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DAWES-REDMAN CTG ANALYSIS™

Clinical Application Guide



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Preface

Advances in technology over the past 40 years now enable us to assess fetal health using safe and noninvasive ultrasound techniques. One such technique is fetal heart rate monitoring, and in pregnancies where there is fetal compromise the fetal heart rate contains crucial information with regard to the optimum timing of delivery. The features of the fetal heart rate are well understood, but numerous studies have shown that expert assessment of traces is prone to inconsistency. In addition, when junior or inexperienced staff review traces important features may not be noticed with the danger that critical decisions are delayed.

Computer analysis of the fetal heart rate using the **DAWES REDMAN**™ algorithm exclusively built into Sonicaid ® Team3, Obix BeCa®* fetal monitors and Centrale 3 software system** much-needed way of standardizing interpretation to the highest standards. Such analysis, while not a substitute for clinical judgement, captures an enormous amount of clinical experience and in effect brings it to the bedside.

This booklet provides some background to the **DAWES REDMAN**™ analysis and explains how it works and why it is useful. I hope you will find it interesting reading.

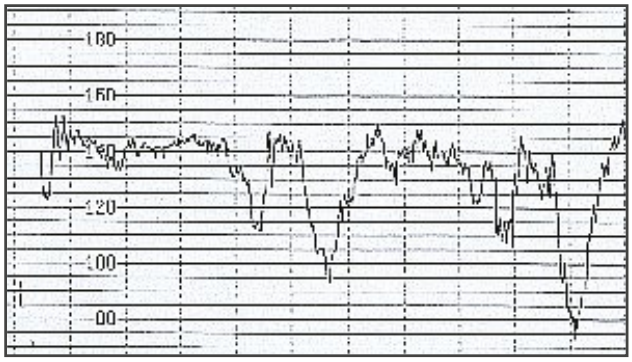
Professor C W G Redman

Oxford, UK, August 2003

* a registered brand of CCSI. ** not commercially available in the USA.

Introduction

The visual assessment of an antepartum fetal heart rate (FHR) trace requires a trained individual to look at the trace, mentally fit a baseline to it, and then ask a number of questions: Are there any accelerations? Is the basal heart rate okay, and does the trace have good variability? Or are there decelerations? Is the basal heart rate too high or too low, or does the trace look a bit flat? Depending on the answers to these questions an opinion is formed as to whether the trace is reassuring or a cause for concern. In most cases this is sufficient because the baby is fine. But subjective assessments such as these are intrinsically unreliable and problems can, and sometimes do, arise. The person assessing the trace may be tired, stressed, or inexperienced. Misinterpreting traces can lead to intervention when it is not needed or, worse still, no intervention when it is urgently needed.



There is no doubt that looking at a trace and forming an opinion of it is useful, but what if we also took measurements? Could this help us to diagnose those tricky, borderline, or rare traces? This was the question that in 1977 Professors Dawes and Redman at Oxford University in the UK set out to investigate. Using a database of 8,000 traces linked to outcome their research led to the development of a computer system for the analysis of antepartum traces, and in 1989 this was released as the Sonicaid System 8000. Over the next five years the database was increased to 48,339 traces and in 1994 an improved version called the Sonicaid System 8002 appeared. Since then the database has increased to well over 100,000 traces and continued research has made the analysis even more powerful. It is now called **DAWES-REDMAN CTG ANALYSIS**™. The purpose of this booklet is to explain how the **DAWES REDMAN**™ algorithm works and why it is useful.

How the DAWES REDMAN™ algorithm works

Fitting a Baseline

The first thing **DAWES-REDMAN CTG ANALYSIS**™ does when analyzing a trace is fit a baseline to it. The baseline is a timevarying line that shows what the resting fetal heart rate is, or would be if accelerations and decelerations are excluded. There is no gold standard for fitting a baseline, so **DAWES-REDMAN CTG ANALYSIS**™ puts the baseline where human experts would typically place it by eye.

