Guide to:

A midwife's perspective on fetal monitoring and the value of Dawes-Redman CTG analysis

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Recommendations for midwives

Promoting excellence in midwifery and women's health
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'It is easy to check an antepartum CTG and see that the baby is dying. But when the CTG is neither normal nor terminal it is much harder to judge what is going on. This is the grey zone to which Beth Albert refers in her accompanying guide. The grey zone also affects the interpretation of intrapartum CTG, which is notorious for provoking needless interventions to deliver babies, who are perfectly healthy. Fetal heart rate patterns are complex with several key features: rate, variability, accelerations and decelerations all with their own properties which make them more or less threatening. Only measurement can deal with this complexity. We take measurement for granted in our daily practice: pulse, blood pressure, temperature, haemoglobin, platelets and so on. But when it comes to CTG interpretation, for some unfathomable reason, clinicians have, for too long, been satisfied with subjective opinions. This is no longer necessary nor justifiable. cCTG gives a precise and reproducible grading of all CTG features. It can remember them all in relation to every baby's outcome. What it cannot do is to fit the measurement into the big picture and make management decisions. That is where your clinical skills come into their own.'

Professor Chris Redman, Professor Emeritus, Oxford University

Cardiotocography (CTG), the simultaneous recording of uterine and fetal cardiac activity, was originally introduced as a screening test in the 1960s for use during labour. Since the 19th century, auscultation of the fetal heart rate (FHR) had been the mainstay of fetal monitoring in routine intrapartum care in many countries. Intermittent auscultation (IA) of the FHR had become part of routine intrapartum care in many countries during the 19th century (Gültekin-Zootzmann, 1975) and remains important in fetal surveillance.

Historically, the only ways to assess fetal health had involved maternal perception of movement and IA using a pinnard stethoscope. Radiography of the uterus was also used under exceptional circumstances (Stewart and Kneale, 1970).

Intrapartum CTG was introduced in the UK in the 1960s, following successful introduction in the US. The aim was to prevent fetal death in labour and delivery of severely compromised fetuses at a high risk of asphyxia.

Initial success quickly led to excessive optimism in the belief that CTG monitoring would detect fetal hypoxaemia, resulting in a reduction in cerebral palsy and perinatal mortality, particularly in high-risk pregnancies (Goddard, 2001). This was asking too much.

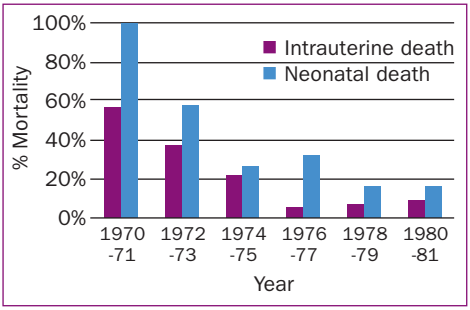

Figure 1. Pre-eclampsia. Delivered <34 weeks in Oxford. Antepartum FHR monitoring began in 1972

Systematic reviews of randomised controlled trials (RCTs) of CTG, or electronic fetal monitoring (EFM), versus intermittent monitoring during labour in the 1990s showed no effect on neonatal outcomes in terms of metabolic acidosis at birth, low Apgar scores or admission to neonatal care (Goddard, 2001).

The first CTGs were never intended for antepartum use. Yet antepartum CTGs were independently developed in several centres around the world, including Oxford in the late 1960s and 1970s.

There have been a few iterations of national guidelines in the UK over the last few years in an attempt to produce information to improve interpretation of fetal monitoring (NICE, 2014; Ayres-de-Campos, 2015).

There are also recent significant studies about the use of cCTG in the intrapartum period (Alfirevic et al, 2017; INFANT collaborative group, 2017).

This guide, however, focuses on the particular issue of antepartum computerised cardiotocography (cCTG).

The extreme patterns associated with imminent fetal death were relatively easy to recognise. It was a revelation at the time and very exciting. No other measurement or observation was available that had the potency to detect the unborn baby *in extremis*. With intervention, babies' lives were saved when previously they would have died (*Figure 1*).

