European Journal of Obstetrics and Gynecology 302 (2024) 346–355

Contents lists available at ScienceDirect

European Journal of Obstetrics & Gynecology and Reproductive Biology

journal homepage: www.journals.elsevier.com/european-journal-of-obstetrics-and-gynecology-and-reproductive-biology

Full length article

International expert consensus statement on physiological interpretation of cardiotocograph (CTG): First revision (2024)

Edwin Chandraharan [a,*], Susana Pereira [b], Tullio Ghi [c], Anna Gracia Perez-Bonfils [d], Stefania Fieni [e], Yan-Ju Jia [f], Katherine Griffiths [g], Suganya Sukumaran [h], Caron Ingram [i], Katharine Reeves [j], Mareike Bolten [k], Katrine Loser [l], Elena Carreras [m,n], Anna Suy [m], Itziar Garcia-Ruiz [m], Letizia Galli [o], Ahmed Zaima [p,1,2]

[a] Global Academy of Medical Education & Training, London, UK
[b] Consultant in Maternal-Fetal Medicine & Clinical Director, The Royal London Hospital, Barts Health NHS Trust, London, UK
[c] Department of Medicine and Surgery, University of Parma, Italy
[d] Consultant Obstetrician & Labour Ward Consultant, Germans Trias i Pujol, Barcelona, Spain
[e] Unit of Obstetrics and Gynecology, University Hospital of Parma, Parma, Italy
[f] Department of Obstetrics, Tianjin Central Hospital of Obstetrics and Gynaecology, Tianjin Key Laboratory of Human Development and Reproductive Regulation, Tianjin, China
[g] Royal College of Midwives, UK
[h] Consultant Obstetrician and Gynaecologist, George Eliot Hospital NHS Trust, UK
[i] Barking, Havering and Redbridge University Hospitals NHS Trust, the United Kingdom of Great Britain and Northern Ireland
[j] Formerly, Fetal Surveillance Midwife, Broomfield Hospital, Essex, UK
[k] Consultant Obstetrics, Gynaecology and Fetal Medicine, Labour Ward & Caesarean Section Lead, Queen Elizabeth Hospital Woolwich, Stadium Road, London, SE18 4QH, UK
[l] Lead Obstetrician at the Hospital of Southern Jutland, Aabenraa, Denmark
[m] Maternal Fetal Medicine Unit, Department of Obstetrics, Vall d'Hebron University Hospital, Spain
[n] Universitat de Vic-Universitat Central de Catalunya, Spain
[o] Consultant in Obstetrics, Unit of Obstetrics and Gynecology, University Hospital of Parma, Parma, Italy
[p] Obstetrician & Gynaecologist, Kingston Hospital, UK & Member of Advisory Board, UK

ARTICLE INFO

Keywords:
Cardiotocograph (CTG)
How is THIS Fetus?
ZigZag Pattern
Fetal heart rate cycling
Chorioamnionitis

ABSTRACT

The first international consensus guideline on physiological interpretation of cardiotocograph (CTG) produced by 44 CTG experts from 14 countries was published in 2018. This guideline ensured a paradigm shift from classifying CTG by arbitrarily grouping certain features of the fetal heart rate into different "categories", and then, randomly combining them to arrive at an overall classification of CTG traces into "Normal, Suspicious and Pathological" (or Category I, II and III) to a classification which is based on the understanding of fetal

* Corresponding author.
E-mail addresses: edwin.c@sky.com (E. Chandraharan), katherine.griffiths6@nhs.net (K. Griffiths), suganya.sukumaran@geh.nhs.uk (S. Sukumaran), mareike.bolten@nhs.net (M. Bolten), katrin.loeser@rsyd.dk (K. Loser).

[1] Editorial Board, on behalf of the International Expert Panel on Physiological Interpretation of CTG***. **International Expert Consensus Panel on Physiological Interpretation of CTG*****.** Abigail Spring (UK), Alex Juusela (USA), Ana Morata Latorre (Spain), Andrea Dall'Asta (Italy), Badriya Al Fahdi (Oman), Begona Martinez De Tejada Weber (Switzerland), Carmina Comas (Spain), Christophe Vayssiere (France), Conrado Milani Coutinho (Brazil), Deepika Deshpande (India), Devendra Kanagalingham (Singapore), Divyatha Jayaram (UAE), Eduardo Cordioli (Brazil), Elvira di Pasquo (Italy), Eman Al Uthmani (UAE), Ewelina Rzyska (UK), Federico Mecacci (Italy), Floriana Carbone (Italy), Frank Reister (Germany), Geoff Mathews (Australia), Giuseppe Rizzo (Italy), Jasmine Leonce (UK), Juan de Dios Gutiérrez Henares (Spain), Jude Horscraft (UK), Karradene Aird (UAE), Letchuman Shankar (Wales), Luka Velemir (France), Maggie Xie (China), Manjula Samyraju (UK), Maitreyee Deshpande (UK), Mandeep Singh (UAE), Maria Oikonomou (Greece), Mariam Algobari (UAE), Mary Edmonston (UK), Miriam Crespo Rodriguez (Spain), Mkpe Abbey (Nigeria), Mohamed Rishard (Sri Lanka), Morten Lebech (Denmark), Naheed Tahir (UK), Neerja Gupta (UK), Niraj Yanamandra (India), Prabath Suraweera (UK), Priyantha Kandanearachchi (UK), Raajkumar Sundararajah (UK), Radu Botezatu (Romania), Rafa Campoamor (Spain), Raul de Diego (Spain), Ruben Ramirez Zeggara (Italy), Sabrina Kuah (Australia), Sailaja Vuppu (UAE), Sarah Soanes (UK), Serantha Foolchand (South Africa), Silumini Tennakoon (Sri Lanka), Silvia Espuela Malon (Spain), Sophia Andres (Germany), Tasabih Ali EL Hassan Mohamed (Scotland), Valerie Guinto (Philippines), Veena Paliwal (Oman), Vera Silva (Portugal), Yves Jacquemyn (Belgium).

[2] Physiological CTG. com.

https://doi.org/10.1016/j.ejogrb.2024.09.034
Received 8 September 2024; Accepted 23 September 2024
Available online 2 October 2024

Relative utero-placental insufficiency of labour (RUP-L)
Suggestive of Fetal Inflammation (SOFI)

pathophysiology. The guideline recommended the recognition of different types of fetal hypoxia, and the determination of features of fetal compensatory responses as well as decompensation to ongoing hypoxic stress on the CTG trace. Since its first publication in 2018, there have been several scientific publications relating physiological interpretation of CTG, especially relating to features indicative of autonomic instability due to hypoxic stress (i.e., the ZigZag pattern), and of fetal inflammation. Moreover, emerging evidence has suggested improvement in maternal and perinatal outcomes in maternity units which had implemented physiological interpretation of CTG. Therefore, the guideline on Physiological Interpretation of CTG has been revised to incorporate new scientific evidence, and the interpretation table has been expanded to include features of chorioamnionitis and relative utero-placental insufficiency of labour (RUPI-L).

Introduction

The first international expert consensus guideline on Physiological Interpretation of cardiotocograph (CTG) was produced by 44 CTG experts from 14 countries in 2018 [1]. This ensured a paradigm shift in classifying CTG traces by grouping the pre-determined features of the CTG trace into different "categories" often with unscientific time limits, and then, randomly combining them to arrive at an "overall classification" CTG traces into "normal, suspicious, pathological" (or Category I, II or III) categories [2–5]. Instead, the international consensus guideline on Physiological CTG interpretation advocated the classification of CTG traces based on the recognition of different types of fetal hypoxia and assessing the fetal responses to ongoing stress by differentiating features suggestive of fetal compensation from decompensation [1]. The interpretation tools recommended by this international expert consensus statement on physiological interpretation of CTG to aid interpretation of observed fetal heart rate (FHR) changes were aimed at individualisation of care. This should be done by use of the "Fetal Monitoring checklist" to determine whether if THIS fetus was "fit" to undertake the progressively hypoxic journey of labour at the beginning of recording. Once pre-existing fetal compromise has been excluded by this checklist, then, determining the types of fetal hypoxia and the central organ oxygenation ("How is THIS fetus?") during labour by the use of "Intrapartum Fetal Assessment Tool" was recommended [1].