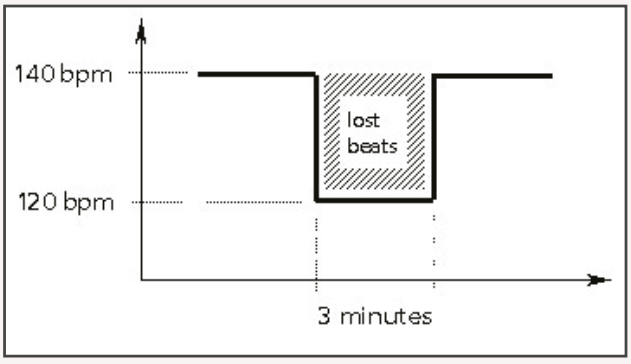
Accelerations and Decelerations

Once the analysis has fitted a baseline to the trace it identifies any accelerations or decelerations that are present and measures their size. The size of a deceleration is expressed in 'lost beats' as explained in the box below.

Measuring the Size of a Deceleration

Consider the 'square' deceleration shown below, in which a fetal heart is beating at 140 bpm, drops suddenly to 120 bpm for 3 minutes, and then returns to 140 bpm again.

If the heart rate had stayed at 140 bpm then in 3 minutes there would have been 3 x 140 = 420 heartbeats. However,



because of the deceleration there were only 3 x 120 = 360 beats. So 420 heartbeats were expected but only 360 occurred,
and we say that the size of the deceleration is
420 – 360 = 60 lost beats.

Long-Term Variation

The long-term variation (LTV) is a measure of the minute-by-minute 'macro' fluctuations of the FHR around the baseline. The FHR values are initially represented as pulse intervals (see box at the top of the next page) and then converted into beats per minute (bpm). To measure LTV **DAWES-REDMAN CTG ANALYSIS**™ finds the highest and lowest FHR in each minute relative to the baseline. The difference between these values is the minute range. For example, if in one minute the FHR varies between 120 bpm and 150 bpm then the equivalent pulse intervals are 500ms and 400ms respectively and the minute range is 100ms.

What is a Pulse Interval?

The time between two consecutive fetal heartbeats is called a pulse interval and is measured to an accuracy of 1/1000th of a second, or one millisecond (ms). As the fetal heart rate increases the pulse interval gets shorter, as demonstrated in these examples:

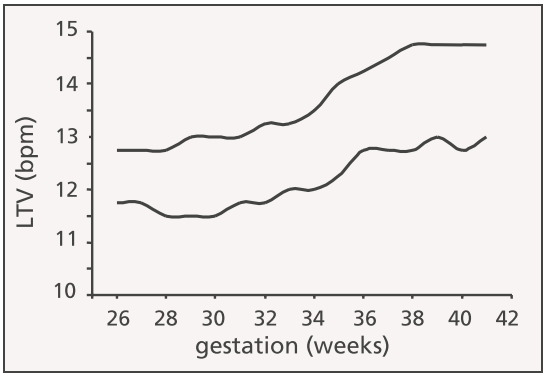
Heart rate (bpm)	Pulse interval (ms)
60	1000
80	750
120	500
150	400

If the heart rate is 120 bpm then the heart beats every 0.5 seconds and the pulse interval is 500ms. If the heart rate increases to 150 bpm then a heart beat occurs every 0.4 seconds and the pulse interval is 400ms.

If the minute range exceeds 32ms for at least 5 out of 6 consecutive minutes then **DAWES REDMAN**™ algorithm marks this as the start of an episode of high variation. The episode continues for as long as this 5-out-of-6-minute rule is met, and ends when it is no longer met. The average minute range for the episode is then compared against a threshold calculated well over 100,000 traces in the **DAWES REDMAN**™ database. If it exceeds this threshold then the episode of high variation is confirmed and the trace

is considered reactive. This definition of reactivity is unique in two respects: first, the threshold varies according to the gestational age of the fetus as shown in the box below; and second, it does not depend on the presence of accelerations, as these are not always present in traces from healthy fetuses. Other definitions of reactivity typically require two or more accelerations within a given time.