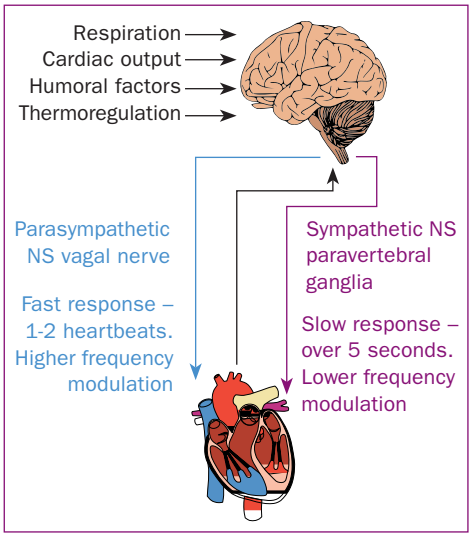

Figure 2. A CTG trace reflects fetal brain function

In order to avoid the last-minute emergencies, midwives began to consider the traces that were not normal but not clearly terminal (the 'grey zone'). This grey zone is problematic because the fetus, being tough, can compensate to a remarkable degree for hypoxic stress and hide its problems from the clinical observer, even on a CTG. When it can no longer compensate, normality is lost and suddenly replaced by extreme distress and imminent death.

Why are CTGs important?

A CTG displays the changes in fetal heart rate. These reflect fetal brain activity (Nijhuis, 2003). Severely depressed fetal brain function causes the FHR to lose it's fine tuning, which the nervous system normally and continually imposes. The FHR pattern becomes flat and featureless (Nijhuis et al, 1990).

Other causes of abnormal fetal brain function, including maternal alcohol intoxication and central nervous system abnormalities (Terao et al, 1984) can similarly affect FHR patterns (*Figure 2*). Hence the antepartum CTG can readily detect the dying fetus (Visser et al, 1980).

For this reason alone it is of great importance. What it does less well is to detect less extreme compromise, the grey zone (see below), where computerised analysis has much to offer.

A CTG also gives information about fetal sleep state. When the baby is in active sleep, the heart rate is said to be 'reactive' and the heart trace will demonstrate many accelerations. In deep sleep, the FHR is relatively flat with lower short-term variability. An episode of deep sleep may last as long as 50 minutes but almost never more than 60 minutes. Therefore, one of the most important features of the antepartum FHR is a discernible episode of active sleep for each 60 minutes of monitoring.

Shades of grey

The ongoing challenge in interpreting and assessing CTG traces is the multitude of patterns between what is clearly normal and what is grossly abnormal, which constitutes the grey zone.

> ***'The grey zone is of huge importance to clinicians. In this group are a small number of key patients where trouble is coming and where timely intervention will ensure fetal safety. However, in this zone are also many more normal fetuses, which are not yet destined for acute distress and for whom urgent intervention is not necessary' (Redman and Moulden, unpublished).***

Fetal heart rate patterns are not easy to interpret. Visual assessment is the process whereby an observer subjectively judges the complexities of the CTG by eye and forms an opinion about its normality. In terms of discriminating between the many graduations between normal and abnormal this is difficult, if not impossible. It cannot be standardised so that different observers reach similar conclusions about similar traces. Poor inter- and intra-observer reproducibility is inevitable and is well documented. Studies repeatedly confirm this as a problem (Bernades et al 1997; Devoe et al, 2000; Chauhan et al, 2008) that applies to intrapartum and antepartum CTG.

There have been many attempts at finding a solution including the 'fresh eyes' approach and using a 'buddy' to help enhance the learning process essential for effective professional practice (Fitzpatrick and Holt, 2008). This may mitigate but does not resolve the unsatisfactory nature of subjective visual interpretation. Symon et al (2006) identify fatigue and experience as important factors, so consultation with colleagues is always helpful.

It is not realistic to expect even the most experienced observer to recall the vast array of patterns and the resulting significance. In a test, that can lead to life or death intervention, guesswork or relying solely on one individual's visual interpretation is inadequate, which is why many efforts have been made to quantify the variables seen with CTG, to improve reliability and reproducibility of the measurements.