The above principles of Physiological interpretation of CTG traces have been implemented in more than 20 maternity units in the UK, and several hospitals in Spain, Belgium, France, Italy, Australia, Denmark, Estonia, Switzerland, Lithuania, Romania, Sri Lanka, China, Singapore, Oman and the United Arab Emirates, and several hospitals have demonstrated a reduction in the rate of intrapartum-related hypoxic-ischaemic encephalopathy (HIE), and the rate of emergency caesarean sections for suspected fetal compromise [6,7].

What is the key driver behind the revision of the international expert consensus guideline on physiological interpretation of CTG (IEPIC)?

The first version of this guideline was aimed at recognising different types of fetal hypoxia and determining fetal compensatory responses to ongoing intrapartum mechanical and hypoxic stresses to help improve perinatal outcomes and /or to reduce unnecessary intrapartum operative interventions for women. Since the publication of this guideline in 2018, there have been emerging scientific evidence highlighting the different concepts of physiological CTG interpretation [8], including the ZigZag Pattern [9,10], fetal heart rate cycling [11], features suggestive of chorioamnionitis and inflammation [12–16]. Moreover, some recent animal experimental studies have questioned the role of baroreceptors in the causation of fetal heart rate decelerations [17]. In addition, there have been scientific publications highlighting the importance of "higher than expected baseline fetal heart rate" [18], perinatal outcomes in different types of fetal hypoxia [19,20], and correlation of different types of hypoxia with neurological outcomes [21]. Eventually the CTG features and the pathophysiology of a subtype of hypoxic stress arising at the onset of regular uterine activity have been described under the definition of RUPI-L (Relative Utero-Placental Insufficiency of Labour) [22].

The following changes which are highlighted in this revised International Expert Consensus Statement on Physiological Interpretation of CTG (IEPIC) will replace and supersede the first version of the guideline published in 2018 [1]. However, this revision must be used in conjunction with the original guideline to understand the principles of physiological CTG interpretation (Supplement 1).

a. Mechanisms of fetal heart rate decelerations

The international expert consensus group noted the ongoing controversy due to some researchers who predominantly conduct animal experimental studies questioning the role of baroreceptors in the causation of decelerations [17,23]. This is despite the same research group having stated earlier that baroreceptors do play an initial role in fetal heart rate decelerations, but they are soon overwhelmed by peripheral chemoreceptors [24]. The panel felt that the experimental animal studies which attempt to cause umbilical cord compression by occluding a loop of the umbilical cord with a silicone ring in fetuses subjected to a general anaesthetic and intrauterine invasive procedures to monitor the vital parameters do not truly reflect what really happens during human labour. It has been shown that with the onset of uterine contractions, due to the compression of the placental sinuses, there is a bolus of blood reaching the fetus leading to an increase in fetal oxygen saturation [25]. This initial bolus of increased blood volume at the beginning of uterine contractions is very likely to increase fetal cardiac output, increasing the systemic blood pressure, with the activation of baroreceptors which caused a sudden and an abrupt drop in the fetal heart rate. It is obvious that the isolated compression of the umbilical cord which is performed during experimental animal studies will not have this initial increase in the blood volume and resultant increase in blood pressure, giving the erroneous impression that all decelerations are mediated by peripheral chemoreceptors. This potential confounding effect has been recently highlighted [25]. Moreover, the arguments regarding which receptors mediate the drop in the FHR do not help frontline clinicians who need to understand the underlying mechanisms so that the ongoing stress can be alleviated to improve perinatal outcomes [26]. Based on available data and the reasoning above, the panel concluded that unnecessary academic arguments regarding the receptors with those who conduct animal experimental studies will take the focus away from real-life clinical practice. Therefore, the panel has removed the reference to "baro-receptor" and "chemo-receptor" mediated decelerations, and has simply recommended the classification of decelerations into two types based on the likely underlying cause.

The panel recognises the historical obstetric practice of classifying fetal heart rate decelerations based on the morphology, duration and in relation to the uterine contractions. It is important to appreciate that morphology of observed decelerations (eg., early, variable, late, typical, atypical etc) have been reported to have no correlation with poor perinatal outcomes. Therefore, the panel strongly recommends that the intervening baseline between ongoing decelerations must be scrutinised to determine its stability and the presence of reassuring variability and continuing cycling to determine fetal response to ongoing intrapartum

hypoxic stress. Nonetheless, the panel appreciates that some clinicians, due to the continuing influence of traditional obstetric teaching, may wish to determine the morphology of decelerations, until they develop complete confidence in the principles of physiological CTG interpretation. Therefore, the panel has opted to include two morphological types of decelerations, based on the likely underlying pathophysiological mechanisms.

Any deceleration which has an abrupt drop from the baseline (>30 bpm), reaching the nadir within 30 s from the onset of the decelerations, and demonstrating a quick recovery to the baseline may be termed a "Quicklie" (Fig. 1). These are believed to be due to the compression of umbilical cord, and resultant transient hypoxaemia, and not due to hypoxia and/or acidosis. The intervening baseline and variability should be assessed to determine the oxygenation of the central organs. If such "quicklie" decelerations are associated with an increase in the baseline FHR (i.e., catecholamine surge), then changes in maternal position and/or reducing the rate of oxytocin infusion may help restoring the baseline to normal.

Any deceleration which has a gradual drop from the baseline, and then recovers slowly to the baseline even after the cessation of uterine contractions may be termed "tardy" (Fig. 2). These "tardy" decelerations are due to an ongoing utero-placental insufficiency and may be associated with acidosis if they are associated with a reduced baseline variability. These "tardy" decelerations are often due to a structural damage to the placenta (e.g., infarction, thrombosis or an abnormal placentation), and therefore, cannot be reversed by changes in the maternal position or administration of fluids to the mother.

Important Note

Regarding the morphology of FHR decelerations, the international expert consensus group recommends that with evolving understanding and confidence in physiological CTG interpretation, clinicians should move away from identifying the morphology of decelerations but assess the intervening baseline FHR for stability, reassuring variability and cycling to determine fetal wellbeing".

b. Change in terminology for excessive baseline variability due to a rapidly evolving hypoxia: The ZigZag pattern

Increased variability was referred to "saltatory pattern" which is a general term used to describe an increased baseline variability lasting > 25 bpm lasting for at least 30 min [9]. However, saltatory pattern was found to be very rare (<5%) during labour [27,28], most likely because due to intermittent interruption of fetal oxygenation due to ongoing uterine contractions, it is not possible to have such "uniform" increased bandwidth lasting for 30 min. Gracia Perez-Bonfils proposed to differentiate the use of "saltatory pattern" to refer to a uniform increase in the bandwidth lasting for more than 30 min, which is mostly due to an antenatal acute and profound (non-fatal), hypoxic-ischaemic insult, from the "ZigZag" pattern to refer to an abrupt and erratic up and down fluctuation of the baseline FHR variability (>25 bpm). The latter occurs when the intensity of hypoxic stress increases with insufficient time available at the baseline to ensure adequate gas exchange, and such an erratic fluctuation of baseline FHRV>25 bpm lasts for at least 1 min [9]. It has been reported that the ZigZag pattern persisting for more than 2 min is associated with approximately 11-fold increase in the admission to the neonatal unit [9,10].

Subsequently, it has been reported that marked increased variability lasting for more than one minute during labour was associated with a two-fold increase in neonatal acidosis [29].

Although, the exact mechanism for the ZigZag pattern (Fig. 3) is unknown, it is considered to be due to an autonomic instability, and recent animal experimental studies have suggested that it is predominantly mediated by the parasympathetic nervous system [30].

A ZigZag pattern persisting for more than 1 min requires immediate action to improve fetal oxygenation (reducing or stopping oxytocin infusion and /or administering a tocolytic). If ZigZag pattern is observed with a subacute hypoxic pattern during active maternal pushing, then, immediate cessation of active, directed pushing is recommended to rapidly improve fetal cerebral oxygenation through the carotid arteries [13–16]. If the ZigZag pattern is seen with an increase in the baseline FHR without repetitive decelerations [13–16], then, this should raise the suspicion of fetal neuroinflammation in the context of chorioamnionitis, then, continuing super-imposed hypoxic stress should be avoided to reduce the likelihood of neonatal encephalopathy (NNE).

