause alterations in energy balance and myocardial performance (such as prematurity, infections, maternal fever, myocardial dystrophy, cardiac malformations) (6-9-10).

Fetal blood sampling from the scalp and fetal ECG

Pros and cons (11):

One of the shortcomings of scalp sampling is that it is not used when necessary, and vice versa it is used when it is superfluous. The execution technique is complicated, and it takes time to get the results (about 30 minutes). Since it only provides us with instant information, it must be repeated several times. The fetal ECG, on the other hand, tells us continuous information about the fetal condition.

Based on current knowledge, the use of blood sampling from the fetal scalp in addition to CTG + ST provides us with useful information in the case of recording initiated with abnormal CTG pictures or intermediate when the ST is normal. In this situation, there is a lack of information on available fetal resources and fetal well-being.

GUIDELINES

Specific information on ST tracing and T/QRS ratio should be used in conjunction with CTG. In principle, a normal and reactive EFM trace (reassuring CTG) indicates that the fetus is healthy. These guidelines are valid for a fetus at term (>36 weeks of pregnancy).

A reassuring CTG means that the fetus is healthy and changes in the fetal ECG can be accepted. A healthy fetus may react with awakening reactions in which an elevation of the T/QRS ratio can be observed for 20-30 minutes. Therefore, in the presence of a normal CTG, the appearance of electrocardiographic abnormalities should not prompt intervention, but clinical observation should be continued.

In the presence of an intermediate CTG, intervention will be required if:

- there is an episodic increase in T/QRS > 0.15
- there is a baseline increase in T/QRS > 0.10
- there are 3 biphasic STs of grade 2 or 3

In the presence of an abnormal CTG, action will be taken if:

- there is an episodic T/QRS increase > 0.10
- there is a baseline T/QRS increase > 0.05
- there are two biphasic STs of grade 2 or 3

Immediate delivery is always indicated in the presence of pre-terminal CTG (absence of variability and reactivity).

Before using the combined CTG + ST analysis, therefore, it is necessary to verify.

- the gestational age (>36 weeks gestation)
- the presence of ruptured membranes or practising amniorexis
- the absence of contraindications to applying the electrode to the fetal scalp

It is also recommended to start the recording as early as possible, ideally in the dilating period with reassuring CTG, in the expulsive period when there is absence of pushing.

At the beginning of the combined CTG +ST analysis, check for.

- the presence of reactivity and a good fetal condition that is not deteriorating
- a normal ECG waveform and sufficient signal quality
- the message "baseline T/QRS determined" in the event log

The following aspects should not be forgotten.

- the STAN calculates the T/QRS baseline and adjusts it if it becomes low and after 3 hours of recording.
- the recording should start in the first stage of labour (dilating period), ideally with reassuring CTG.
- if CTG is not reassuring and no previous information is available, to exclude the possibility of pre-existing hypoxia and the possibility of it not being recognised by STAN, perform fetal scalp sampling for pH
- signal quality must be good: no intervals in the T/QRS ratio > 4 minutes.
- do not stop STAN recording if CTG is abnormal and if you stop it to avoid losing the T/QRS baseline already determined, use the "temporary stop" function.
- if CTG is abnormal for a period longer than 60 minutes with normal ST, verify fetal status by taking a sample from the fetal scalp.
- in the dilating period the intervention, mandated by guidelines, may consist of intrauterine resuscitation manoeuvres: continue with recording only when CTG and ST are normalised. In the expulsive period or if CTG and ST are not normalised (in the dilating period), the intervention is immediate delivery within 20 minutes.
- the presence of maternal fever in labour with intermediate CTG and ST events dictates intervention.
- the presence of two biphasic ST events with intermediate CTG mandates intervention.

Before Starting Combined Registration

Integrate the information from the combined CTG + ST monitoring with the clinical picture consisting of:

- clinical history
- progress of labour
- intensity of contractions
- time factor

Caution:

It is very important that during a CTG+ST recording a correct CTG classification is performed.

Table No. 1 - CTG classification

CTG classification	Basic heart rate	Variability	Decelerations
Normal CTG	110-150 bpm	5-25 bpm Accelerations	Early decelerations Uncomplicated variable decelerations (duration < 60 seconds drop < 60 bpm)
Intermediate CTG	100-110 bpm 150-170 bpm Brief episode of bradycardia	> 25 bpm without acceleration < 5 bpm for < 40 minutes	Uncomplicated variable decelerations (duration < 60 seconds drop > 60 bpm)
The association of several concomitant intermediate observations will result in an abnormal CTG			
Abnormal CTG	150-170 bpm > 170 bpm Persistent bradycardia	< 5 bpm for > 40 minutes Sinusoidal appearance	Complicated variable decelerations with duration > 60 seconds Repeated late decelerations
Terminal CTG	Complete lack of variability and reactivity, with or without decelerations and bradycardia		

Tabella n.2 - Linee Guida STAN

ST event	Normal CTG	Intermediate CTG	Abnormal CTG	Pre-terminal CTG
Episodic increase T/QRS	Continuous observation	> 0,15	> 0,10	Immediate delivery
T/QRS baseline increase		> 0,10	>0,05	
ST biphasic		3 biphasic ST	2 biphasic ST	

DETERMINATION OF ACID-BASE BALANCE ON UMBILICAL CORD BLOOD

Determination of the pH and acid-base balance on umbilical cord blood constitutes essential additional information on the neonatal condition at birth (12).

The ACOG suggests above all that this determination be carried out in the following cases:

1. The ACOG suggests above all that this determination be carried out in the following cases:

2. Caesarean section for non-reassuring foetal condition
3. Low Apgar Score at 5 minutes
4. Severe IUGR (Intrauterine Growth Restriction)
5. EFM abnormality
6. Thyroid disease
7. Intrapartum fever
8. Multiple pregnancy

Values derived from the umbilical artery reflect the fetal condition, while values from the umbilical vein reflect placental function.

Table 3 - Normal blood gas values at birth

Vase	pH	PCO2 (mmHg)	PO2 (mmHg)	Basic deficits
Artery	7,2-7,3	45-55	15-25	<12
Vein	7,3-7,4	35-45	25-35	<12

The base deficit reflects the use of bases to stabilise pH. An umbilical arterial pH value of less than 7.20 is essential to define a possible acidaemia, but a much lower value (<7.0) is required to have a risk of potential neurological damage.