Computerised CTG

Computerised CTG (cCTG) resolves many of the limitations of subjective assessment of a CTG trace. It allows different patterns to be graded in a standardised way. The cCTG can draw on experience from archived records, more than any one individual could possibly remember. While cCTG during labour is still in development and not ready for clinical testing, antepartum cCTG has been in use for about 25 years in the form of the Dawes-Redman (DR) system.

DR antepartum system

Development of the DR system began in 1978 in response to the need for reliable, reproducible and accurate measurements of antepartum CTG patterns to aid interpretation. The first commercial system was marketed towards the end of the 1980s.

The principles of the system are to determine when there are enough data to conclude that the CTG trace is normal and can be stopped. It also sets a time limit (60 minutes). If normality according to the DR criteria has not been proved by then, the CTG is deemed to be non-reassuring or, in rarer circumstances, abnormal.

Box 1. The Dawes-Redman criteria

- The recording must contain at least 1 reactive episode
- No high frequency sinusoidal rhythm (fetal anaemia)
- Normal short- and long-term variation (3 criteria)
- Accelerations present (2 criteria)
- Fetal movements present (2 criteria)
- No large or repeated decelerations (2 criteria)
- Normal heart rate (2 criteria)
- No excessive signal loss and no artefacts when record stopped (2 criteria)

The DR system is designed to be used alongside, rather than to replace, clinical judgement, which will always be needed to interpret information gathered in the setting (risk factors, drugs, social factors, ethnic factors, congenital abnormalities). Clearly, accurate history taking and listening to maternal concerns and perceptions about her baby's behaviour is paramount.

Numerous guidelines are available for interpreting the CTG both before and during labour. The DR system has its own guidelines and criteria, which are more precise. Because it numerically measures whether or not the criteria are met, it is consistent. It cannot miss

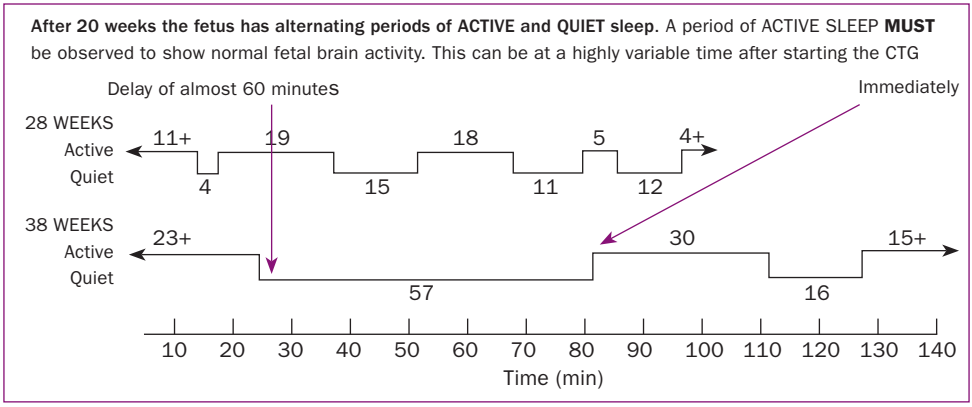

Figure 3. Variation in active and quiet periods detected on the basis of fetal movements and FHR variability

the features which it has been programmed to detect. It is more important to place the CTG result in the clinical context in which it is taken.

The DR criteria (*Box 1*) make CTG interpretation more robust and provide a powerful defence if things go wrong.

Measurements

The DR system quantifies variables including baseline FHR, variation, accelerations and decelerations. Measurements are consistent and cannot change on reassessment.

Evidence of active fetal sleep episodes is sought in two ways:

- Episodes of high FHR variation, which are consistent with active sleep.
- Maternal perception of fetal movements by using the fetal movement button. This is an important contributor to DR analysis (*Figure 3*).

The onset of an episode of active sleep may or may not coincide with starting the trace and so the time taken to prove normality will vary. The fetus might already be in active sleep in which case there will be instant proof of good health. The trace need last only 10 minutes, the minimum length in the DR system. However, commencing the trace might coincide with the start of a long period of quiet sleep and the trace will have to run for 40 minutes or longer.