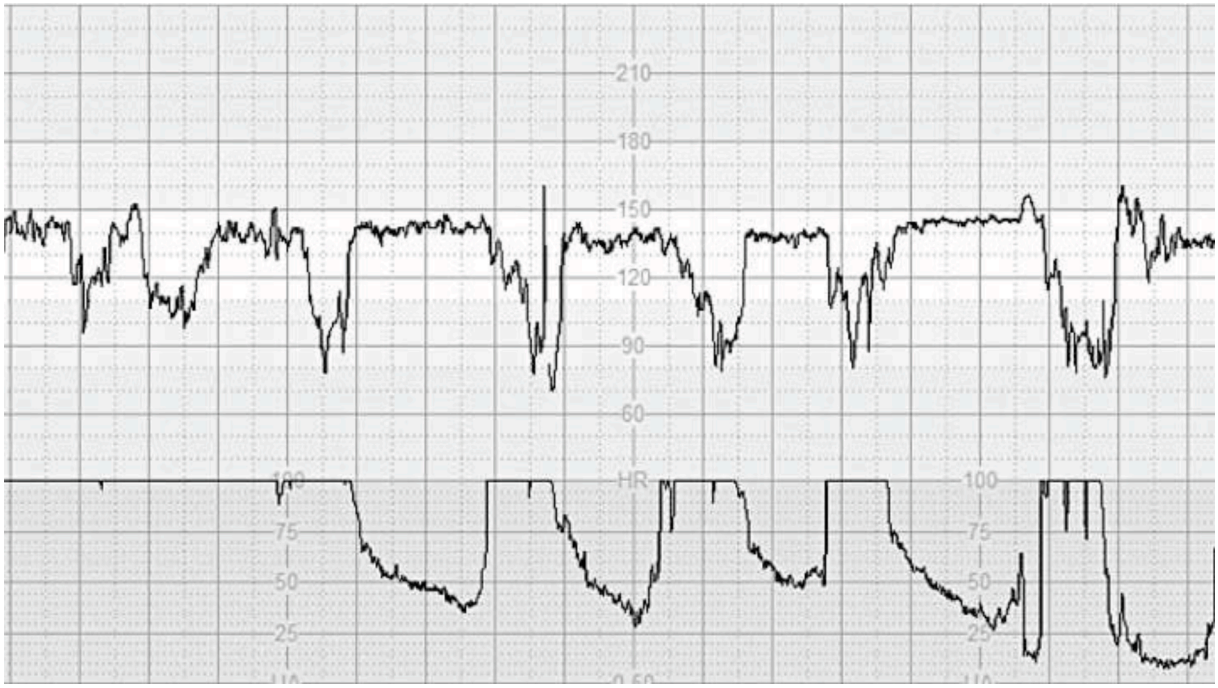

Fig. 1. "Quicklie" Deceleration.

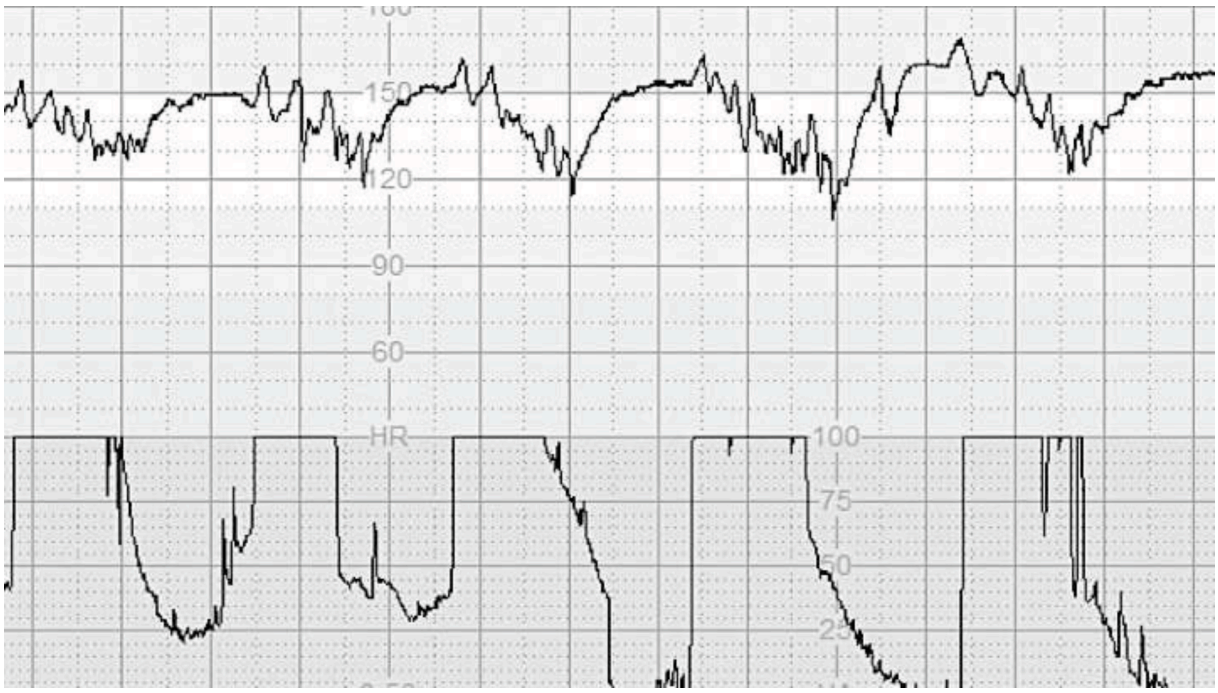

Fig. 2. "Tardy" Deceleration.

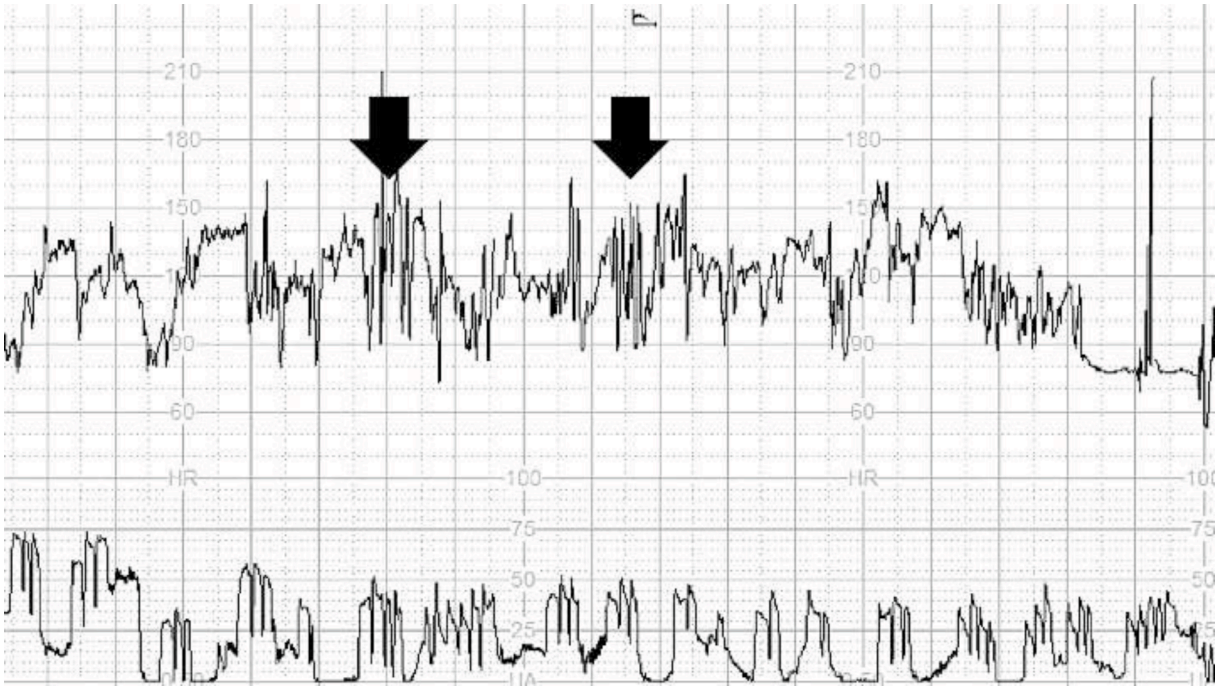

Fig. 3. "ZigZag" Pattern.

c. Features suggestive of fetal inflammation (SOFI) to recognise chorioamnionitis (intraamniotic inflammation and/or infection)

An increase in the baseline FHR by > 10 % without preceding deceleration and/or a baseline FHR>10 % higher than what is expected for the gestational age should be considered as SOFI [13–16]. Recently, it has been shown that the interleukin-6 (IL-6) levels in the umbilical artery at birth is approximately five-fold higher in fetuses with > 10 % increase in the baseline FHR without repetitive, preceding decelerations [16]. Furthermore, absence of fetal heart rate cycling was also associated with approximately 4-fold increased prevalence of maternal pyrexia [11]. Recent evidence has shown that in the presence of neuroinflammation (absence of cycling, ZigZag Pattern or sinusoidal patterns) the IL-6 levels in the umbilical cord increase by approximately 4-fold, compared to fetuses with > 10 % increase in the baseline FHR alone [16]. In addition, increased IL-6 levels were associated with a significant increase in the composite adverse outcomes (poor neonatal condition at birth, admission to neonatal unit or special care baby unit), and fetuses with SOFI contributed to approximately 30 % of all cases of CAO (composite adverse outcomes).