Isolated respiratory acidaemia is characterised by umbilical arterial pH values below 7.20 with elevated PCO2 and base deficit <12mmol/L. This situation occurs when there is altered gas exchange in the blood, usually due to transient cord compression; it is not associated with fetal neurological damage. An isolated metabolic acidemia, on the other hand, has the characteristics of pH <7.20, normal PCO2 and a base deficit of at least 12 mmol/L. It may be caused by a prolonged or recurrent interruption of fetal oxygenation that has progressed to the stage of peripheral tissue hypoxia, anaerobic metabolism, and lactic acid production that exceeds the buffering capacity of bicarbonate bases. The risk of neurological damage becomes significant if the pH is below 7.0 and the base deficit exceeds 12 mmol/L (13).

Mixed (respiratory and metabolic) acidemia is characterised by pH <7.0, elevated PCO2 and a base deficit >12 mmol/L. Its clinical significance is similar to that of isolated metabolic acidaemia (Table no. 4).

Table no. 4 - Differential diagnosis between respiratory, metabolic and mixed acidaemia.

Value	Respiratory	Metabolic	Mixed
pH	<7,20	<7,20	<7,20
PCO2	Elevated	Normal	Elevated
Basic Deficit	<12 mmol/L	>12 mmol/L	>12 mmol/L

FETAL ELECTROCADIOGRAPHY, FETAL ST TRAIT ANALYSIS AND SCIENTIFIC EVIDENCE

There have been five randomised controlled trials studying 15,365 patients; in these studies, the main fetal and maternal outcomes were compared in two populations of women, one of whom was continuously monitored with CTG alone, the other with fetal CTG monitoring and ST-track analysis (14-18).

Westgate et al. (14) published the first randomised controlled trial and monitored 2434 women with CTG alone or with integrated CTG+ST monitoring during labour using visual and non-computational ST-tract and T/QRS ratio observation in this their first study. In women monitored with CTG+ST, a 46% decrease in the number of vaginal operative deliveries and an approximately 50% decrease in

cases of metabolic acidosis at birth were observed. Having obtained these encouraging results, a second randomised controlled clinical trial was carried out using the computerised modality and the above-mentioned guidelines for ST-tract and T/QRS ratio analysis. In this second study a significant reduction in the number of infants suffering from metabolic acidosis at birth (approximately 53% less) and vaginal obstetrical operation (47%) was found (15). No similar results were achieved in the three subsequent randomised controlled clinical trials (16,17,18). These three studies, however, had not collected sufficient numbers of patients to obtain statistically significant results on the incidence of metabolic acidosis and the presence of elevated base deficiency. The analysis had been performed on total blood and not on extracellular fluid (16).
In the study by Vayssiere et al. (17), the presence of an abnormal CTG had been considered as a criterion for the inclusion and admission of women to CTG+ST monitoring but without having previously ascertained the actual fetal condition. This was in blatant violation of STAN guidelines that prescribe starting CTG+ST monitoring as early as possible in labor and, preferably with a normal CTG.

In 2015 an o multicenter randomized trial was performed by the National Institute of Child Health and Human Development (NICHD)-USA (19) that observed 11. 108 women monitored with STAN, demonstrating that the use of this technology as a supplement to CTG alone did not produce an improvement in neonatal outcomes (0.9% versus 0.7%, RR 1.31, CI 95% 0.87-1.98) nor did it reduce the number of cesarean sections (16.9% vs 16.2%) or instrumental operative deliveries (22.8% vs 22.0%).

The 'incidence of asphyxia, in the control group monitored with CTG was already very low and therefore this situation greatly limited the possibility for the group monitored with STAN to improve this outcome. There was in this group of patients monitored with STAN a reduction in asphyxiated infants, but a larger study sample would be needed. In the U.S. clinical trial, about 5.9 percent of cesarean sections were performed in violation of STAN guidelines that would have mandated continuing labor. In Europe and Australia, a 4-class CTG classification system is used, while in the US a 3-class classification system was used. Clinical intervention was recommended in the presence of any ST event (without considering its type and size) in the presence of a type 2 CTG tracing.

The literature review by Cochrane (20) considered the 5 randomized clinical trials with about 15,000 patients. Comparing the use in labor of STAN methodology as a supplementary technique to CTG (CTG+STAN) versus the use of cardiotocography alone (CTG), it was noted that there was no significant reduction in metabolic acidosis at birth (pH <7 and base deficit >12 mmol/L) (RR 0.78, CI 95% 0.44-1.37). The number of cesarean sections in the two test groups was similar (RR 0.99, CI 95% 0.91-1.08) and there was a reduction in the use of fetal scalp blood sampling ((RR 0.61, CI 95% 0.41-0.91) and in the number of vaginal operative deliveries (14.5% versus 16.2%, RR 0.89, CI 95% 0.81-0.98).

Olofsson et al. (21,22) in a meta-analysis in 2014 in which they eliminated the many flaws present in previous studies (variable definitions of observed outcomes, incorrect use of data) found a significant reduction in the use of fetal scalp blood sampling (RR 0. 64, 95% CI 0.47-0.88), a reduction in total

obstetrical operability ((RR 0.93, 95% CI 0.88-0.99), neonatal metabolic acidosis (RR 0.61 , 95% CI 0.41-0.91) in women monitored with CTG + STAN versus those monitored with CTG alone. STAN monitoring reduced the need for fetal scalp blood sampling in women undergoing epidural analgesia (RR 0.46%, 95% CI 0.40-0.52). These beneficial effects were especially evident in the group of women with fetuses at high risk of asphyxia such as women with protracted pregnancy or with IUGR fetuses.