At any time after the first 10 minutes all of the criteria of normality might be met, the operator is informed and the trace can be stopped. If it is not stopped at this time, the criteria can sometimes revert to 'not met'. This typically happens when the trace is on the threshold of normality. In these cases the baby is usually cycling normally and normal criteria will return within a short period of time.

Unless there is a clinical reason to expect sudden changes (the woman's condition is unstable: for example there is vaginal bleeding) continuing the trace because 'something might happen' is rarely appropriate.

The analysis starts at 10 minutes from commencing the trace. Findings are reported every 2 minutes thereafter.

Action taken next is dependent on the clinical picture and the availability of investigations locally. Actions might include a repeat trace later in the day, extending the range of information about the fetus (e.g. umbilical artery doppler [UAD] studies), biophysical profiling, ultrasound growth assessment, or detailed scan assessment of other fetal parameters.

Box 2. DR system outcomes

The 3 possible outcomes are:

- **Criteria met:** There is adequate evidence for normality, the CTG is normal and continuing the trace will provide no further information unless a new event develops. The trace can be stopped
- **Criteria NOT YET met:** The CTG needs to continue in order to gain more information. There are many reasons why a trace may not meet the criteria. The CTG needs to be continued until criteria are met unless there are pathological features present which would warrant more immediate action
- **Criteria NOT met:** The criteria are not met after a full 60-minute analysis. The reasons for failure to meet the criteria are shown. This must be considered at best a non-reassuring or at worst a pathological outcome. Appropriate case review and action must be taken. Intervention on the basis of the CTG alone should not happen

Box 3. Short-term variation: when criteria are not met, check the values

>4.0	The fetus is not hypoxic or acidotic
3.0-3.9	The fetus may be stressed but is NOT distressed by acidosis
<3.0	High-probability of metabolic acidosis and asphyxia

Understanding short-term variation

Short-term variation (STV) of fetal heart rate, is an important indicator of fetal wellbeing, but is by no means the only one. Clinicians often place too much emphasis on this, which can result in stopping the recording too soon when the STV is deemed low.

Unless there are obvious pathological concerns, this can be a mistake. This might be a trace of a baby having a long quiet-sleep period, which may yet become active. If it does not, only then can the criteria be confirmed 'not met' (*Box 2*).

Box 4. Problems with the DR system
● Poor quality traces with a high loss of contact
● Lack of recorded movements
● Premature stopping of the analysis before sufficient data has been collected in order to determine normality
● Inappropriate continuation of the analysis after the criteria have been met and unnecessary prolongation
● Over reliance on STV
● Unrealistic expectations of predictive reliability
● Inappropriate use in labour
● Inadequate staff training and resulting lack of trust in the reliability of the system
● Equipment issues
● Lack of funding and resources

Box 5. Oxford Scoring System	
10	A satisfactory CTG scores 10/10. When this score is reached, recording can stop If the trace lasts for 60 minutes without reaching 10/10, then take action based on the score
8/9	a) gestation >=37 weeks—repeat later the same day b) gestation <37 weeks—no action, repeat the next day, no specific communication with medical staff needed
7	Repeat the trace later the same day
6	Repeat the trace later the same day and notify the medical staff non-urgently
5 or less	Abnormal trace—notify the medical staff urgently

The STV is commonly reviewed before 60 minutes. This reflects inadequate understanding of the measurement and is always wrong. Whether or not a low STV (<3-4 milliseconds) denotes a problem (*Box 3*) depends without exception on a trace lasting 60 minutes.

Performing a DR trace

Using the DR system is straightforward. The CTG is set up as normal using US and Toco sensors. The woman is given the hand-held movement recorder and an explanation of what to do.

Although it is not possible within the constraints of this article to explore acceptability of computerised CTG systems for women, this is clearly of substantial importance. There is scope for studies to further explore maternal acceptability. From the user's point of view it is virtually the same as a routine CTG but on average is shorter. Careful explanation of the analysis when gaining consent will help with reducing anxiety. Appropriate midwifery expertise and knowledge of the system are vital during these consultations.