Table 1
Intrapartum CTG Classification Tool.

Hypoxia	Features	Management
No Hypoxia	• Baseline appropriate for G.A, and stable Normal FHR variability and presence of cycling No repetitive decelerations	• Consider whether the CTG needs to continue. If continuing the CTG perform routine hourly review to determine the onset of hypoxic or inflammatory/ non-hypoxic stress (see below)
Evidence of Hypoxia		
Chronic Hypoxia	• Higher baseline than expected for G.A. Reduced variability and/ or absence of cycling Absence of accelerations Shallow decelerations Consider the clinical indicators: reduced fetal movements, thick meconium, bleeding, evidence of chorioamnionitis, post maturity, IUGR	Avoid further hypoxic stress: consider tocolysis if a delay is anticipated to accomplish birth (e.g., operating theatre busy) of if there is evidence of progressive reduction in the baseline FHR. Expedite delivery, if birth is not imminent.
RUPI-L	• A sudden increase in the FHR immediately after the onset of established contractions/ induction of labour ZigZag pattern and/or widening /deepening of decelerations	Consider the overall clinical context including background risk factors to determine if birth should be expedited.
Gradually Evolving Hypoxia	**Compensated** Rise in the baseline (with normal variability and stable baseline) preceded by decelerations and loss of accelerations, with inter-deceleration interval greater than the time spent during decelerations **Decompensated** • Reduced or increased variability (ZigZag pattern), preceded by repetitive decelerations and an increase in the baseline FHR. Unstable/ progressive decline in the baseline FHR (step ladder pattern to death)	• Likely to respond to conservative interventions Regular review every 30–60 min to assess the resolution of the catecholamine response or increased time spent on the baseline FHR. The wider clinical context such as reduced placental reserve, stage and the rate of progress of labour, presence of meconium or co-existing chorioamnionitis MUST be considered and managed accordingly. • Needs urgent intervention to reverse the hypoxic stress (remove prostaglandin pessary, stop oxytocin infusion, and/ or administer a tocolytic) Delivery should be expedited, if no signs of improvement (restoration of stable baseline FHR and normal variability) are seen
Subacute Hypoxia	More time spent during decelerations (>90 s) than at the baseline (<30 s) May be associated with the "ZigZag" pattern (increased variability) lasting for > 1 min	**First Stage** • Remove prostaglandins/stop oxytocin infusion If no improvement is seen, needs urgent tocolysis If no evidence of improvement within 10–15 min of the above measures, review the overall clinical context, and expedite delivery, if appropriate. **Second Stage** • Stop oxytocin infusion and stop maternal active pushing during contractions until improvement is noted. If no improvement in noted, consider tocolysis if delivery is not imminent or expedite delivery by operative vaginal delivery
Acute Hypoxia	Prolonged Deceleration (>3 min)	**Preceded by reduced variability and lack of cycling or reduced variability within the first 3 min** ***Immediate delivery by the safest and quickest route*** **Preceded by normal variability and cycling and normal variability during the first 3 min of the deceleration** **High chance of recovery – see 3 min rule below** • Exclude the 3 intrapartum irreversible accidents (i.e. umbilical cord prolapse, placental abruption, uterine rupture – if such an accident is suspected prepare for immediate delivery) Correct the reversible causes (uterine hyperstimulation/hypertonus, maternal hypotension and sustained umbilical cord compression) If no improvement by 9 min or any of the accidents diagnosed, immediate delivery by the safest and quickest route
Chorioamnionitis (SOFI)	>10 % increase in the baseline FHR without any repetitive preceding decelerations Neuroinflammation = loss of cycling, ZigZag or sinusoidal patterns	• Consider the overall clinical context including parity and the stage of labour and the rate of progress of labour In the presence of features of neuroinflammation, expedite birth to avoid the detrimental effects of superimposed hypoxia on the background fetal systemic inflammatory response syndrome (FIRS)
Other Abnormal CTG Patterns	(Double Mountain Peak Sign, Poole Shark Teeth Pattern, Typical Sinusoidal Pattern, uncertain / unstable baseline)	• Escalate to senior team – exclude erroneous recording of maternal heart rate and other non-hypoxic causes such as feto-maternal haemorrhage or chronic fetal anaemia and acidosis as well as fetal cardiac arrhythmias and heart blocks. Consider the application of a Fetal Scalp Electrode (FSE) to improve signal quality if there is evidence of poor quality recording.

Based on this new scientific evidence since the publication of the last guideline, the international consensus group has included "chorioamnionitis" as an additional parameter in the classification of CTG (Table 1). This term encompasses both intraamniotic infection and/or inflammation due to an ascending infection from the maternal genital tract as well as transplacental passage of infection /inflammatory mediators from the maternal compartment. Based on the published scientific evidence, birth should be expedited if features of neuroinflammation is observed on the CTG trace (Figs. 4 a&b). A scoring system (the "Chorio Duck Score") has been recently published to help recognise ongoing chorioamnionitis and to enable timely and appropriate action [15]. Although, a Chorio Duck Score > 5 may be used as a clinical guide to timely recognise ongoing chorioamnionitis, evidence from large studies confirm its effectiveness is required prior to recommending this in routine clinical practice.

d. Relative utero-placental insufficiency of labour (RUPI-L)

The international expert consensus group recognised that some fetuses may present with a relative utero-placental insufficiency at the onset of regular uterine activity and may not show any abnormalities in the features of the FHR in the absence of uterine contractions. This relative utero-placental insufficiency may be due to a reduced ratio between placental supply and fetal demand due to a sub clinically impaired placental function [22]. This imbalance might not produce overt manifestations before labour (such as fetal growth restriction or features of chronic hypoxia at antepartum CTG) but it is unmasked only by the onset of regular uterine activity. The onset of regular uterine activity may further diminish the oxygen supply to these fetuses affected by subclinical placental insufficiency because uterine contractions cause intermittent reductions of the perfusion of the uteroplacental bed. Therefore, with the onset of regular or strong uterine contractions (e.g., induction of labour or established labour), these fetuses start manifesting abnormal fetal heart rate patterns which reflect the attempt to compensate the hypoxic stress and maintain adequate perfusion to essential central organs during episodes of transient reduction in oxygenation. The most commonly observed FHR changes on the CTG trace in fetuses with RUPI-L are represented by:

- Wide and deep decelerations as soon as regular uterine activity – either spontaneous or secondary to the use of oxytocin or administration of prostaglandins – begins.
- The decelerations disappear or reduce their width and depth as uterine contractions decrease in intensity and frequency (Figs. 2 and 3).
- Fetal heart rate baseline between fetal decelerations commonly on the upper limit of the normal range. This occurs as a result of the chronic release of adrenal-derived catecholamines in fetuses with a long-standing exposure to subclinical hypoxia. > 10 % increase in the baseline FHR expected for the given gestational age compared to the previous recording and/or > 150 bpm at 41 weeks or > 140 bpm at 42 weeks of gestation should be considered as abnormal for the given fetus.
- Periods of abruptly increased fetal heart rate variability > 25 bpm lasting between one to ten minutes – i.e., "Zig-Zag" pattern – may occur in cases of rapidly evolving hypoxic stress. The exclusive parasympathetic control on the fetal heart leads to the instability of the heart rate pulses and this could result in intermittent oscillations of baseline > 25 bpm