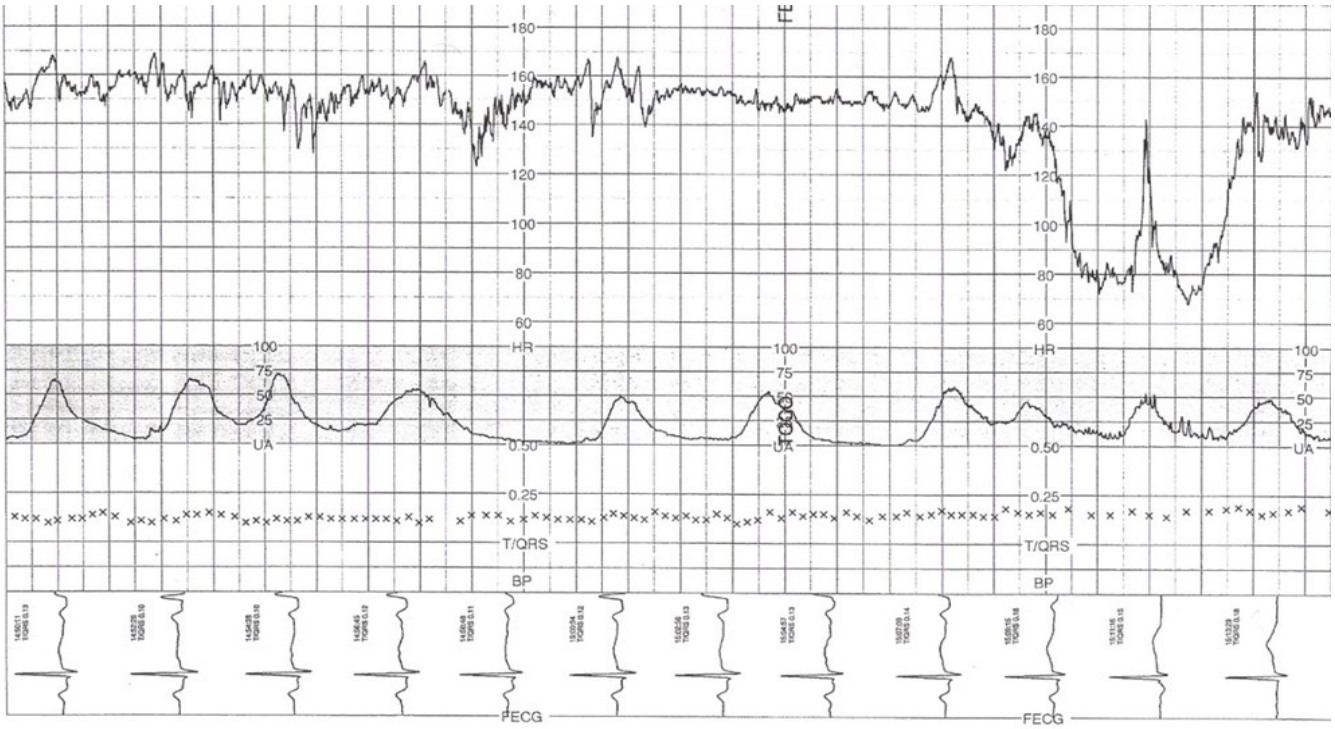
In addition, CTG+ST monitoring reduces the incidence of metabolic acidosis calculated on arterial blood, the need for admission to the neonatal intensive care unit, the incidence of hypoxic-ischemic encephalopathy, the need for endotracheal intubation, seizures, and adverse perinatal outcomes, although not by statistically significant values. The number of cesarean sections remains unchanged in the two patient groups (RR 0.99; CI 95% 0.91-1.09). Integrated CTG+ST monitoring also reduces the incidence of admission to the neonatal intensive care unit for infants born after 41 weeks' gestation (RR 0.61; CI 95% 0.39-0.95).

Many cohort and observational studies have been published that have sought to investigate the long-term effects of using STAN monitoring. Due to the increasing and ubiquitous use of this new technology and the improved training of health care personnel, there has been a remarkable reduction in the incidence of neonatal metabolic acidosis (27-45).

STAN is a system that studies the level of central fetal oxygenation (e.g., myocardium) of the fetus, and intensive training and study of both midwives and physicians on fetal physiology is necessary. All clinical studies, randomized and observational (44,45), have shown improved neonatal outcomes after performing all-staff training, and this study also improved the understanding of CTG. The use of STAN technology requires the physician or midwife to be able to interpret the CTG tracing according to STAN guidelines and, therefore, relati the type and extent of STAN events reported by the computer to the clinical picture of the patient in labor. These elements will guide subsequent clinical action. Many failures in the application of this technique are determined by 'human error in the correct interpretation of the CTG and the subsequent assessment of the patient's clinical picture (such as the presence of meconium or clinical or subclinical chorioamnionitis, arrest in the progression of labor labor, and incorrect use of oxytocin) (Figure No. 5).

The 'use of CTG alone in labor presents a 'high incidence of false positives (60%) and also a lower rate of false negatives. The 'use of STAN has the advantage of reducing the incidence of fetal asphyxia in high-risk patients and in low-risk populations reduces inappropriate obstetric interventions such as vaginal operative deliveries or cesarean sections.

Figure No. 5 - CTG+ST plot



FETAL SCALP SAMPLING IN LABOR

Assessment of fetal acid-base balance can be done directly by taking blood from the fetal scalp.

Fetal blood sampling involves taking a capillary blood sample from the fetal scalp and subsequent pH or lactate analysis (Figure No. 6) (46). The measurement of fetal pH is considered by some authors to be a gold standard in the assessment of fetal well-being. Correlation with pH on cord blood at birth shows almost corresponding results taking into account that this correlation is strictly affected by the time elapsing between collection and birth. The only variable between cord blood and capillary blood is the redistribution of circulation that is activated in case of hypoxia going to safeguard the central organs at the expense of the more peripheral areas; however, this aspect makes the blood sample from the scalp, which is disfavored by redistribution, allow early identification of fetal hypoxia.

Possible pH values associated with neonatal seizure risk are noted in Table 5 below.

Table No. 5 - Umbilical arterial pH and associated seizure risk association

pH	pH values	Associated neonatal convulsion risk
Normal	*>7,25*	*0,1 %*
Intermediate	*7,20 < x < 7,25*	*0,3 %*
Patologic	*<7,2*	*9,2 %*

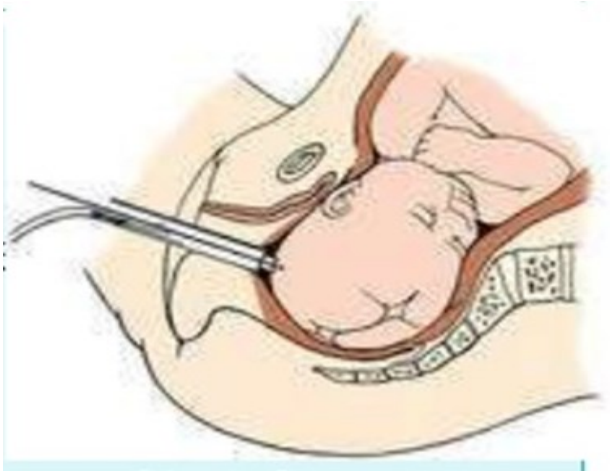
The measurement of lactates appears to be comparable to that of pH and has two advantages: it requires less time to perform and less blood needed, only 5 microliters.

