



Recognising Fetal Compromise in the Cardiograph during the Antenatal Period: Pearls and Pitfalls

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Authors' contributions

This work was carried out in collaboration among all authors. Authors SP and EC conceived the commentary and author CI provided the CTG Traces. Authors SP and EC co-wrote the first draft of the manuscript. Authors SP, CI, NG, MS and EC reviewed and edited the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

There are several national and international guidelines to aid the interpretation of the cardiotocograph (CTG) trace during labour. These guidelines are based on assessing changes in the fetal heart rate (i.e. cardiograph) in response to mechanical and hypoxic stresses during labour secondary to ongoing frequency, duration and strength of uterine contractions (i.e. tocograph). However, during the antenatal period, uterine contractions are absent, and therefore, these intrapartum CTG guidelines cannot be used to reliably identify fetuses at risk of compromise.

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Computerised analysis of CTG using the Dawes-Redman Criteria could be used to detect fetal compromise. However, clinicians should be aware of the multiple pathways of fetal damage (i.e. inflammation, infection, intrauterine fetal stroke, chronic fetal anaemia, acute fetomaternal haemorrhage and fetal cardiac or neurological disorders) which can cause changes on the CTG trace which may not be recognised by using CTG guidelines.

Keywords: Antenatal cardiograph; computerised CTG; short term variability; sinusoidal pattern; Dawes-Redman Criteria; Chronic Hypoxia.

1. INTRODUCTION

The aim of cardiocograph (CTG) is to timely identify the onset of fetal decompensation so that appropriate action can be taken to alleviate ongoing hypoxic or mechanical stresses (uteroplacental insufficiency or repetitive or sustained compression of the umbilical cord). However, current guidelines on CTG interpretation (NICE [1], FIGO [1], ACOG [2]) which stipulate normal ranges for the parameters of the fetal heart rate (baseline heart rate, baseline variability and accelerations) that reflect the fetal central organs' oxygenation have been intended to be used during labour. Fetal responses to ongoing hypoxic or mechanical stresses (decelerations) are key features in the classification of CTGs [3]. However, in the antenatal period, strong and repetitive uterine contractions which cause utero-placental insufficiency or umbilical cord compression do not occur. Therefore, in the absence of contractions on the tocograph, one cannot interpret the cardiocograph based on intrapartum guidelines to detect intrapartum hypoxia.

Moreover, unlike during labour where intrapartum hypoxic stress evolves over a number of hours, during the antenatal period, utero-placental insufficiency develops over a number of weeks or months. The changes observed on the CTG may be very subtle, and the large and repetitive decelerations may be absent. The 'human eye' cannot accurately and reliably determine the short-term variability (STV) [4] which becomes reduced in such a chronic hypoxic process. Therefore, one needs a computer to analyse the STV during the antenatal period. In addition, several non-hypoxic causes such as intra-uterine fetal stroke, chronic fetal anaemia and acute fetomaternal haemorrhage may result in CTG changes, and these may be missed by the CTG Guidelines which have been developed to identify intrapartum fetal hypoxic stress.

2. COMPUTERISED ANALYSIS OF CTG USING THE DAWES-REDMAN CRITERIA [5]: BASIC PRINCIPLES

Visual interpretation of the CTG trace not only has a significant inter and intra-observer variability, it may also miss an ongoing fetal hypoxia in the antenatal period. The use of a computer to analyse pre-defined individual features of the CTG enables clinicians to reduce the inter- and intra-observer variability that occurs during the visual interpretation of CTG traces. In addition, it allows quantification of the short term variability which cannot be reliably assessed by the human eye.

The pre-loaded software programme which is derived from one of the world's largest CTG databases, with several CTG features linked to perinatal outcomes, compares the parameters of the CTG from the fetus in question with approximately 100,000 CTG traces within the installed database to determine whether the "Dawes-Redman Criteria" [5] are met.

The computer first analyses the individual parameters of the CTG trace at the given gestation, and then applies the Dawes-Redman criteria to this dataset to determine whether the pre-determined criteria have been met (Fig. 1), within a defined time frame (60 minutes). However, midwives and obstetricians should not blindly follow the computerised analysis and management plans should be based on the entire clinical assessment (history, examination, results of ultrasound growth scan with Doppler blood flow) [6].

2.1 What Does the Computer Analyse?

The Dawes-Redman criteria are derived from the analysis of a pre-determined dataset [7] (Table 1):

STV (see above) cannot be assessed visually by looking at the trace. It is not the same as the

variability that one assesses whilst interpreting a ctg trace during labour, at term. It must not be used in isolation as an indicator of fetal condition as it is possible to have normal stv with a severely compromised fetus, due to a non-hypoxic cause. It is only significant as part of a full 60-minute analysis. If the criteria are not met (Fig. 2), an immediate obstetric review should be requested so that a decision can be made regarding the need for delivery based on the overall clinical picture.