Short-Term Variation



The short-term variation (STV) is a measure of the 'micro' fluctuations of the FHR that are much shorter than the macro fluctuations measured by LTV. STV cannot be measured by eye, but **DAWES-REDMAN CTG ANALYSIS™** can measure it, as described in the box below. STV is a very important parameter for two reasons. Firstly, it does not depend on the baseline – unlike accelerations, decelerations, and LTV – so it is valid even in those tricky traces where a baseline is difficult to fit, either by eye or by computer. And secondly, in the absence of an episode of high variation (a non-reactive trace) low STV is strongly linked to the development of metabolic acidaemia and impending intrauterine death.[1,2]

How is STV Measured?

DAWES-REDMAN CTG ANALYSIS™ measures STV by dividing each minute of the trace into 16 sections. Each section is 3.75 seconds long and typically contains about 7–10 fetal heartbeats, or 6–9 pulse intervals. The average pulse interval in each section is calculated, and the change in these average values from one section to the next determines the STV. The use of 3.75 seconds is not a magic number; it is simply that division by 2, 4, 8, 16, etc., is very fast on a computer, and 3.75 seconds is 1/16th of a minute.

In healthy fetuses STV increases with gestation.[3]

Basal Heart Rate

The basal heart rate, in bpm, is the average fetal heart rate during the trace when accelerations and decelerations are excluded. The **DAWES REDMAN™** algorithm checks that the basal heart rate is in the normal range, which for antepartum traces is 116–160 bpm. An abnormal basal heart rate is usually due to an arrhythmia, although a sustained tachycardia may indicate fetal infection or maternal pyrexia, while a sustained bradycardia is sometimes seen prior to fetal death and requires immediate investigation. However, in compromised fetuses it is not uncommon for the basal heart rate to be normal, so its value is usually of secondary importance compared to other parameters such as STV. In healthy fetuses the basal heart rate decreases with gestation.[3]

Sinusoidal Rhythm

The **DAWES REDMAN™** analysis also checks that there is no evidence of a sinusoidal rhythm. This is a rare but important pattern in which the FHR trace oscillates smoothly up and down. A slow sinusoidal rhythm of one oscillation every 2–5 minutes, in conjunction with low STV, indicates pathology and poor fetal outcome. A fast sinusoidal rhythm (or sawtooth pattern) of 2–5 oscillations per minute may indicate fetal anaemia due to Rhesus isoimmunization, fetal intracranial hemorrhage, or fetal-maternal hemorrhage.[4]

The Rules of DAWES-REDMAN CTG ANALYSIS™

Once the algorithm has analyzed the trace and measured all the parameters described above, it is in a position to report its findings. However, simply presenting a list of numbers and measurements would be of limited use and may confuse more than it clarifies. What is required is a way of distilling all this information into a bottom line which states whether the trace is reassuring and can be stopped, or whether it is non-reassuring and should be continued. To do this **DAWES-REDMAN CTG ANALYSIS**™ uses a number of rules that for historical reasons were known as the **DAWES REDMAN**™ criteria. These rules take into account the standard features of visual assessment – such as accelerations, decelerations, and basal heart rate – as well as those parameters which are difficult or impossible to measure visually, such as STV, sinusoidal rhythm, and the number of minutes of high variation. Some of the rules are quite simple and some are more complex and mathematical[5] but what they look for can be broadly summarized as follows:

- STV of 3ms or greater
- No evidence of a sinusoidal rhythm
- At least one episode of high variation
- No large or repeated decelerations
- Accelerations and / or fetal movements
- No evidence of a baseline misfit
- A normal basal heart rate (if the trace is short)

The important point about these rules is that they take into account all the measurements described above and not just visual features. With **DAWES REDMAN**™ algorithm we are now able to start a trace, start the analysis, and after ten minutes look at the results to see what the bottom line says: 'Criteria Met' or 'Criteria Not Met'.