Table No. 6 - Values of lactates possible

Lactates	Values
Normal	< 4,2
Intermediate	4,2 - 4,8
Patologic	> 4,8

No significant data exist to date, but international guidelines cite fetal scalp sampling in labor inappropriately as a possible aid in reducing the incidence of operative deliveries and cesarean sections, with low level of evidence. In both the Cochrane systematic reviews performed in 2008 and 2013 (47,48) and the NICE guidelines on Intrapartum Care in 2007 concluded that fetal blood sampling does not lead to a reduction in the number of cesarean cuts or vaginal operative deliveries. A review of the literature published in 2011 reports the occurrence of possible complications, even serious ones (0.4-6%), such as hemorrhage and sepsis (49). Thus, using a technique that has no scientific evidence of leading to a benefit for the conduct of labor but rather at risk of possible harm to the fetus constitutes not only an obvious case of inappropriate care but is also ethically unjustifiable. To properly perform this technique and obtain its results requires about 18 minutes and an average of 37 minutes to achieve immediate birth of the newborn (50,51,52). Therefore, blood sampling from the fetal scalp not only does not reduce the number of cesarean sections but also delays the birth of a fetus at possible hypoxic risk, contributing to the worsening of its oxygen statusaking from the fetal scalp and determining lactates does not produce an improvement in neonatal condition or a reduction in obstetric interventions in labor. From this point of view, simply performing digital stimulation of the fetal scalp in labor has a higher fetal predictive value for the detection of possible fetal acidemia than this technique, resulting in a 73% reduction in the need for its use (53,54,55).

Figure No.6 - Blood sampling from the fetal scalp.



PULSED OXIMETRY

Pulsed oximetry aims to assess the oxygen saturation of fetal blood through a probe introduced inside the cervix in contact with fetal skin. This technique has also been proposed as a supplement in cases of unreassuring cardiotocography to reduce the number of operative deliveries and improve neonatal outcome. However, to date there is no evidence that its application significantly improves these parameters.

FETAL SCALP STIMULATION

Fetal scalp stimulation has also been proposed as a biophysical test to be combined with cardiotocography to increase the specificity of the diagnosis of fetal acidosis. This technique is based on tactile stimulation of the fetal scalp (digital or instrumental) or vibroacoustic stimulation on the maternal abdomen, which under conditions of fetal well-being results in the appearance of an acceleration on the cardiotocographic trace. The occurrence of this sign is an excellent indicator of good acid-base balance of the fetus. However, the non-appearance of acceleration is not as specific in indicating a state of fetal hypoxia. Therefore, in the case of non

-acceleration, it may be indicated to use acid-base balance assessment. Il vantaggio di tale tecnica è di essere molto facile da eseguire ed economica. Il principale scopo è quello di valutare un feto che mostra variabilità ridotta, distinguendo tra sonno fetale e ipossia/acidosi. Non bisogna però dimenticare che il valore predittivo positivo di ipossia in caso di mancata risposta è basso (53,55).

CONCLUSIONS

During the past thirty years, there have been two major changes in labor labor care: the introduction of cardiotocography and the increase in cesarean sections. Identifying cases at risk of asphyxia remains an unsolved problem. There has not been the expected improvement in the reduction of long-term neurological consequences in hypoxic infants: this is because the investigation methods used are not sufficiently sensitive and not optimally employed. Combined use of information obtained from CTG and fetal electrocardiogram may improve neonatal outcome. Available results suggest that the new integrated technology (CTG + ST) improves the ability of health care providers to identify normal and abnormal CTG and intervene early. In fact, the fetal ECG method provides a more understandable and objective alert in cases of fetal hypoxia than CTG alone. Often healthcare providers underestimate abnormal tracings because CTG changes alone are not specific; instead, CTG + ST changes together are a more specific sign of hypoxia and not to be underestimated.

CTG + ST analysis also provides better inter/intraobserver reproducibility. Adequate education and training of health care providers during a sufficiently long period (initial period 2-6 months) and continuous evaluation (audit) of clinical cases appears crucial.

Equally important is to call attention to the fact that no intrapartum test can accurately predict all cases of adverse neonatal outcome, and the use of fetal ECG does not escape this rule. Assessment must be performed by carefully judging the whole clinical situation because cellular damage in the fetus can occur in a wide variety of circumstances. In addition to developments in electronic fetal monitoring we need to intensify our efforts both culturally and operationally in the development and dissemination of computerized systems to reduce uncertainties in the treatment of abnormal tracings. The future hope is also to be able to investigate fetal conditions before the onset of labor labor, the cause of long-term neurological problems in about 70% of cases.

CLINICAL CASE 1.

Ms. A.E. Age 20 years.

Diagnosis on admission: I pregnancy 40+5 weeks amenorrhea, gestational hypertension on therapy (Aldomet 1 gr/day).