It is essential scrutinise the CTG trace and timely recognise RUPI-L so that fetal decompensation can be avoided by modifying stress or by expediting birth. For specific FHR patterns suggestive of RUPI-L, the reader may wish to read the recent Commentary on RUPI-L (https://obgyn.onlinelibrary.wiley.com/doi/epdf/https://doi.org/10.1111/aogs.14937)

e. Interpretation of antenatal CTG traces

The international expert consensus group noted the publications on the role of computerised analysis of cardiograph to determine the short-term variability (STV) during the antenatal period. However, the international expert consensus group on physiological interpretation of CTG emphasizes the importance of considering a range of conditions including inflammation, feto-maternal haemorrhage, chronic fetal anaemia and acidosis which may contribute to fetal compromise during the antenatal period, and these may not be detected by the computerised

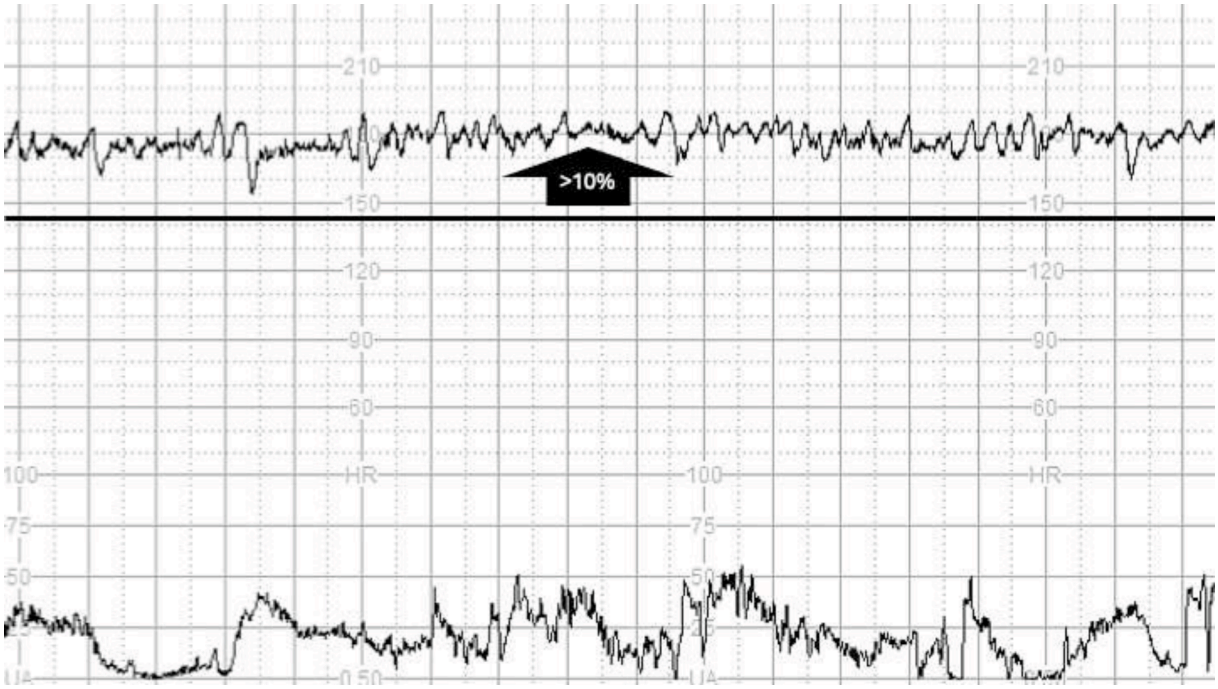

Fig. 4a. SOFI –> 10 % increase in the baseline FHR without preceding deceleration and ongoing myometrial irritability.

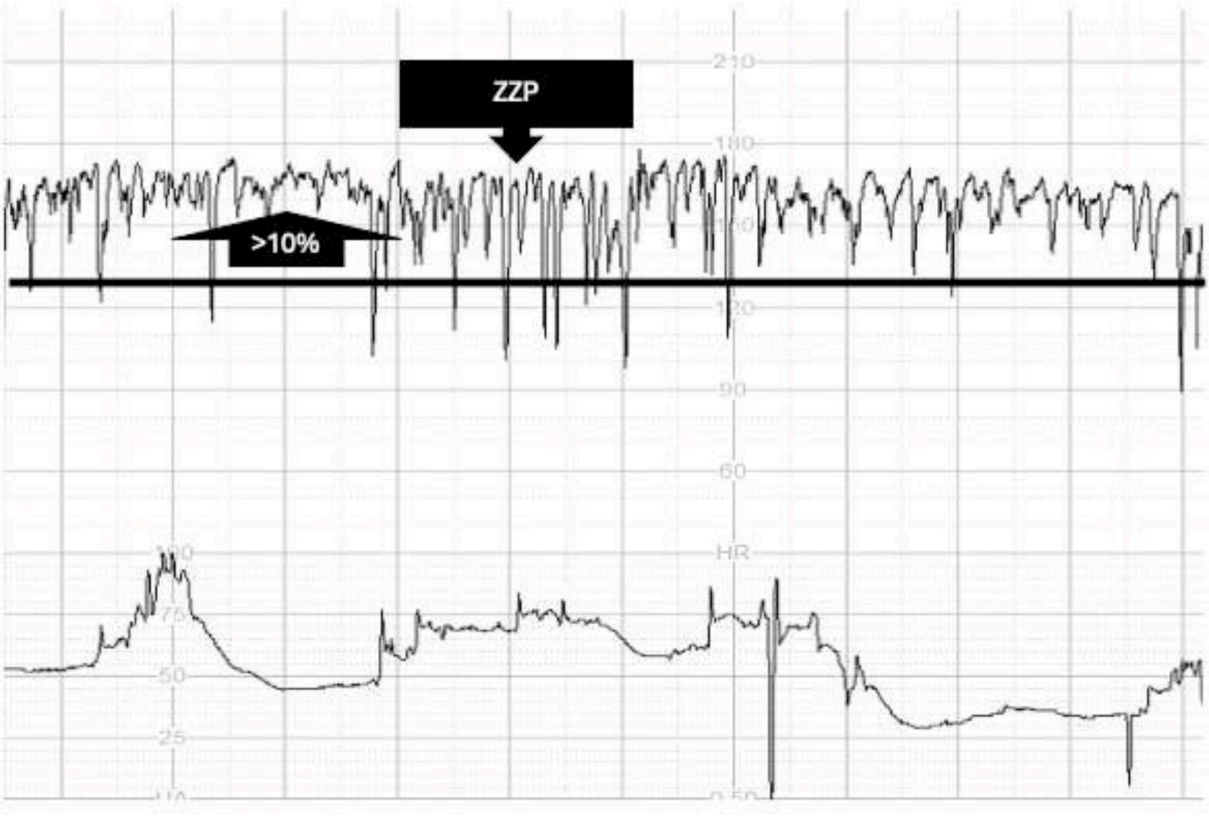

Fig. 4b. SOFI –> 10 % increase in the baseline FHR without preceding deceleration and the presence of the "ZigZag" pattern and ongoing absence of cycling.

CTG. It is important to appreciate that the expected features observed during the intrapartum period such as repetitive decelerations may not be observed before labour due to the absence of ongoing regular or intense uterine contractions. The use of the "CAUTION Checklist" [31] has been proposed as a guide to considering the wider clinical context whilst interpreting CTG traces during the antenatal period, even if the STV is within the normal range for the given gestational age (Table 2). In settings where a computerised antenatal CTG software package is not available, use of the CAUTION checklist is recommended without any reference to STV. See (Fig. 5).

f. Fetal Monitoring checklist

The fetal monitoring checklist which has been recommended in the guideline (2018) to recognise features of chronic hypoxia and pre-existing fetal compromise [32], to ask the question "Is THIS fetus FIT to undertake a progressive hypoxic journey of labour?" has been amended to include chorioamnionitis and RUPI-L (Table 3).

g. Intrapartum fetal Assessment Tool: "How is THIS Fetus?"