2.2 How to Perform a Computerised CTG Using the Dawes-Redman Criteria?

CTG machines with integrated software are capable of performing the Dawes-Redman analysis in the antenatal period at any gestational age from 26 weeks onwards. The software has been updated multiple times and different generation machines may have different versions of the software and present the information in slightly different ways.

- Start the CTG, turn 'analysis on'
- Enter the gestational age in weeks and days.
- Turn the printing on.
- If, after 10 minutes the Dawes-Redman Criteria are met (see Fig. 3), this will be displayed on the bottom of the screen with a tick or with the 'CARE' box turning green, depending on the type of machine. The CTG trace be reviewed by pressing the 'menu' and then pressing the 'review' button. The report can be generated by first stopping the recording and then pressing the "print" button. One should not turn off the CTG machine until it has completed printing.
- If the Dawes-Redman criteria are not met, then, the CTG monitoring should be continued for an hour before printing the report.

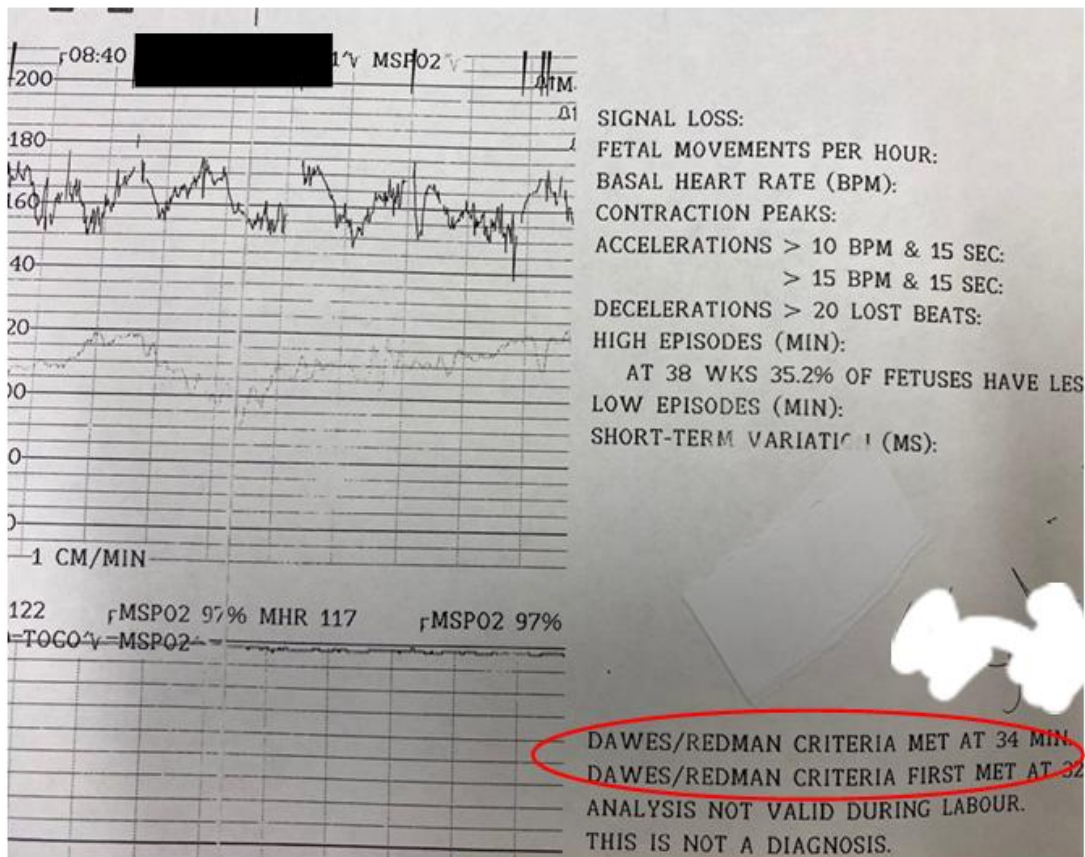


Fig. 1. Computerised analysis of the CTG (The Dawes-Redman criteria have been met)