- 7:40 pm, fetal electrode application

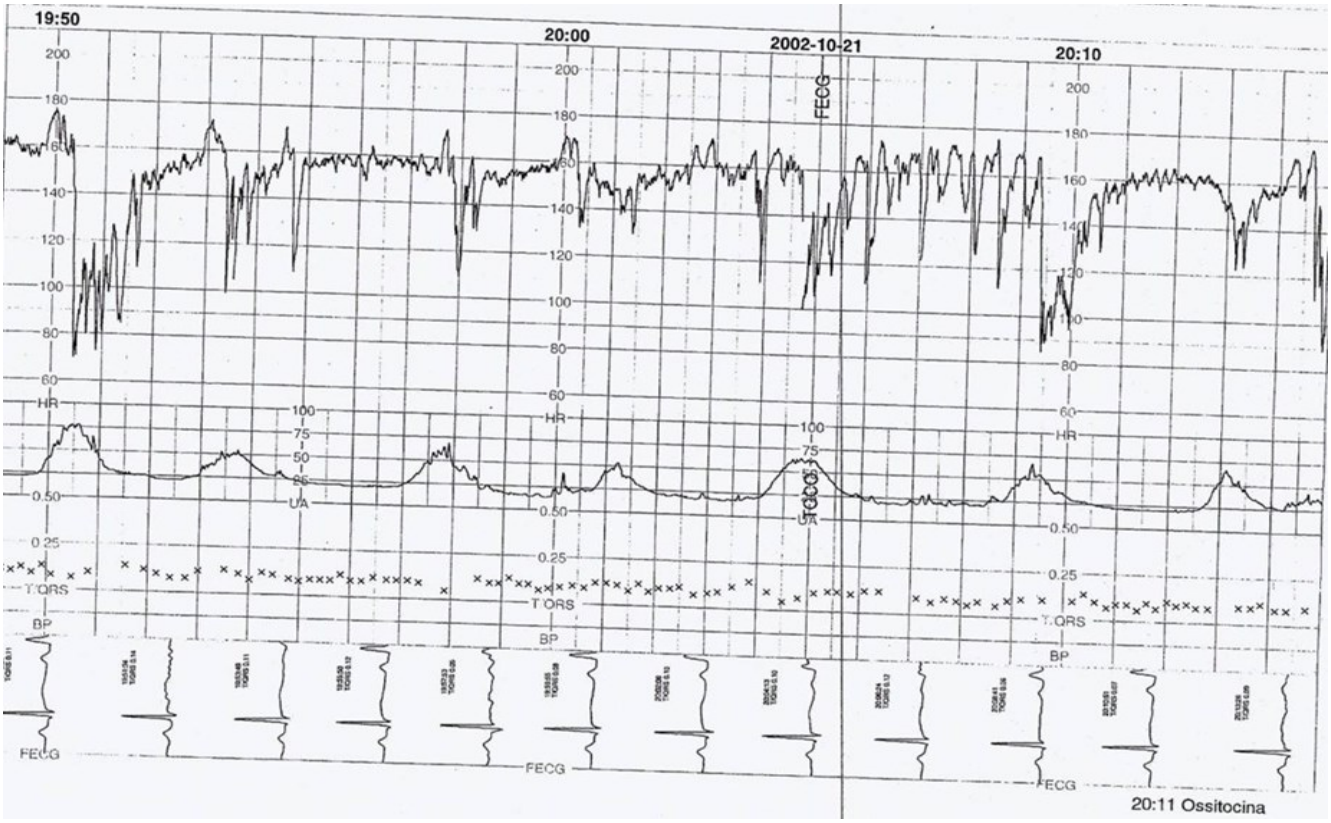


Figure 7

- h 19:50 to 20:15, Figure 7.

CTG: picture characterized by baseline 160bpm, increased variability, variable atypical baro-chemoreceptor decelerations indicative of slowly evolving hypoxemia.

Fetal ECG: stable T/QRS ratio and absence of biphasic ST indicative of normal myocardial function and oxygenation, so oxygen deprivations are compensated at the level of central organs (heart, CNS) without activation of anaerobic metabolism.

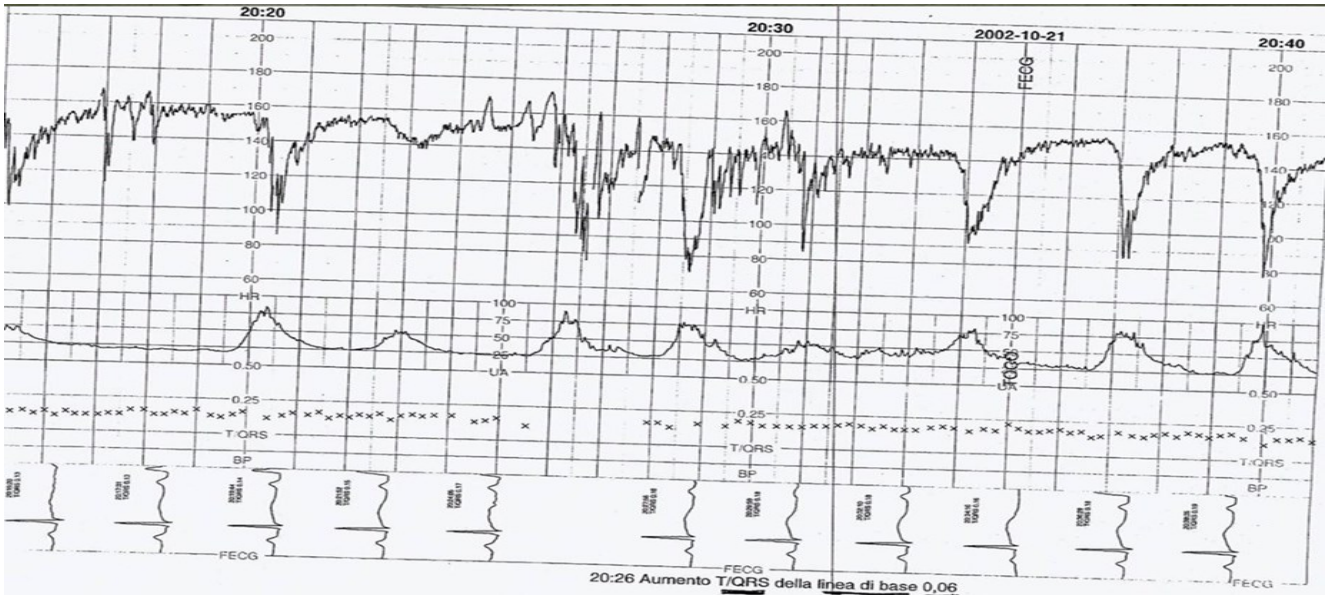


Figure 8

- h 20:20 to 20:40, Figure 8

CTG: baseline 160bpm, increased variability, variable atypical baro-chemoreceptor decelerations indicative of slowly evolving hypoxemia.

Fetal ECG: baseline elevation of T/QRS ratio of 0.06 but this elevation, according to STAN guidelines, is not an indication for clinical action.