If the fetus is deemed "FIT" to withstand the anticipated hypoxic stresses during labour, then, it is important to recognise any new onset of an intrapartum hypoxic or inflammatory stress by the use of the intrapartum fetal assessment tool (Table 4). This tool has been revised to help recognise the features of non-hypoxic causes of fetal compromise. It is important to appreciate that there may a combination of different types of intrapartum hypoxia with progressively increasing hypoxic stress. For example, a gradually evolving hypoxia may become a subacute hypoxia with the onset of active maternal pushing. The tool has been modified to include the initial heart rate to facilitate the easy recognition of > 10 % increase in the FHR, and to help recognise fetal hypoxic stress superimposed on an ongoing fetal inflammation.

h. Recognition of the "Double Mountain Peak Sign" to recognise erroneous monitoring of the maternal heart rate as fetal heart rate

Large amplitude accelerations coinciding with uterine contractions (the "Double Mountain Peak sign") or a sudden drop in the observed baseline FHR, sudden disappearing of FHR, a sudden improvement in the baseline FHR variability or disappearance of decelerations may indicate erroneous monitoring of maternal heart rate as FHR [33–35]. In such cases, oxytocin infusion/ active maternal pushing should be immediately stopped until fetal heart rate is appropriately identified (by the use of maternal pulse oximetry, ultrasound scan or application of fetal scalp electrode).

Recently, the use of maternal pulse oximetry, and simultaneous recording of the maternal heart rate has been emphasised to avoid erroneous recording of the maternal heart rate as fetal heart rate [36,37].

i. Clinical practices which are NOT recommended

Fetal scalp blood sampling (FBS)

In addition to repetitive Cochrane Systematic Reviews from 2007, 2013, and 2017 [38] concluding that fetal scalp blood sampling (FBS) did not improve long term perinatal outcomes or reduce intrapartum operative interventions, subsequent studies have shown that repetitive fetal blood sampling increased operative interventions without improving perinatal outcomes [39]. Moreover, a multi-centre study in the UK concluded in 2019 that FBS did not improve perinatal outcomes, but it increased the rate of emergency caesarean section by approximately 60 % [40]. The only randomised controlled trial published so far, which directly compared FBS to assess the lactates and CTG with CTG monitoring alone, (The Flamingo Trial) has also failed to show any

Table 2
The Fetal Monitoring Checklist" Is THIS Fetus FIT to undertake the progressive hypoxic journey of labour?"

Antenatal CTG Tool The CAUTION checklist to detect Antenatal Fetal Compromise.			
Antenatal History:			**Sig 2**
Cycling absent	**YES**	**NO**	Depression of the CNS
Accelerations absent	**YES**	**NO**	Depression of the somatic NS
Unstable baseline	**YES**	**NO**	MyocardiaI decompensation
Tardy recovery (late decelerations)	**YES**	**NO**	Utero-placental insufficiency
Irritability of the uterus/ Inappropriate baseline for gestational age	**YES**	**NO**	Potential abruption or chorioamnionitis
Obvious history: vaginal bleeding, PPROM, reduced fetal movement, abdominal pain	**YES**	**NO**	Underlying pathology that may contribute to fetal compromise
Non-hypoxic features: Zig-zag pattern or sinusoidal	**YES**	**NO**	Feto-maternal haemorrhage, chronic fetal anaemia or CNS irritability
Date and time			
Print name and sign	1)		2)

Table 3
Intrapartum Fetal Monitoring Tool "How is THIS Fetus"?

Fetal Monitoring Checklist: Is THIS Fetus Fit for Labour? Pereira&Chandraharan 2017			
	CTG Features / Risk Factors	**Assessment**	
1	Baseline fetal heart rate *stable* and *appropriate* for the gestational age.	Yes	**No**
2	Normal variability and cycling	Yes	**No**
3	Presence of *TRUE* accelerations (not in labour or latent phase of labour)	Yes	**No**
4	**No** shallow/ tardy decelerations	Yes	**No**
5	Consider the wider clinical picture: meconium, pyrexia, fetal growth restriction, reduced fetal movements, gestational DM. pre-eclampsia, induction/augmentation, other	Yes	**No**
Overall Impression: Normal/ Chronic Hypoxia/ Chorioamnionitis /RUPI/ Other: **Management Plan:** **Date Time. Name. Signature.**			

benefit of FBS [41]. Therefore, based on current evidence, the risks of FBS outweigh its benefits [42–44]. Therefore, the clinical guideline development group recommends that FBS should no longer be used in clinical practice.

Fetal electrocardiograph (Fetal ECG) / ST-analyser (STAN)

The international expert consensus group noted that the use of fetal CTG (ST-Analyser or STAN) holds a promise due to its reliance on cardiac physiology and the timely recognition of the negative energy balance within the myocardium. However, after reviewing the recent systematic review and a *meta*-analysis, which had included all nine RCTs on STAN and has questioned its usefulness in reducing intrapartum operative interventions [45], the use of STAN with the current CTG guideline table ("Normal, Intermediary, Abnormal") is not recommended. It has been suggested that STAN may be beneficial if a physiological approach is used for CTG/STAN guideline [46,47]. The international expert consensus group will review this recommendation once the physiological CTG/STAN guidelines are fully implemented, and if the emerging scientific evidence after the implementation of the physiological approach confirms the benefits of STAN in reducing intrapartum operative interventions and/or an improvement in perinatal outcomes.

Administration of fluids or oxygen to the mother to correct abnormal FHR changes

Maternal fluids should only be administered to correct abnormalities in the maternal circulation (dehydration, hypotension, sepsis,

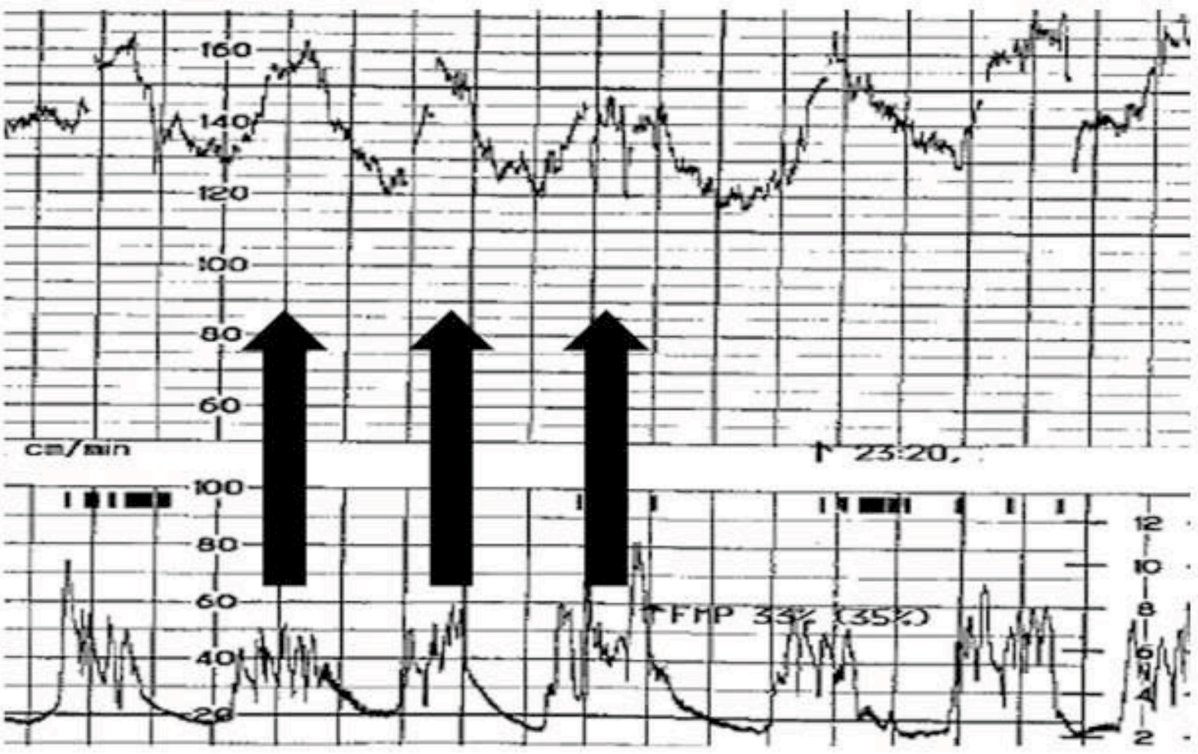

Fig. 5. "Double Mountain Peak" sign.

Table 4
Antenatal CTG Interpretation Tool: the "CAUTION" Checklist.