Table 1. Parameters analysed by the Dawes-Redman computerised software

Parameter	Explanation
Signal Loss	Percentage of the trace length for which there is no FHR data.
Fetal Movements	As per traditional technique based on movements perceived by the patient. This is not used in monitoring twin pregnancies as movements cannot be attributed to a particular fetus.
Basal heart rate	As per traditional technique based on movements perceived by the patient. This is not used in monitoring twin pregnancies as movements cannot be attributed to a particular fetus.
Uterine Contractions	Are recorded as per the traditional technique using the tocograph
Accelerations	Same as conventional CTG analysis definition but are quantified and presented in 2 groups (amplitude >10 bpm and amplitude >15 bpm, based on the gestational age).
Decelerations	The number of decelerations is defined as per conventional CTG analysis but additionally, they are quantified in terms of “>20 Lost Beats”- a measure of the depth and duration of the deceleration.
Reactivity of fetal heart beat:	Fetal heart rate variation has been shown to be the most useful computerised CTG indicator of antepartum fetal well-being. Two normal sources of FHR variation are gestational maturity and episodic changes in fetal behavioural states after 28 weeks gestation. The system was designed to take into account the episodic changes in fetal heart rate and fetal movement’s characteristic of sleep states. The detection of an episode of high FHR variation is accepted evidence of normality and corresponds to the concept of reactivity used in the visual analysis.
Long term variation (LTV)	This is in the form of high and low episodes in minutes. Variation in the pulse interval or rate from the baseline gives a measure of LTV. Periods for which LTV or beat-to-beat variation is >32 milliseconds for five or six consecutive minutes are described as high episodes and when the LTV is low the period is described as low episodes.
Short term variation (STV)	This is similar to baseline variability, and LTV, but measured over a much smaller interval of just 3.75 s (typically 7 to 10 beats). A significant benefit is that it is independent of baseline rate. The mean STV increases as gestational age advances.
Overall the thresholds of abnormal STV are as below	< 4 ms: Low < 3 ms: Abnormal < 2 ms: Highly abnormal. If the Short term variability is < 4 ms - seek an obstetric opinion urgently.

Note: STV is only valid if measured after 60 min of recording

2.3 Understanding the Output of the Computer Using the Dawes-Redman Criteria

The computer software assesses the above-mentioned dataset, and then creates a report. The first result is available after 10 minutes and is updated every 2 minutes up to max of 60 minutes.

There are 2 possible outcomes:

- Criteria met
- Criteria not met

2.4 What to Do When Criteria are Met?

Dawes-Redman Criteria can be met after as early as 10 minutes (i.e. after the first analysis). It indicates a normal trace with reassuring fetal wellbeing. The CTG can be stopped, but only after it is subjected to a visual assessment and considering the overall clinical picture. Clinical judgement is paramount and one should not rely on the computerised analysis in isolation. It may not always identify unusual or pathological patterns that may be more obvious from visual interpretation. Therefore, a holistic assessment should be performed incorporating the knowledge of the whole clinical scenario. For

example, if there is a history of reduced fetal movements at term, consider using the 'Chronic Hypoxia Checklist' (Table 2) [8] to complement Dawes-Redman Analysis, because the computer may fail to consider a combination of abnormalities. If the recording is continued after

the criteria are met, then, the computer may need an additional 60 minutes to meet the criteria, and if the recording is stopped prior to meeting the criteria, it may provide an error message 'incomplete time for analysis'.

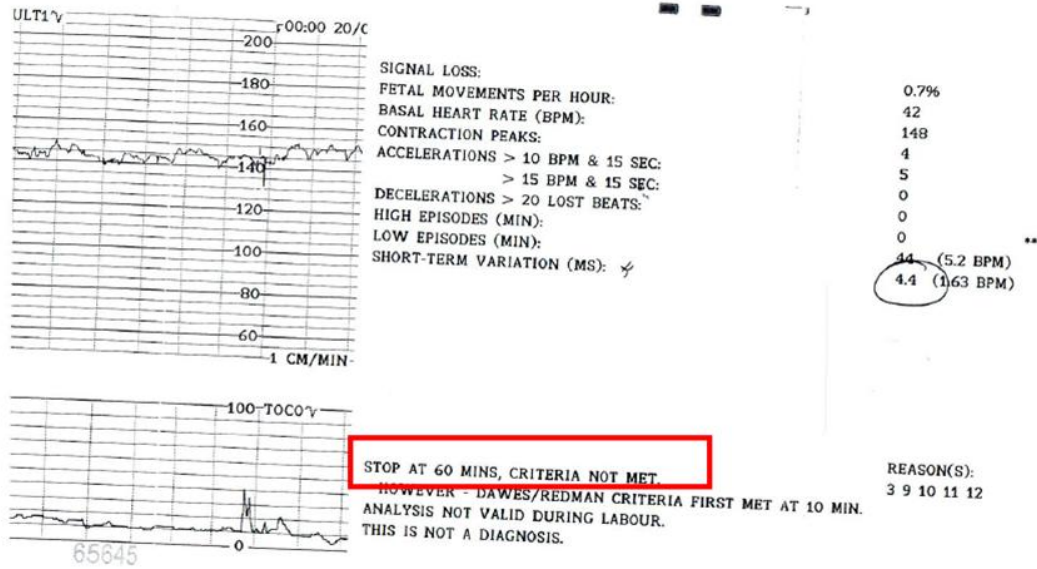


Fig. 2. An example of computerised analysis of the CTG using the Dawes-Redman criteria to analyse individual parameters