Criteria Met

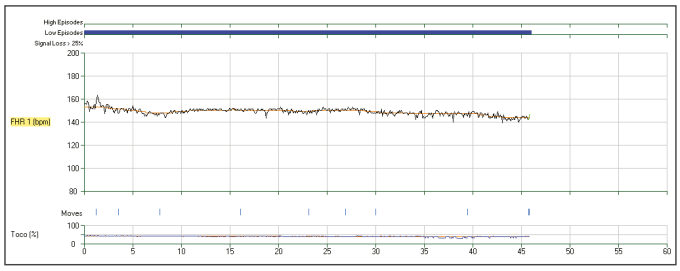
If the **DAWES REDMAN**™ analysis has found enough evidence that the trace is reassuring then it will report 'Criteria Met' and monitoring can be stopped. There is no real need to look at the numbers and measurements themselves as analysis has already checked that they are all normal; hence 'Criteria Met' – the trace is reassuring.

Criteria Not Met

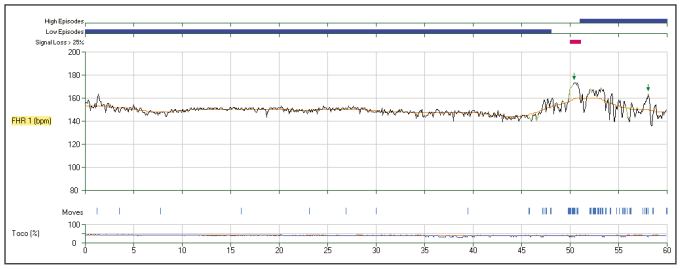
If the analysis has not found sufficient evidence of normality then it will report 'Criteria Not Met' and recommend that monitoring be continued. After the first analysis at ten minutes the trace is re-analyzed every two minutes, so it is important to continue monitoring to see whether 'Criteria Met' is eventually reported.

How Long Should We Monitor For?

From about 28 weeks gestation a healthy fetus cycles between episodes of active and quiet sleep. Active sleep is associated with accelerations, increased FHR variation and clusters of fetal movements, so the appearance of these features – a reactive trace – is a primary indication of fetal wellbeing. Quiet sleep is associated with reduced variation and reduced fetal movements, so during quiet sleep it is not possible to assess fetal wellbeing. This is because the non-reactive trace of a healthy fetus in quiet sleep is indistinguishable from the trace of a compromised fetus. To make the distinction monitoring must continue until a time when we would expect to see the appearance of a reactive trace, but this time will vary depending on the point in the fetal sleep cycle at which monitoring begins. Episodes of quiet sleep can last for up to 50 minutes, so if the start of monitoring coincides with the start of quiet sleep it may be up to 50 minutes before a reactive trace starts to appear. However, if the same fetus is monitored again later the same day it may already be in active sleep and a 10–15 minute trace will be sufficient to confirm reactivity. A study of over one thousand traces[6] concluded that a reactive trace is indicative of fetal wellbeing irrespective of the time required to detect reactivity, up to a limit beyond which it becomes abnormal that the trace is not reactive. In **DAWES-REDMAN CTG ANALYSIS**™ this limit is set to 60 minutes for the reasons given above.



The trace shown above was recorded at 36 weeks gestation and has been running for about 45 minutes. But is it reassuring or not? If the trace is stopped at this point **DAWES-REDMAN CTG ANALYSIS**™ reports 'Criteria Not Met', STV less than 3ms, no episode of high variation, and no accelerations. However, if monitoring is continued, as shown below, the trace finally becomes reactive and the analysis reports 'Criteria Met'. But this only happens during the final 10-12 minutes, so stopping prematurely would have led to an incorrect assessment.