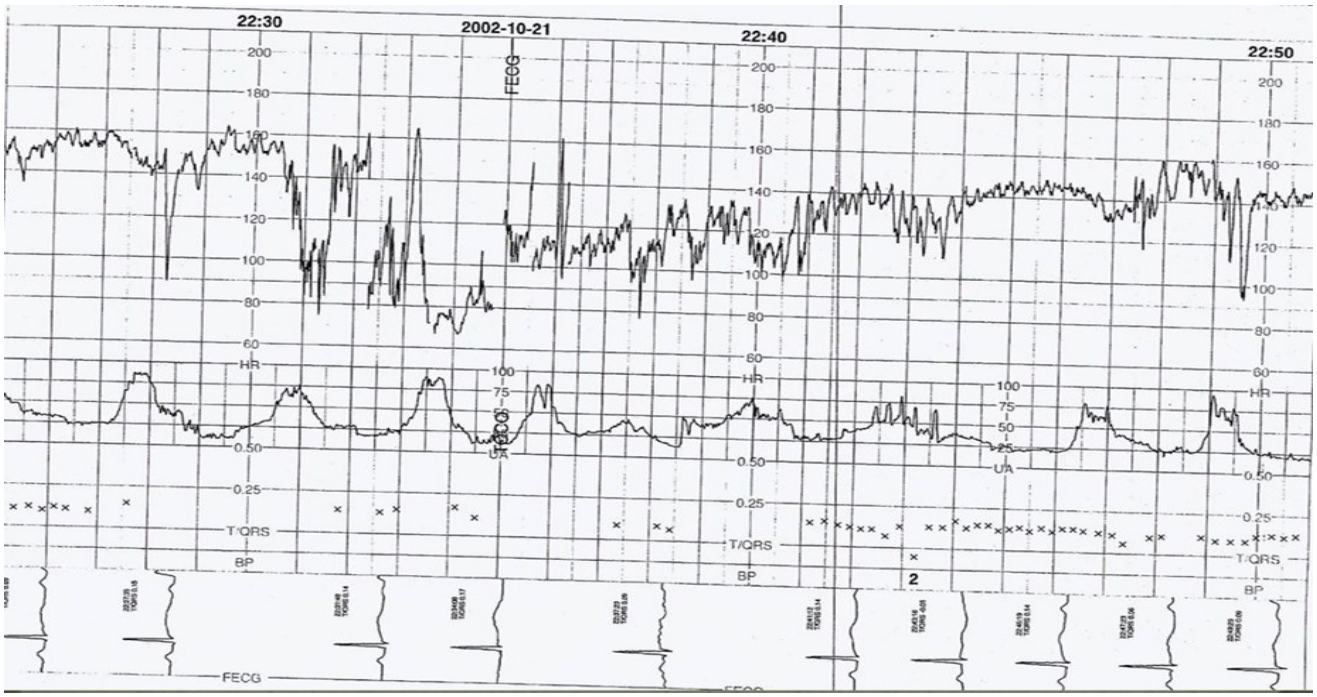


Figure 9

- h 22:25 to 22:50. Figure 9

CTG: subacute hypoxia characterized by: severe atypical baro-chemoreceptor-like variable decelerations with tachycardia and initial loss of variability indicative of an evolution toward an acidemic picture.

Fetal ECG: shows a stable T/QRS ratio with the presence of an isolated biphasic type 2 ST (indicative of ST-segment subleveling with subsequent return to baseline) isolated. According to the guidelines, this alteration is not an indication for clinical action.

- h 23.20, termination of surveillance.
- h 23.24, spontaneous delivery.

NEONATE:
Female sex, weight 3,900 g.

Apgar: 1'-9; 5'-10.

Hemogasanalysis

- Artery: pH 7.305; pCO2 40.5 mmHg; pO2 27.8 mmHg; dBase -5.7 mmol/L.

CLINICAL CASE 2

Mr. N.A. Age 37 years.

Diagnosis on admission: I pregnancy at 40+4 weeks amenorrhea. PROM, amniotic fluid stained with M3 meconium.

VO: uterine cervix intermediate, flattened, dilatation 1-2 cm, cephalic PP -1.

- h 16.02, start monitoring with FECG.

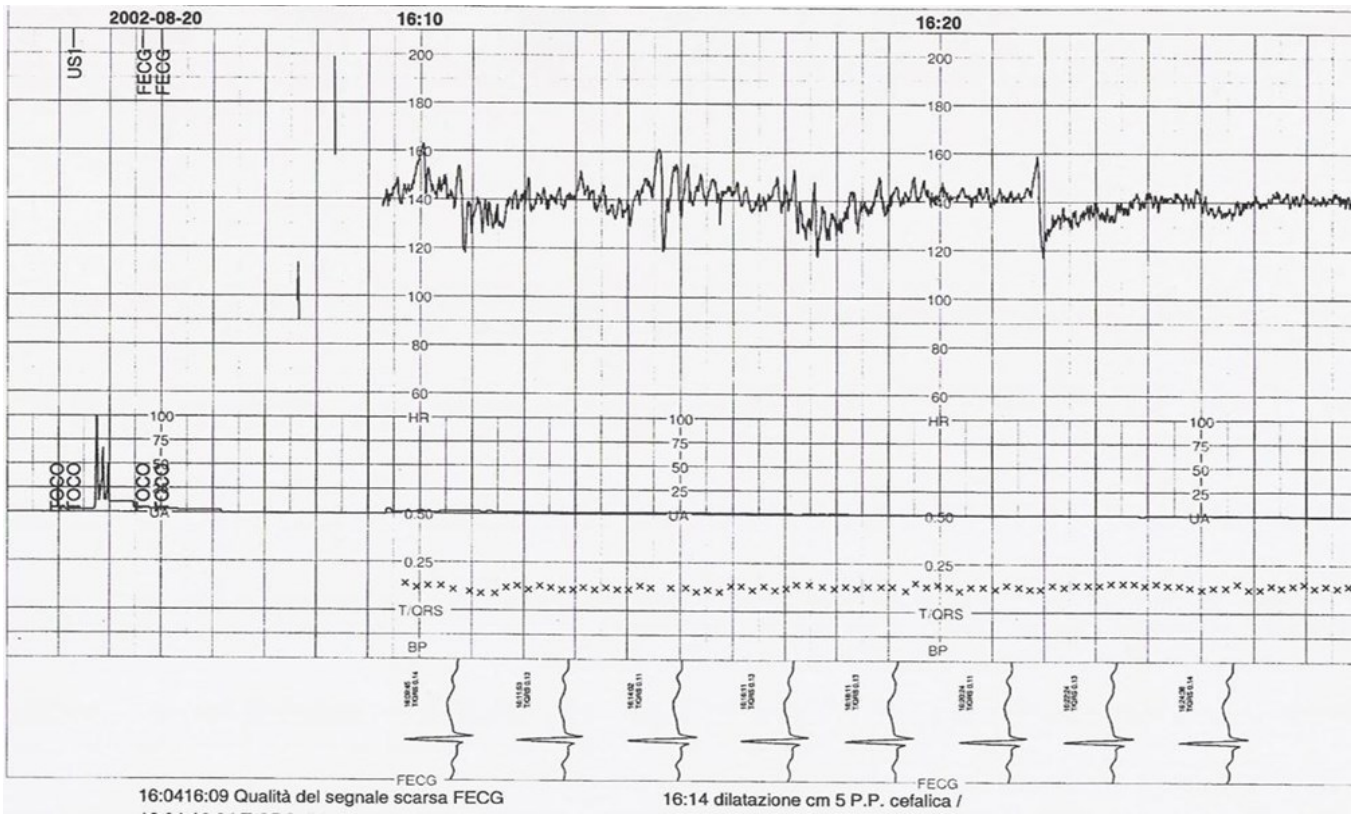


Figure 10

h 16:15. Figure 10

ECG: normal picture with baseline 140 bpm, preserved variability, presence of accelerations and absence of decelerations. Fetal ECG: in normal range with normal T/QRS ratio and absence of biphasic ST.