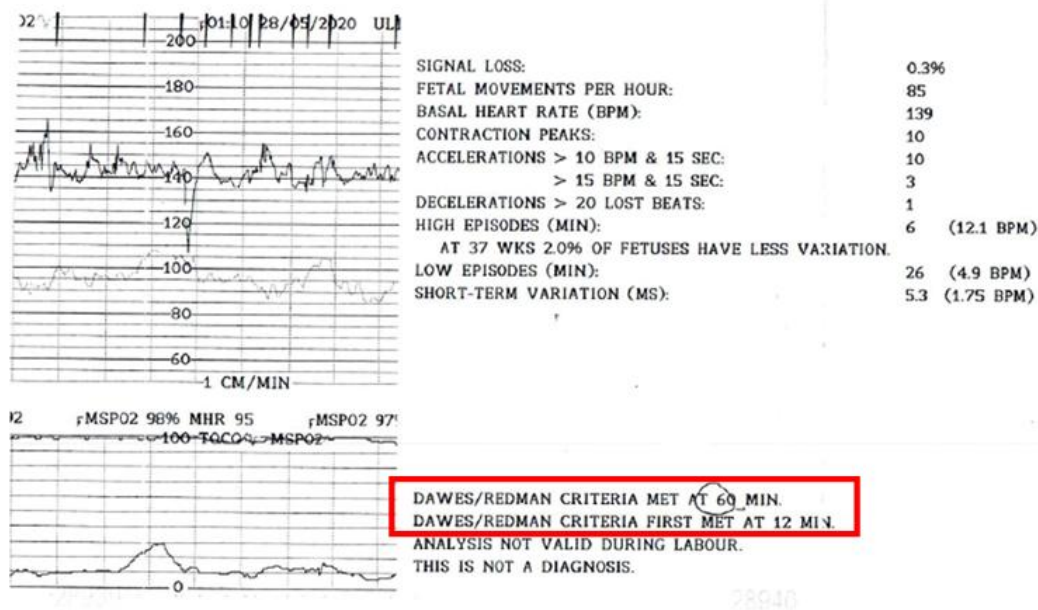


Fig. 3. Note the Dawes-Redman criteria have been met by 60 minutes in the following case. Therefore, the CTG trace can be discontinued after considering the overall clinical picture

Table 2. The ‘chronic hypoxia checklist (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 biomedical journal 2017; 2(4): 124-129)

Parameter	Yes / No
Is the Baseline Heart Rate Appropriate for the Gestational age?	
Is the baseline variability normal with the presence of cycling?	
Are there accelerations in early labour/in the antenatal period?	
Are there any shallow / late decelerations?	
Are there any risk factors? (meconium, pyrexia, IUGR, chorioamnionitis, uterine scar, GDM)	