Intrapartum Fetal Assessment Tool			
Mat Pulse:	***Temp:***	**Initial Baseline FHR**	**Induced / Augmented labour? Y/N**
Risk Factors.			
Current Baseline FHR Paper speed	**Variability**	**Accelerations**	**Decelerations** Quicklies/ Tardies/Both
Rise in Baseline (≥10 %)	**No**	**Yes**	
Inter-contraction interval < 90 s	**No**	**Yes**	
Abnormal Variability (<5 or > 25)	**No**	**Yes**	
No Cycling / Loss of Cycling	**No**	**Yes**	
Features of Hypoxia	**No**	**Yes**	
TYPE of Hypoxia	**Gradually Evolving/Sub-acute/ Combination/ Acute /None**		
Depression of Fetal Central Organs	**No**	**Yes**	
New risk factors noted	**No**	**Yes**	
Any signs of chorioamnionitis/ infection?	**No**	**Yes**	
Any signs of non-hypoxic compromise, ZigZag or Sinusoidal Patterns?	**No**	**Yes**	
Second Opinion needed?	**No**	**Yes**	
Recommended Management Plan			
Date:			
Time:			
NAME			
SIGNATURE			

ketoacidosis etc), and should not be administered to correct fetal heart rate abnormalities. NHS Resolution (a body which defends clinical negligence claims against the NHS) Report in 2019 has reported that administration of excessive fluids during labour increases maternal and neonatal morbidity due to fluid overload and electrolyte imbalance and neonatal convulsions due to dilutional hyponatremia [48].

Maternal oxygen supplementation to treat fetal heart rate abnormalities

This has been discontinued in clinical practice for several years as the potential risks outweigh harm [49], and it was not recommended in the first edition of the international expert consensus guidelines on physiological interpretation of CTG in 2018. Recently, the American College of Obstetricians and Gynaecologists (ACOG) have also released a Practice Bulletin, which has stated that based on scientific evidence, routine use of oxygen supplementation in individuals with normal oxygen saturation is not recommended for fetal intrauterine resuscitation [50]. Therefore, maternal oxygen or fluid therapy to correct fetal heart rate abnormalities is no longer recommended in clinical practice [49]. Maternal oxygen supplementation is recommended in all clinical situations where administration of oxygen is essential to ensure maternal wellbeing (e.g., bronchial asthma, maternal sepsis, maternal cardiopulmonary disorders etc).

CRediT authorship contribution statement

Edwin Chandraharan: Conceptualization, Formal analysis, Methodology, Project administration, Supervision, Writing – original draft, Writing – review & editing. **Susana Pereira:** Methodology, Writing – original draft, Writing – review & editing. **Tullio Ghi:** Conceptualization, Resources, Writing – original draft, Writing – review & editing. **Anna Gracia Perez-Bonfils:** Writing – review & editing. **Stefania Fieni:** Writing – original draft, Writing – review & editing. **Yan-Ju Jia:** Writing – original draft, Writing – review & editing. **Katherine Griffiths:** Writing – review & editing. **Suganya Sukumaran:** Writing – review & editing. **Caron Ingram:** Writing – review & editing. **Katharine Reeves:** Writing – review & editing. **Mareike Bolten:** Methodology, Writing – review & editing. **Katrine Loser:** . **Elena Carreras:** Writing – review & editing. **Anna Suy:** Writing – review & editing. **Itziar Garcia-Ruiz:** Writing – review & editing. **Letizia Galli:** Writing – review & editing. **Ahmed Zaima:** Methodology, Resources, Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ejogrb.2024.09.034.

References

[1] Chandraharan E, Evans SA, Krueger D, Pereira S, Skivens S, et al. Physiological CTG interpretation. Intrapartum Fetal Monitoring Guideline 2018. https://physiological-ctg.com/guideline.htmlhttps://physiological-ctg.com/guideline.html.

[2] National Institute of Clinical Excellence. Intrapartum care: care of healthy women and their babies during labour. NICE Clinical Guideline, December 2014. https://www.nice.org.uk/guidance/cg190/resources/intrapartum-care-for-healthy-women-and-babies-pdf-35109866447557.

[3] ACOG. Practice Bulletin No 106: intrapartum fetal heart rate monitoring: nomenclature, interpretation, and general management principles. Obstet Gynecol 2009;114:192–202.

[4] Ayres-De-Campos D, Spong CY, Chandraharan E. FIGO intrapartum fetal monitoring expert consensus panel. FIGO consensus guidelines on intrapartum fetal monitoring: cardiotocography. Int J Gynaecol Obstet 2015;131:13–24.

[5] Fetal monitoring in labour. NICE Guideline [NG 229], December 2022 (https://www.nice.org.uk/guidance/ng229).

[6] Chandraharan E. Physiological interpretation of cardiotocograph: does the emerging scientific evidence suggest a reversal in the "thunder and lightning" phenomenon? J Clin Med Surgery 2023;3(1):1098.

[7] Jia YJ, Ghi T, Pereira S, Gracia Perez-Bonfils A, Chandraharan E. Pathophysiological interpretation of fetal heart rate tracings in clinical practice. Am J Obstet Gynecol 2023;228(6):622–44.

[8] Jia YJ, Chen X, Cui HY, Whelehan V, Archer A, Chandraharan E. Physiological CTG interpretation: the significance of baseline fetal heart rate changes after the onset of decelerations and associated perinatal outcomes. J Matern Fetal Neonatal Med 2019:1–6.

[9] Gracia-Perez-Bonfils A, Vigneswaran K, Cuadras D, Chandraharan E. Does the saltatory pattern on cardiotocograph (CT G) trace really exist? The ZigZag pattern as an alternative definition and its correlation with perinatal outcomes. J Matern Fetal Neonatal Med 2019:1–9.

[10] Tarvonen M, Hovi P, Sainio S, Vuorela P, Andersson S, Teramo K. Intrapartum zigzag pattern of fetal heart rate is an early sign of fetal hypoxia: a large obstetric retrospective cohort study. Acta Obstet Gynecol Scand 2021;100(2):252–62.

[11] Pereira S, Lau K, Modestini C, Wertheim D, Chandraharan E. Absence of fetal heart rate cycling on the intrapartum cardiotocograph (CTG) is associated with intrapartum pyrexia and lower Apgar scores. J Matern Fetal Neonatal Med 2021; 22:1–6. https://doi.org/10.1080/14767058.2021.1940130.

[12] Galli L, Dall'Asta A, Whelehan V, Archer A, Chandraharan E. Intrapartum cardiotocography patterns observed in suspected clinical and subclinical chorioamnionitis in term fetuses. J Obstet Gynaecol Res 2019;45:2343–50.

[13] Sukumaran S, Pereira V, Mallur S, Chandraharan E. Cardiotocograph (CTG) changes and maternal and neonatal outcomes in chorioamnionitis and/or funisitis confirmed on histopathology. Eur J Obstet Gynecol Reprod Biol 2021;260:183–8. https://doi.org/10.1016/j.ejogrb.2021.03.029. Epub 2021 Mar 30.