Again, once the criteria are met the actual numbers and measurements do not need to concern us. Only if the **DAWES REDMAN**™ algorithm is still reporting that the criteria are not met at 60 minutes does it make sense to look at the numbers and start considering what may be amiss.

DAWES-REDMAN CTG ANALYSIS™ in Practice

Indications for Monitoring

Typical indications for fetal heart rate monitoring, irrespective of whether we are using analysis or not, are as follows:

- Reduced fetal movements
- Intrauterine growth restriction
- Antepartum hemorrhage
- Twins
- Uterine pain
- Hypertension or pre-eclampsia
- Reduced amniotic fluid volume
- Abnormal umbilical artery Doppler velocimetry
- Suspected fetal anomalies
- Suspicion of substance or alcohol abuse
- Maternal accident or injury
- Previous questionable FHR traces
- Poor obstetric history

What DAWES-REDMAN CTG ANALYSIS™ can and cannot tell us

Some of the things **DAWES-REDMAN CTG ANALYSIS**™ can tell us are listed below.

- The fetus is acidaemic or hypoxic
- The fetus is anaemic
- The fetal central nervous system is impaired
- The fetus may have an infection
- The fetus has an arrhythmia
- Further investigation is required

However, even a normal trace does not give an absolute guarantee that a fetus is safe. A woman may present with reduced fetal movements and a trace is done which seems normal, but hours later an intrauterine death occurs. Fortunately this is rare, but that is of no consolation to those involved in such a tragic event. Both staff and mother may feel the trace should have warned them, but this perception is incorrect. A reassuring trace cannot anticipate a placental abruption that happens some time later, without warning, and with devastating suddenness. Neither a human expert nor **DAWES-REDMAN CTG ANALYSIS**™ can predict such catastrophes. But in pregnancies affected by conditions such as placental insufficiency, where the deterioration is gradual, **DAWES-REDMAN CTG ANALYSIS**™ can help us to predict when delivery is likely to become necessary.[7,8]

The Importance of STV

The importance of STV was established in two studies of compromised babies where traces were obtained within the 24 hours prior to intrauterine death (IUD) or delivery by caesarean section without labor.[1,2] The table below shows the outcomes for these pregnancies. When the STV was less than 2.6ms there was a dramatic increase in the likelihood of metabolic acidaemia (as defined by an umbilical artery blood pH less than 7 .12 and base deficit greater than 12mmol/L) or intrauterine death.

STV (ms)	<2.6	2.6-3.0	3.0
Gestation (weeks)	25-38	26-38	27-37
Metabolic acidaemia	10.3%	4.3%	2.7%
IUD	24.1%	4.3%	0.0%

This is a key finding because with STV **DAWES-REDMAN CTG ANALYSIS**™ is not just doing what the human eye does. **DAWES-REDMAN CTG ANALYSIS**™ does detect accelerations and decelerations, but we can see those ourselves. However, the human eye cannot detect the precise amount of STV, and it is the precise amount, as the table above demonstrates, which is important.

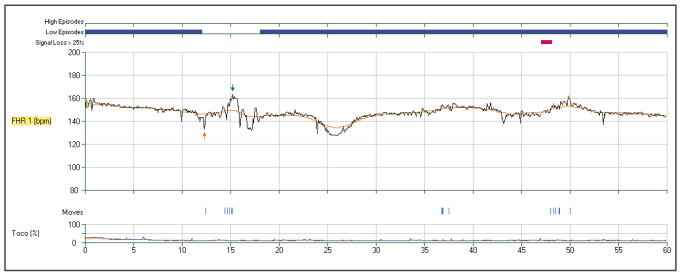
Criteria Not Met for No Apparent Reason

Sometimes a trace is not right and **DAWES-REDMAN CTG ANALYSIS**™ reports 'Criteria Not Met' but we cannot decide what the problem is. This is an indication that further investigation is required. This may mean extending our range of information about the fetus using other tests such as umbilical artery Doppler velocimetry or a biophysical profile. Or it may be as simple as repeating the trace later on. Perhaps this was just a very quiet period for the baby. But if **DAWES-REDMAN CTG ANALYSIS**™ still reports 'Criteria Not Met' and all the other tests are normal, then it may be necessary to consider the possibility of impaired brain function. The point here is that there is no substitute for clinical diagnosis, where a conclusion is formed using information gathered from different sources.