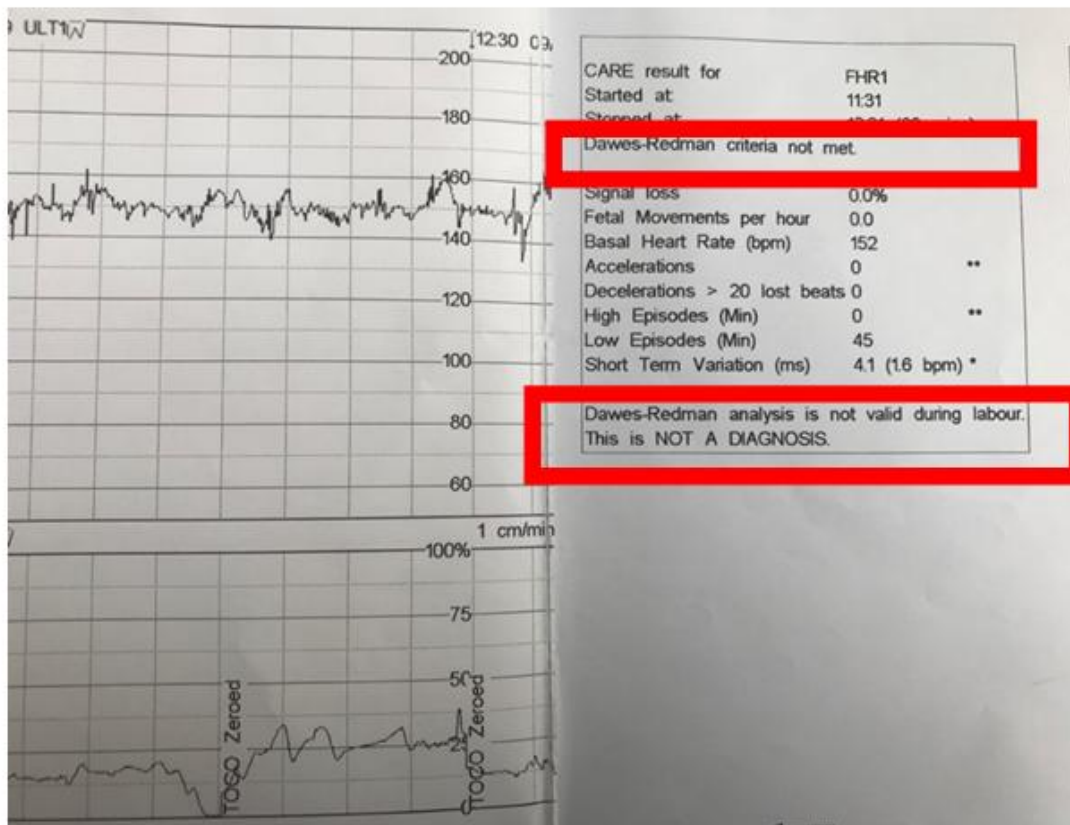


Fig. 4. Note the Dawes-Redman criteria were not met in this case for ‘decelerations’

2.5 What to Do When Criteria are Not Met by 60 Minutes

The Computer has been programmed to assume that all the reassuring parameters should be met within 60 minutes, and if this is not the case, it would highlight that the criteria have not been met (Fig. 4). However, this does not always mean that there was an ongoing fetal compromise. In a cross-sectional study of the first cCTG record from 4412 singleton fetuses with good pregnancy outcome, criteria were not

met in 2.3% of the cases, being this more common at the extremes of gestational age (before 28 and after 42 weeks [7]). There are many reasons why a CTG trace may not meet the criteria for during the stipulated period of recording, including uncertain basal rate determination and fetal behavioural state (e.g. sleep state). However, the reason for not meeting the criteria such as decelerations (Fig. 4) should be noted, and action should be taken accordingly [8,9]. The obstetric team should be informed.

Table 3. The ‘reasons codes’ provided by the computer when the Dawes-Redman criteria are not met at 60 minutes [10]

Dawes Redman Criteria NOT MET codes:

1. Basal Heart Rate outside normal range (110 – 160)
2. Large decelerations
3. No episodes of high variation
4. No movements and fewer than 3 accelerations
5. Baseline fitting is uncertain
6. Short-term variation is less than 3 ms
7. Possible error at end of the record
8. Deceleration at the end of the record
9. High-frequency sinusoidal rhythm
10. Suspected sinusoidal rhythm
11. Long-term variation in high episodes below acceptable level
12. No accelerations

The reasons for failure to meet the criteria are shown as “reason codes” in the recording (Table 3). Unless there are clear features suggestive of an ongoing fetal compromise (i.e. recurrent decelerations, absence of variability or sinusoidal patterns) where urgent action is needed, the CTG trace should be continued, whilst it is escalated waiting the obstetric team to do an overall review of the entire clinical situation.

2.6 How Frequently Should Computerised CTG be Carried Out in High-risk Pregnancies?

The decision with regard to the timing and frequency of computerised CTGs depends mostly on the indication for the CTG itself rather than the observed CTG findings. In cases where the CTG is performed because of an episode of reduced fetal movements for instance, one CTG assessment may be enough, where criteria are met and the visual assessment is normal and fetal movements return to usual. When cCTG is used to monitor growth restricted fetuses at early gestations more frequent assessments are necessary and a clear plan should be made by the Fetal Medicine team involved in the management of the patient, to determine threshold for intervention and frequency of assessments. The STV can deteriorate very rapidly, especially at less than 32 weeks gestation, if there is a progressively worsening maternal disorders such as pre-eclampsia with fluctuations of maternal blood pressure and in cases of severe growth restriction with deteriorating placental function. Therefore, it may need to be repeated more than once daily in such cases. Caution should be exercised in using CTG trace between 26 – 28 weeks of gestation due to the immaturity of the fetal

autonomic nervous system [11]. Visual analysis of the CTG may increase unnecessary operative interventions and also may miss early onset placental failure. Computerised analysis of the CTG should be considered during this gestation [12].