In the presence of risk factors such as PROM and strongly meconium-stained fluid, it seems particularly appropriate to initiate CTG supplemented with additional ECG information as this mode of examination allows early ascertainment of any hypoxemic pictures. It is, moreover, advisable to start the integrated recording as early as possible, under conditions of CTG and ECG normality, thus it is possible to ex-

clude the existence of electrocardiographic false negatives due to hypoxia preexisting the electrocardiographic recording.

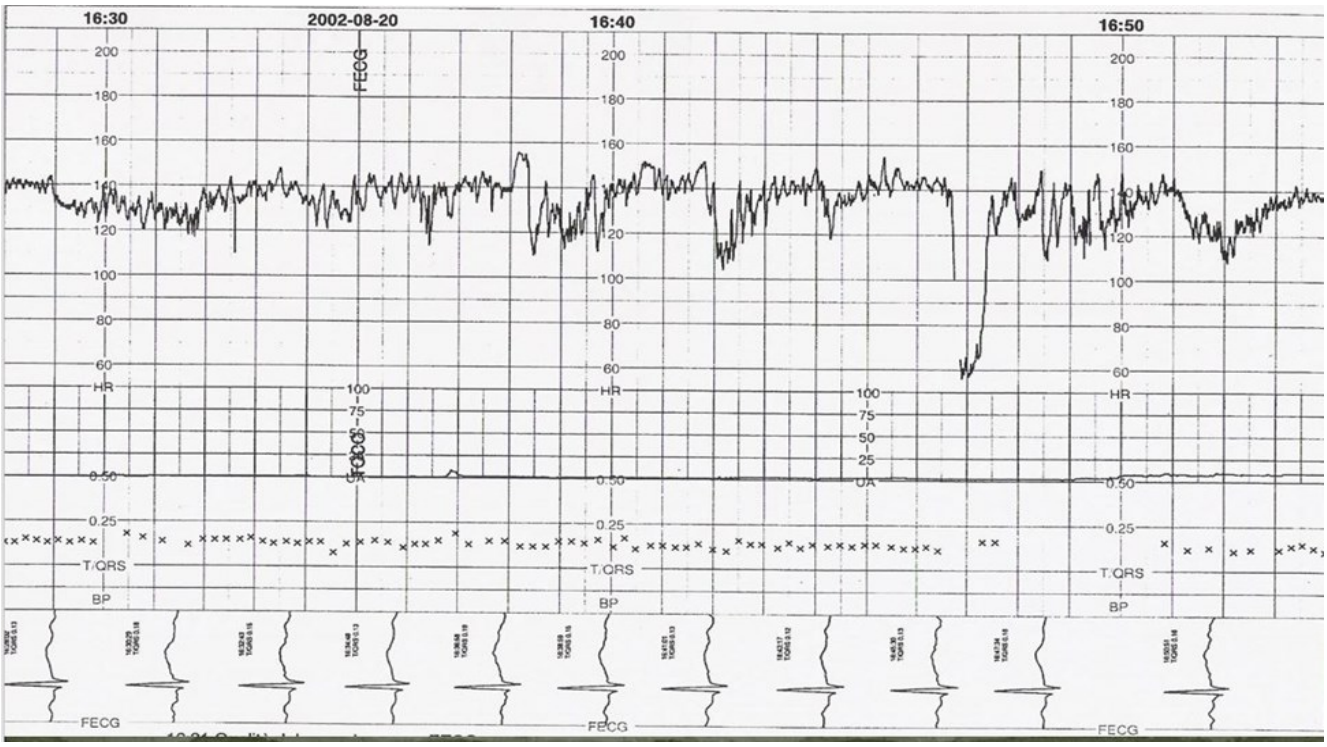


Figure 11

h 16:30. Figure 11

CTG: variable decelerations occur, indicative of transient fetal hypoxemia that the fetus is able to compensate for without evidence of altered myocardial function.