[14] Gracia-Perez-Bonfils A, Martinez-Perez O, Llurba E, Chandraharan E. Fetal heart rate changes on the cardiotocograph trace secondary to maternal COVID-19 infection. Eur J Obstet Gynecol Reprod Biol 2020;252:286–93.
[15] Chandraharan E, Bolten M. Recognition of chorioamnionitis on the cardiotocograph (CTG): the role of the "chorio duck score". European Journal of Medical and Health Sciences 2024;6(1):1–9.
[16] di Pasquo E, Fieni S, Chandraharan E, Dall'Asta A, Morganelli G, Spinelli M, et al. Correlation between intrapartum CTG findings and interleukin-6 levels in the umbilical cord arterial blood: a prospective cohort study. Eur J Obstet Gynecol Reprod Biol 2024;13(294):128–34.
[17] Lear CA, Wassink G, Westgate JA, et al. The peripheral chemoreflex: indefatigable guardian of fetal physiological adaptation to labour. J Physiol 2018;596:5611–23.
[18] Ghi T, Di Pasquo E, Dall'Asta A, Commare A, Melandri E, Casciaro A, et al. Intrapartum fetal heart rate between 150 and 160 bpm at or after 40 weeks and labor outcome. Acta Obstet Gynecol Scand 2021;100(3):548–54.
[19] di Pasquo E, Commare A, Masturzo B, Paolucci S, Cromi A, Montersino B, et al. Short-term morbidity and types of intrapartum hypoxia in the newborn with metabolic acidaemia: a retrospective cohort study. BJOG 2022;129(11):1916–25.
[20] Descourvieres L, Ghesquiere L, Drumez E, Martin C, Sauvage A, Subtil D, et al. Types of intrapartum hypoxia in the newborn at term with metabolic acidemia: a retrospective study. Acta Obstet Gynecol Scand 2022;101(11):1276–81.
[21] Pereira S, Patel R, Zaima A, Tvarozkova K, Chisholm P, Kappelou O, et al. Physiological CTG categorization in types of hypoxia compared with MRI and neurodevelopmental outcome in infants with HIE. J Matern Fetal Neonatal Med 2022;35(25):9675–83.
[22] Ghi T, Fieni S, Ramirez Zegarra R, Pereira S, Dall'Asta A, Chandraharan E. Relative uteroplacental insufficiency of labor. Acta Obstet Gynecol Scand. 2024 Aug 6. doi: 10.1111/aogs.14937. Epub ahead of print. PMID: 39107951.
[23] Lear CA, Galinsky R, Wassink G, Yamaguchi K, Davidson JO, Westgate JA, et al. The myths and physiology surrounding intrapartum decelerations: the critical role of the peripheral chemoreflex. J Physiol 2016;594(17):4711–25.
[24] Lear CA, Kasai M, Booth LC, Drury PP, Davidson JO, Maeda Y, et al. Peripheral chemoreflex control of fetal heart rate decelerations overwhelms the baroreflex during brief umbilical cord occlusions in fetal sheep. J Physiol 2020;598(20):4523–36.
[25] McNamara H, Johnson N. The effect of uterine contractions on fetal oxygen saturation. Br J Obstet Gynaecol 1995;102(8):644–7.
[26] Chandraharan E, Ghi T, Pereira S. It is time for midwives and obstetricians to forget about the baroreflex in labor: a response. Am J Obstet Gynecol 2023;229(6):708.
[27] Gimovsky ML, Goh W, Fitzgerald K. Fetal monitoring casebook. The saltatory fetal heart rate pattern. J Perinatol 1991;11(4):386–9.
[28] O'Brien-Abel NE, Benedetti TJ. Saltatory fetal heart rate pattern. J Perinatol 1992;12(1):13–7.
[29] Loussert L, Berveiller P, Magadoux A, Allouche M, Vayssiere C, Garabedian C, et al. Association between marked fetal heart rate variability and neonatal acidosis: a prospective cohort study. BJOG 2023;130(4):407–14.
[30] Lear CA, Westgate JA, Kasai M, Beacom MJ, Maeda Y, Magawa S, et al. Parasympathetic activity is the key regulator of heart rate variability between decelerations during brief repeated umbilical cord occlusions in fetal sheep. Am J Physiol Regul Integr Comp Physiol 2020;319(5):R541–50.
[31] Pereira S, Ingram C, Gupta N, Singh M, Chandraharan E. Recognising fetal compromise in the cardiograph during the antenatal period: pearls and pitfalls. Asian Journal of Medicine and Health 2020;18(9):72–83.
[32] Pereira S, Chandraharan E. Recognition of chronic hypoxia and pre-existing foetal injury on the cardiotocograph (CTG): urgent need to think beyond the guidelines. Porto Biomed J 2017;2(4):124–9.
[33] Al Fahdi B, Chandraharan E. True vs spurious intrapartum fetal heart rate accelerations on the cardiotocograph (CTG): an urgent need for caution. Glob J Reprod Med 2020;7(5):5556722. https://doi.org/10.19080/GJORM.2019.07.555722.
[34] Saeed F, Abeysuriya S, Chandraharan E. Erroneous recording of maternal heart rate as fetal heart rate during second stage of labour: isn't it time to stop this? J Biomed Res Environ Sci 2021;2(5):315–9. https://doi.org/10.37871/jbres1233.
[35] Nurani R, Chandraharan E, Lowe V, Ugwumadu A, Arulkumaran S. Misidentification of maternal heart rate as fetal on cardiotocography during the second stage of labor: the role of the fetal electrocardiograph. Acta Obstet Gynecol Scand 2012;91(12):1428–32. https://doi.org/10.1111/j.1600-0412.2012.01511.x. Epub 2012 Sep 18.
[36] Tarvonen M, Markkanen J, Tuppurainen V, Jernman R, Stefanovic V, Andersson S. Intrapartum cardiotocography with simultaneous maternal heart rate registration improves neonatal outcome. Am J Obstet Gynecol. 2024 Apr;230(4): 379.e1-379.e12. doi: 10.1016/j.ajog.2024.01.011. Epub 2024 Jan 23. PMID: 38272284. - this is in favour of routine MHR monitoring.
[37] Dall'Asta A, Volpi L, Morganelli G, Ghi T. Added value of intrapartum recording of the maternal heart rate as an adjunct to fetal monitoring using external ultrasound transducer: not only about artifacts. Am J Obstet Gynecol. 2024 Mar 6: S0002-9378(24)00427-7. doi: 10.1016/j.ajog.2024.02.313. Epub ahead of print. PMID: 38453130.
[38] Alfirevic Z, Devane D, Gyte G. Continuous cardio- tocography (CTG) as a form of electronic fetal monitor- ing (EFM) for fetal assessment during labour. Cochrane Database Syst Rev 2013;5:CD006066.
[39] Holzmann M, Wretler S, Cnattingius S, Nordström L. Neonatal outcome and delivery mode in labors with repetitive fetal scalp blood sampling. Eur J Obstet Gynecol Reprod Biol 2015;184:97–102.
[40] Al Wattar BH, Lakhiani A, Sacco A, et al. AB-FAB Study Group. evaluating the value of intrapartum fetal scalp blood sampling to predict adverse neonatal out- comes: a UK multicentre observational study. Eur J Obstet Gynecol Reprod Biol 2019;240:62–7.
[41] East CE, Davey MA, Kamlin COF, Davis PG, Sheehan PM, Kane SC, et al. Flamingo Study Group. The addition of fetal scalp blood lactate measurement as an adjunct to cardiotocography to reduce caesarean sections during labour: the Flamingo randomised controlled trial. Aust N Z J Obstet Gynaecol 2021;61(5):684–92.
[42] Chandraharan E. Should national guidelines continue to recommend fetal scalp blood sampling during labor? J Matern Fetal Neonatal Med 2016;29(22):3682–5.
[43] Chandraharan E. Fetal scalp blood sampling during labour: is it a useful diagnostic test or a historical test that no longer has a place in modern clinical obstetrics? BJOG 2014;121(9):1056–62.
[44] Chandraharan E. Fetal scalp blood sampling should be abandoned: FOR: FBS does not fulfil the principle of first do no harm. BJOG 2016;123(11):1770.
[45] Blix E, Brurberg KG, Reierth E, Reinar LM, Øian P. ST waveform analysis vs cardiotocography alone for intrapartum fetal monitoring: an updated systematic review and meta-analysis of randomized trials. Acta Obstet Gynecol Scand 2024;103(3):437–48.
[46] Chandraharan E. Fetal electrocardiograph (ST-Analyser or STAN): is it time for the requiem? J Clin Med Surgery 2023;3(2):1111.
[47] Chandraharan E. Foetal electrocardiograph (ST-analyser or STAN) for intrapartum foetal heart rate monitoring: a friend or a foe? J Matern Fetal Neonatal Med 2018;31(1):123–7.
[48] NHS Resolution, The Early Notification scheme progress report: collaboration and improved experience for families, September 2019. https://resolution.nhs.uk/wp-content/uploads/2019/09/NHS-Resolution-Early-Notification-report.pdf.
[49] Chandraharan E. Maternal, "oxygen and fluids therapy" to correct abnormalities in the cardiotocograph (CT G): scientific principles vs historical (Mal) practices. J Adv Med Med Res 2020;32:10–6.
[50] Committee on Clinical Practice Guidelines—Obstetrics. Oxygen Supplementation in the Setting of Category II or III Fetal Heart Tracings [2022]. https://www.acog.org/clinical/clinical-guidance/practice-advisory/articles/2022/01/oxygen-supplementation-in-the-setting-of-category-ii-or-iii-fetal-heart-tracings.