3. KEY PEARLS: MANAGEMENT WHEN THE DAWES-REDMAN CRITERIA ARE NOT MET

3.1 Clinical Guidance on the Management of Situations Where Criteria Not Met at 60 Minutes

An obstetric trainee or an obstetric consultant should review patient and the CRITERIA NOT MET codes and evaluate other factors associated with increased risk of stillbirth. We have recommended a Flow Chart (Fig. 5).

3.2 Basal Heart Rate Outside Normal Range (110-160 bpm)

NICE guidelines¹ stipulate that an acceptable rate for a term fetus is 110 – 160 beats per minute (recent FIGO 2015 considers a baseline FHR < 100 bpm as pathological but does not have an upper limit to individualise care for each fetus [13]). However, for extremely pre-term fetuses under 28 weeks of gestation, baseline rates under 140 are unusual, due to the immaturity of the parasympathetic nervous system [14]. Therefore, if the baseline FHR is < 140 bpm in a preterm fetus (< 28 weeks), further assessments of fetal wellbeing should be discussed with the on call obstetric consultant. Wrong monitoring of maternal heart rate should also be considered.

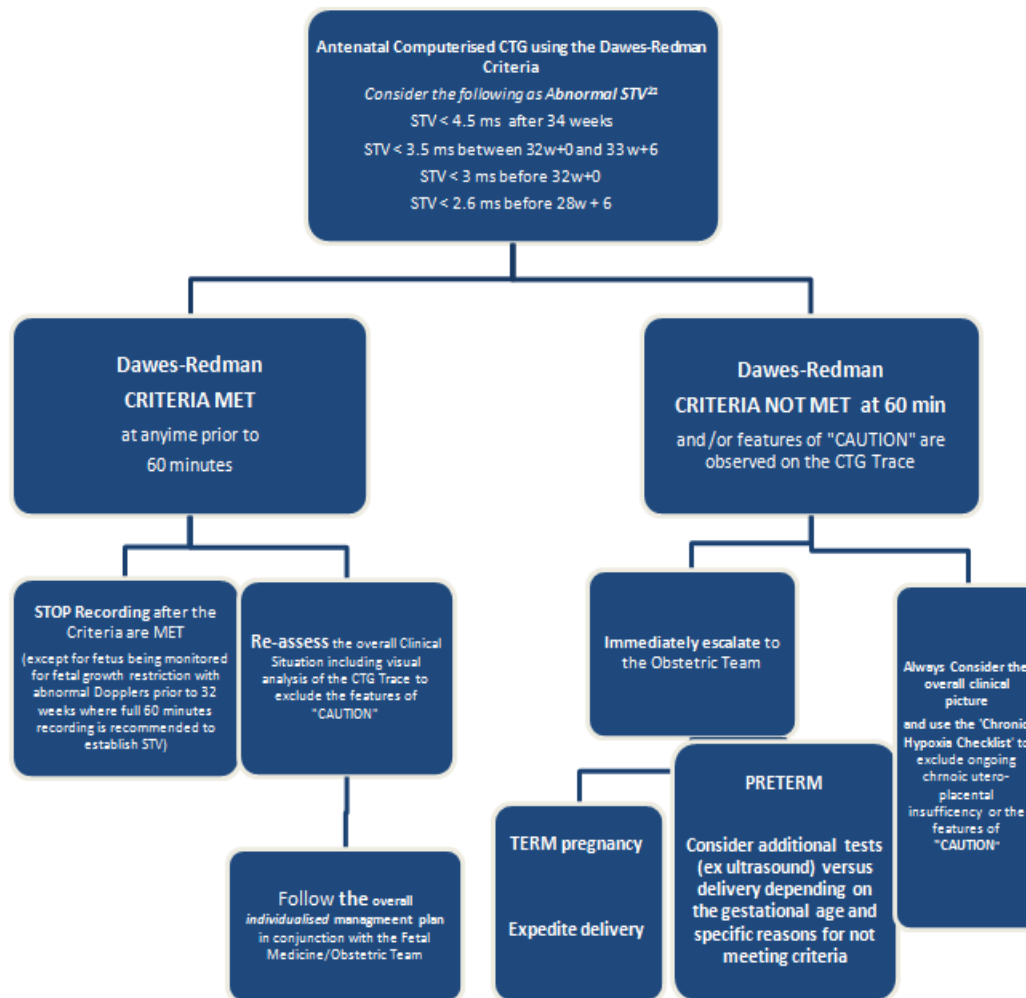


Fig. 5. Recommended flow chart

3.3 Large Decelerations

If the CTG trace is otherwise normal, this can be noted as an isolated variable deceleration, which does not require an urgent intervention. However, the CTG trace should be repeated later and an ultrasound scan is recommended to exclude oligo or anhydramnios (i.e. the cause for the umbilical cord compression leading to a large deceleration). Recurrent decelerations are unusual in the antenatal period in the absence of uterine contractions and this should warrant an immediate escalation to the obstetric team with consideration to expedite delivery.