Case Studies

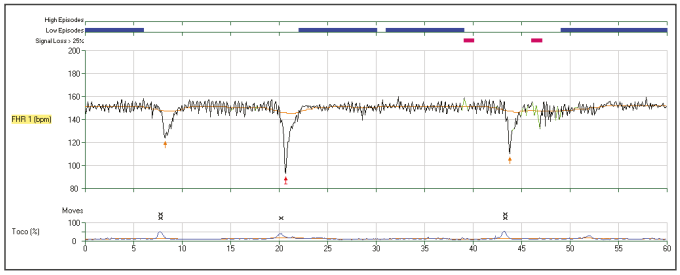
Low STV

The trace shown below was recorded at 34 weeks gestation. **DAWES-REDMAN CTG ANALYSIS**™ reported an STV of 3.0ms and the next day the baby was delivered by caesarean section without labour. Acidaemia was confirmed (arterial pH 6.99, base deficit 13.3 mmol/L) and the baby was resuscitated using intermittent positive pressure ventilation.



Sinusoidal Rhythm

The trace shown below was recorded at 38 weeks gestation. **DAWES-REDMAN CTG ANALYSIS**™ reported a fast sinusoidal rhythm and the baby was delivered less than two hours later by caesarean section without labour (arterial pH 7 .19, base deficit 7.0 mmol/L). Thick meconium was noted, fetalmaternal haemorrhage was confirmed (fetal Hb 5.0g l di}, and a blood transfusion was given.



Why use DAWES-REDMAN CTG ANALYSIS™?

Consistant, Reliable[9]

It Ensures consistent and objective, quantifiable interpretation of CTG patterns, thus reducing the variability that can occur with subjective visual assessments.

"The Dawes Redman CTG analysis has enabled the effective assessment of antepartum CTGs in a consistent and reliable format that significantly outperforms humans." [9]

'The trace is a bit flat.' Opinions on fetal heart rate traces are unreliable. Observers differ from each other, and are not even consistent with themselves. When shown the same trace six months later their opinion has sometimes changed. Opinions are subjective and unreliable while measurements are objective and consistent. So measurements are needed.

Reassurance

A positive assessment supported by the **DAWES REDMAN**™ algorithm provides confidence to both clinicians and mothers. It helps deliver a CTG trace interpretation for early assessment and clinical management.

Short-Term Variation

DAWES-REDMAN CTG ANALYSIS™ measures STV, which the human eye cannot do. Low STV is the best predictor of fetal acidaemia, and tracking STV changes over time can be crucial for the timing of delivery.

Reduced Monitoring Times

The analysis can be concluded in as little as 10 minutes when "Criteria is Met". This helps increase efficiencies by allowing clinicians to focus their time on higher risk mums. A comparative study of visual assessment versus computer analysis found that average monitoring times were reduced from 35 minutes using visual assessment to 16 minutes using computer analysis.[10]

Saving time can also save costs, as more mum can be monitors in a day. More generally, helping clinicians prevent one poor outcome could save millions of pounds in litigation.