The patient details are entered into the DR system, including an accurate gestational age (Serra et al, 2009). Documentation is made onto the CTG in accordance with local guidelines.

The first result is available after 10 minutes (the minimum time required to establish a reliable baseline). The criteria of normality can be met at or after 10 minutes. The analysis is updated every 2 minutes up to a maximum of 60 minutes.

Occasionally issues are encountered with using the system (summarised in *Box 4*). To reduce these at John Radcliffe Maternity Unit, the DR analysis has been included in annual mandatory training for all midwives and obstetricians. A guide to the system is being constructed and will be freely available.

Validation

The system has been developed from a database of more than 100 000 records, the largest in the world. Since it's introduction, the system has continued to be developed and improved, but not all new features are obvious to users.

Data collected in Oxford is routinely checked against outcomes data to confirm proper behaviour of the analysis algorithm. In cases when a suspicious trace is reported (internally or externally by the commercial partner), the trace is collected (when possible), analysed and compared with the Oxford CTG archives. If a trace cannot be retrieved digitally, results of the analysis are used to find appropriate matches in the archives. If an outstanding feature is identified, the

algorithm is improved, and the new version of the analysis is run against the archive to pick similar traces. Outcomes of the picked traces are then reviewed, to see how many of them were abnormal, and whether the new feature is giving false positive results. If the review proves that the new feature is an improvement, it is permanently implemented into the DR system.

No change is made in the system unless it performs reliably in the whole dataset. This ensures a system that is dependable and unique.

Many imitations of this analysis are available on the market but these are based on the original work and exclude the many enhancements made over the past 25 years, as a result of constant validating and updating.

Recently, an extremely rare pattern comprising a fast, high amplitude sinusoidal rhythm interspersed with episodes of maternal pulse detection instead of the fetal heart was recorded. However, this was not identified as abnormal by the system. Algorithms are now being developed to recognise this pattern and will be retrospectively applied to the DR archive. If necessary, the criteria will be amended to specifically detect this situation. In this instance, the pattern was extreme enough to have been recognised by the clinician.

As with a non-computerised CTG, antepartum CTG analysis has one important limitation. It cannot make a diagnosis or give a 100% guarantee of future safety (with the exception of falling short-term variability). It only indicates the current fetal state.

There are rare instances of fetal death occurring within a short time of a normal fetal CTG. These are unexplained stillbirths, which continue to be a major cause of perinatal loss in the UK.

Future developments

In Oxford, a scoring system has been developed to help manage CTGs where the criteria have not been met (*Box 5*). This will be commercially available shortly, as part of the Dawes-Redman analysis. A score of 10 indicates that criteria are met. Scores under 10 grade the severity of the problem. The score will take account of previous CTGs when they are available.

The DR analysis is effective and reliable, It functions as an 'expert CTG assistant' with the equivalent of over 100 years experience and an elephantine memory: it can remember every single CTG and it's outcome. It is straightforward to use and easily integrated with local clinical protocols. It saves time and money, improves quality of care and avoids poor outcomes and their consequences.

The foundation of good fetal surveillance lies in training and education. Whichever iteration of guidelines are put in place within a maternity service, it is imperative that training supports it and that there are regular case reviews for the multidisciplinary team to learn from.

It must be remembered that CTG is only one aspect of antepartum fetal assessment and must not be reviewed in isolation.

Benefits of the DR analysis with cCTG

- The duration of the cCTG is determined by the system, leading to savings on valuable midwifery time. A controlled trial revealed computerised analysis could have saved 200 hours of recording time per 1000 traces (Dawes et al, 1992)
- Measures the important features without estimates or guesswork
- Interpretation is objective, standardised and consistent
- Identifies traces that are normal and abnormal
- Improves quality of care for the mother
- Reduces the risk of poor outcomes saving time and money. In 10 years, the UK spent £3.1B in obstetric litigation; half of all litigation costs (NHS Litigation Authority, 2012)
- Continually updated to extend the screening net by identifying rare cases occurring that have not been encountered in the DR archive (>100 000 records)
- Has the potential to be paperless

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