3.4 No Episodes of High Variation

This is different to baseline variability. Episodes of high variation correspond to active fetal

sleep cycle. Alternative periods of active and quiescent sleep (i.e. cycling) are an important hallmark of fetal wellbeing at term [15]. In deep sleep, the fetal heart rate remains relatively constant with lower short-term variation but this period should not normally exceed 50 minutes. If the short-term variation (STV) is normal, then the CTG trace may be discontinued and repeated in 4 – 8 hours. Fetuses of diabetic women have significantly fewer episodes of high variation although this is not related to abnormal outcome and thus cannot be regarded as pathological. Also in early gestations (26-28 weeks) episodes of high variation were absent in 13% of the recordings although this was not related to abnormal outcome either. Cycling may be lost in both subclinical and clinical chorioamnionitis [16].

3.5 No Movements and Fewer Than 3 Accelerations

During the antenatal period, in the absence of hypoxic or mechanical stresses secondary to ongoing uterine contractions, the fetal somatic nervous system should be intact. Therefore, a normally oxygenated fetus should show accelerations on the CTG trace. Therefore, the absence of accelerations is significant and requires a review by the obstetric team.

3.6 Baseline Fitting is Uncertain

If all other parameters are reassuring, and the baseline FHR falls within the normal range then this can be ignored.

3.7 Short-term Variation (STV) is Less Than 3 ms

Short-term variation is a computerized measure of the micro fluctuations of the fetal heart that are much shorter than the macro fluctuations. It is inversely proportional to the fetal heart rate and does not depend on the baseline. The absence of an episode of high variation (a non-reactive trace) together with reduced STV is strongly linked to the development of metabolic acidaemia and impending intrauterine death.

The association of STV and perinatal outcomes is given below:

STV (ms)	<2.6	2.6-3.0	>3.0
Metabolic acidaemia	10.3%	4.0%	2.7%
IUD	24.1%	4.3%	0.0%

Therefore, a short-term variability (STV) of < 3 ms should be considered significant and the care should be discussed with the Obstetric/ Fetal Medicine Consultant. Expectant management with STV between 2.6 and 3.0 can be considered at very early gestations (<28 weeks) with intense monitoring and supervision from a fetal medicine team. We have recommended a practical Algorithm (Fig. 1).

3.8 Possible Error at End of the Record

This occurs when the machine detects a possible abnormality at the end of the trace which would otherwise be passed as CRITERIA MET. If this is the case, the trace should be continued until the criteria is met again, or, if the clinical evaluation suggests that it is significantly abnormal, for

example prolonged deceleration or a sinusoidal pattern, then action should be taken as appropriate.

3.9 Deceleration at the End of the Record

In this case, the CTG trace should be continued and action taken as appropriate to determine the cause of the observed deceleration. The obstetric team should be immediately informed.

3.10 High Frequency Sinusoidal Rhythm

Sinusoidal FHR patterns are associated with either severe fetal anaemia or severe/prolonged fetal hypoxia with acidosis and are associated with poor fetal outcomes. These traces can be missed on visual analysis by a less experienced operator and the diagnosis of sinusoidal pattern by the Dawes Redman system should be escalated immediately and discussed with a fetal medicine consultant or an obstetric Consultant on call.

3.11 Suspected Sinusoidal Rhythm

Sinusoidal FHR needs to be distinguished from a pseudo-sinusoidal FHR which, while it closely resembles a sinusoidal pattern, is usually transient, resolves spontaneously and is associated with a good fetal outcome. They are usually due to fetal rhythmic movements of the mouth (e.g. thumb sucking) or glottis movements.

3.12 Long-term Variation in High Episodes below Acceptable Level

This should be managed in the same manner as STV.

3.13 No Accelerations

In this event the CTG trace should be continued and should be reviewed by an obstetrician to exclude chronic hypoxia or a pre-existing cause of fetal compromise.

3.14 Avoiding Potential “Pitfalls”

It is important to appreciate that the clinician has better knowledge of the overall clinical picture and the history compared to a computer. Absence of cycling and absence of accelerations during the antenatal period should be taken very seriously. Presence of decelerations which

recovery slowly to the baseline suggestive of utero-placental insufficiency should lower the threshold for delivery. In the absence of strong uterine contractions, if the fetus is responding to ongoing Braxton-Hicks contractions with such chemo-receptor mediated late decelerations, this should be considered seriously and an urgent delivery should be considered especially in the term or near term fetus.