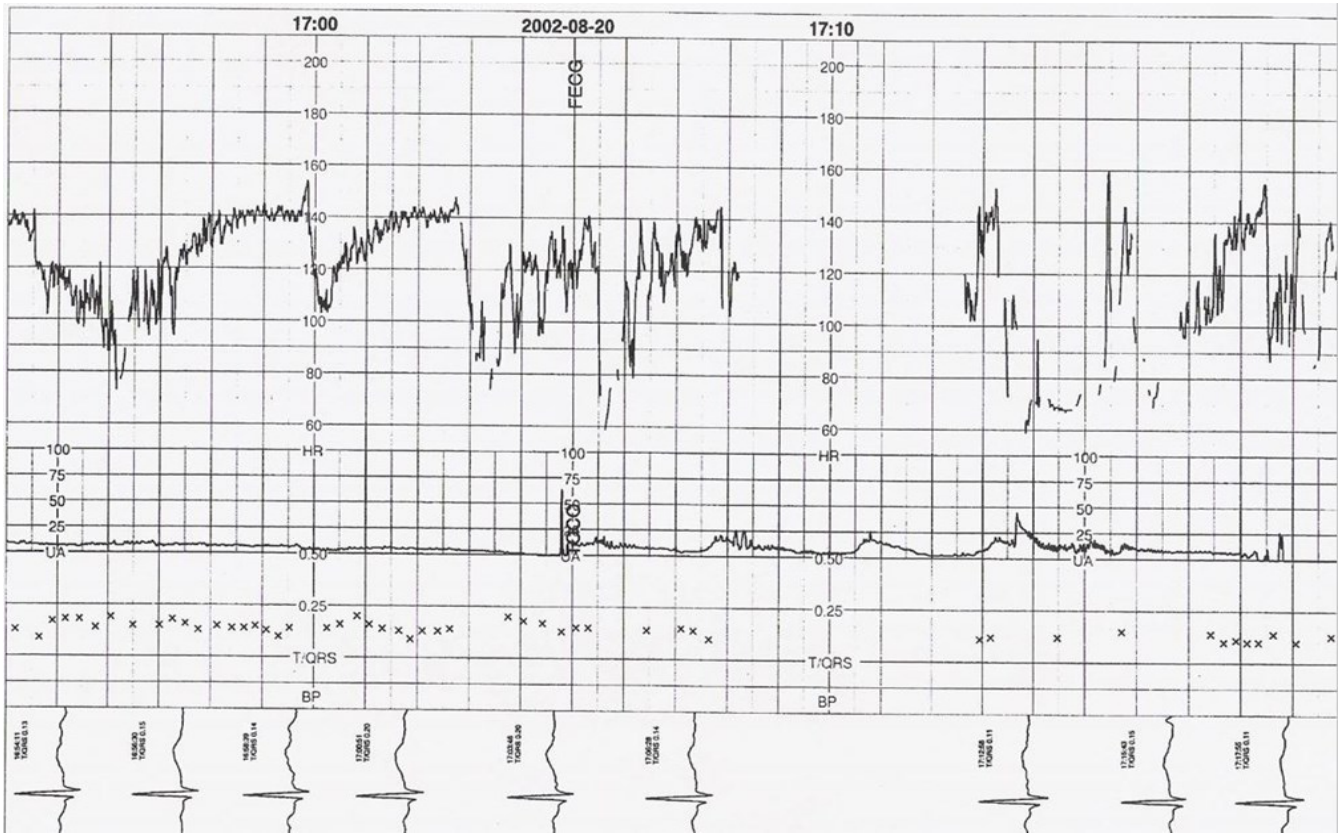


Figure 12

- h 17:00. Figure 12

- CTG: exacerbation of hypoxemia episodes with appearance of atypical baro-chemoreceptor-like variable decelerations.
- Fetal ECG: fetus shows adequate metabolic reserves such that myocardial function appears preserved and there is no activation of anaerobic metabolism: stable T/QRS ratio, absence of biphasic ST.

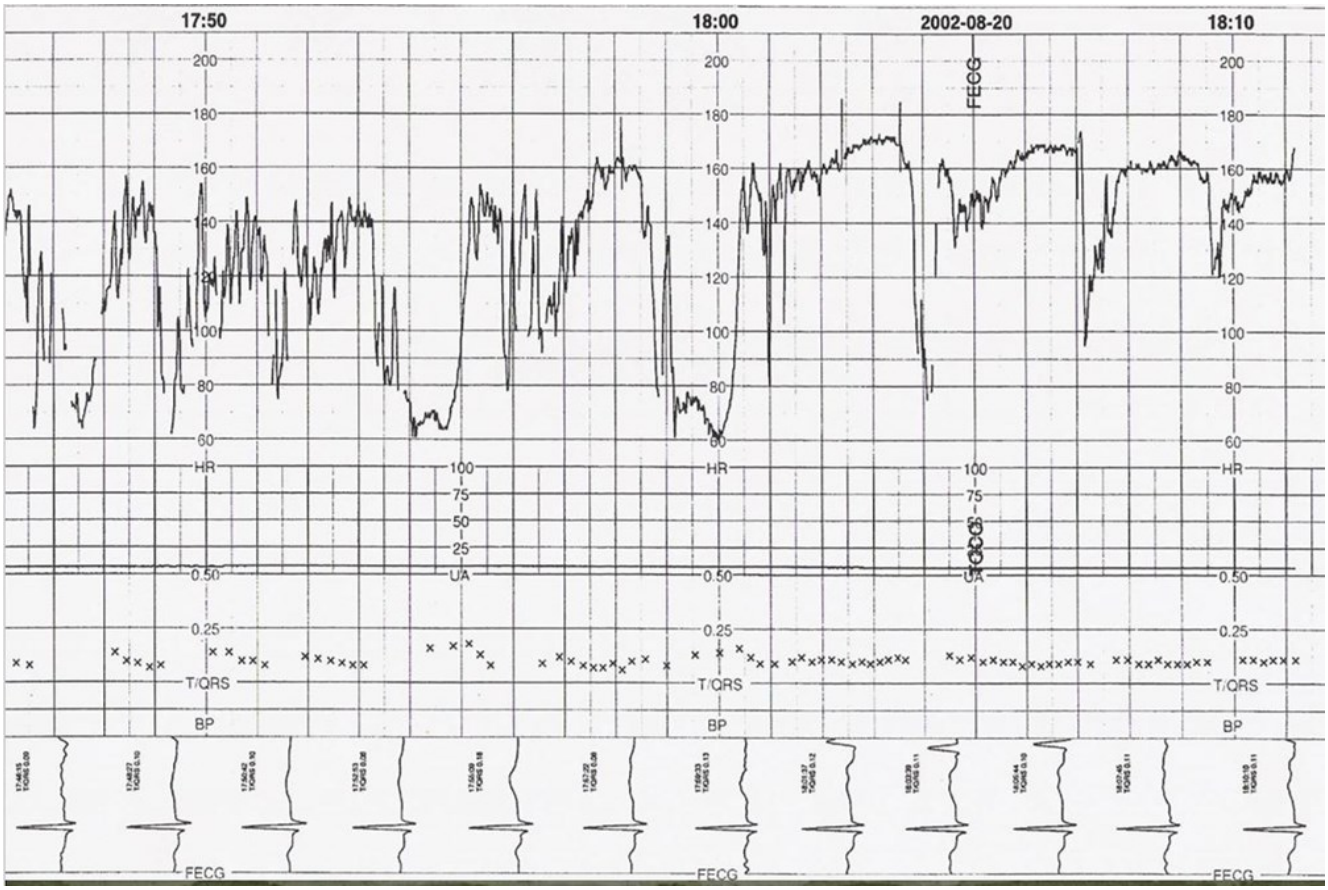


Figure 13

- h 17:50. Figure 13
- CTG: worsening of the previous picture of oxygen deprivation with appearance of severe atypical variable decelerations (having chemo-barocortical character) tachycardia, loss of variability.
- Fetal ECG: the electrocardiographic recording reassures us about the persistence of metabolic reserves, consisting of myocardial glycogen, such that the function of the fetal central organs and especially of my cardio, are not altered and there is no establishment of anaerobic metabolism.
- 6:35 p.m.: eutocic delivery for the vertex.

NEONATE
Male sex, weight 3,190 g.
Apgar: 1'-8; 5'-9.
Hemogasanalysis

Artery: pH 7.37; pCO2 37 mmHg; pO2 19 mmHg; dBase -7.1 mmol/L.

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