Similarly, the Dawes-Redman Criteria was not intended to detect chorioamnionitis, and specific features of chorioamnionitis should prompt an urgent delivery to optimise maternal and fetal outcome. Although, computerised analysis of the CTG may aid in the management of fetuses of diabetic mothers [17], it is important to appreciate that unexplained stillbirths may occur due to diabetic cardiomyopathy or metabolic derangements [18]. Cardiotocography is not a predictive tool and informs clinicians about the fetal condition at the time of recording.

Irrespective of the computerised analysis resulting in Dawes-Redman Criteria "met or not met", it is vital that clinicians carefully scrutinise the history, risk factors and visually analyse the CTG trace to determine whether there are any "unprovoked" decelerations, decelerations with late recovery, absence of cycling or abnormal fetal heart rate patterns such as sinusoidal or the "ZigZag" pattern. They should also consider the gestational age to avoid iatrogenic preterm delivery and resultant complications, and the decision to deliver or to continue the pregnancy should be based on such a holistic approach.

4. SCIENTIFIC EVIDENCE ON ANTENATAL CARDIOGRAPH

Visual interpretation of the CTG traces during the antenatal period is fraught with errors, as the human eye cannot determine short term variability. Therefore, a computerised analysis of the CTG trace is recommended [18] A Cochrane Systematic Review on computerised analysis of antenatal cardiographs has suggested that compared to the "traditional" CTG (i.e. visual analysis using intrapartum CTG guidelines), there was a significant reduction in perinatal mortality (RR 0.20, 95% CI 0.04 to 0.88). However, there was no significant difference identified in potentially preventable deaths (RR 0.23, 95% CI 0.04 to 1.29) or in the rate of caesarean sections (RR 0.87, 95% CI 0.61 to 1.24) [19]. Although, the quality of evidence was not excellent, this suggests that one should desist from using visual interpretation of the CTG during the antenatal period. Standard intrapartum CTG guidelines which have never been validated during the antenatal period in the absence of repetitive uterine contractions or at earlier gestational ages should not be used outside labour. The use of such intrapartum CTG guidelines during the antenatal period may be indefensible in medico-legally, especially if an adverse fetal outcome should occur. Computerised CTG should be an adjunct to a fetal growth scan with the objective measurement of the amniotic fluid volume, doppler velocimetry and documentation of fetal movements in high risk pregnancies. In early onset fetal growth restriction (<32 weeks),

Table 4. Features of "caution" checklist during the antenatal period

Abnormal Feature	Checked	Likely Pathophysiology
Cycling : Absent		Depression of the fetal CNS
Acceleration : Absent		Depression of somatic NS
Unstable Baseline FHR		Myocardial decompensation
Tardy recovery (late decelerations)		Utero-placental insufficiency
Irritability of the uterus / Inappropriate Baseline FHR for the gestational age		? abruption/ chorioamnionitis Higher than expected baseline for the given gestational age (> 140 bpm at 41 weeks & > 150 bpm at 40 weeks) in infection and fetal hypovolemia
Obvious history : vaginal bleeding , PPRM, reduced FM, abdominal pain		Underlying pathology that may contribute to fetal compromise
Non-hypoxic features: Sinusoidal & "ZigZag"		Feto-maternal haemorrhage, chronic fetal anaemia and CNS irritability

TRUFFLE study [20] showed better long-term outcomes when decision to deliver was based on Ductus venosus measurement in conjunction with cCTG safety net. ISUOG has recently recommended thresholds to expedite delivery in growth restricted fetuses based on fetal Dopplers and computerised CTG [21]. Table 4 demonstrates the “Features of Caution” whilst interpreting CTG traces during the antenatal period.

5. CONCLUSION

It is important to appreciate that computerised CTG using the Dawes—Redman Criteria is an adjunct to fetal monitoring during the antenatal period. If the criteria are met, it denotes that the fetus is in a steady state. Therefore, computerised CTG using the Dawes-Redman Criteria should not be used in the absence of the steady state (e.g. after the onset of uterine contractions). Caution should also be exercised in the presence of vaginal bleeding or abdominal pain. Even if the STV is normal, if the criteria are not met, the risks of poor outcomes may be significantly increased [22]. Therefore, the maternal history, the overall clinical picture and the visual inspection for absence of cycling, abnormal baseline for the given gestational age, sinusoidal and Zigzag Patterns [23] and shallow or late decelerations with late recovery to the baseline should also be considered whilst making management decisions.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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