Over the past 11 years, the NHS has paid out £3.6bn for 1,307 cases involving babies who suffered brain damage.[11]

Staff Training

A question that is frequently asked is whether **DAWES-REDMAN CTG ANALYSIS**™ is better at assessing traces than a skilled human. The answer is that it is better in some ways and not so good in others. For example, **DAWES-REDMAN CTG ANALYSIS**™ can measure STV which a skilled human cannot, but a skilled human can exercise clinical judgment in a way that a computer cannot. However, if we compare **DAWES-REDMAN CTG ANALYSIS**™ with less experienced staff then it has two clear benefits. First, it provides an accurate assessment of the trace irrespective of the skill and experience of the operator. The trace itself must be of a reasonable quality, but that is all. And second, by using **DAWES-REDMAN CTG ANALYSIS**™ less experienced staff rapidly develop an understanding of what normal and abnormal traces look like. Simply by using **DAWES-REDMAN CTG ANALYSIS**™ they quickly gain experience.

Ease of Use

DAWES-REDMAN CTG ANALYSIS™ is simple and easy to use. It is much less complicated than the equipment used in other methods of fetal assessment. And if a trace gives us cause for concern we can repeat it, as often as we like.

Archiving and Audit

DAWES-REDMAN CTG ANALYSIS™ enables traces to be electronically archived for later retrieval and auditing. Are we monitoring for long enough or for too long? Was an abnormal trace missed? This can all be audited.

Glossary

Terms in *italics* are defined under their own entry. Some definitions are specific to **DAWES-REDMAN CTG ANALYSIS™**.

Acceleration An increase in *fetal heart rate* above the *baseline* that lasts for more than 15 seconds and has a maximum excursion above the baseline of more than 10 bpm.

Basal Heart Rate The resting *fetal heart rate* when it is not in an *acceleration or deceleration*.

Baseline A time-varying line superimposed on a *fetal heart rate* trace to show the resting *fetal heart rate* when *accelerations and decelerations* are excluded.

Cardiotocograph (CTG) A trace showing the *fetal heart rate* and uterine contractions.

DAWES REDMAN™ Criteria A set of rules used in **DAWES-REDMAN CTG ANALYSIS™** to minimise monitoring time by advising staff when monitoring can be stopped because the trace is reassuring.

Deceleration A decrease in *fetal heart* rate below the *baseline* that lasts for more than 60 seconds and has a maximum excursion below the *baseline* of more than 10 bpm, or lasts for more than 30 seconds and has a maximum excursion below the baseline of more than 20 bpm.

Fetal Heart Rate (FHR) The number of times the fetal heart beats in one minute, measured in beats per minute (bpm).

High Variation A section of *fetal heart* rate trace in which the *long-term variation* exceeds a pre-defined threshold. This threshold varies with the gestational age of the fetus.

Long-Term Variation (LTV) The average *minute range* during all or part of a *fetal heart rate* trace.

Lost Beats The units of measurement used to describe the size of a *deceleration*.

Minute Range The difference in milliseconds between the longest and shortest *pulse intervals* in one minute of a *fetal heart rate* trace.

Non-Reactive Trace A *fetal heart rate* trace that does not satisfy the definition of a *reactive trace*.

Nonstress Test (NST) The name given to an antepartum trace in the United States.

Pulse Interval The time in milliseconds between two consecutive fetal heartbeats.

Reactive Trace A *fetal heart rate* trace that contains at least one episode of *high variation*.

Short-Term Variation (STV) The difference in milliseconds between the mean *pulse* intervals in consecutive time periods of 1/16th of a minute, averaged over a *fetal heart rate* trace.

Sinusoidal Rhythm A rare FHR pattern in which the trace oscillates smoothly up and down. A slow sinusoidal rhythm may indicate pathology and poor fetal outcome, while a fast sinusoidal rhythm may indicate fetal anaemia.

Sonicaid System 8000 A computer system for the analysis of antepartum traces that was developed at Oxford University in the UK between 1978 and 1989 using a database of 8,000 antepartum traces and incorporating the **DAWES REDMAN™** criteria.

Sonicaid System 8002 The upgraded version of the *Sonicaid System 8000* that was developed between 1989 and 1994 using a database of 48,339 antepartum traces.

Sonicaid FetalCare improved version of the *Sonicaid System 8002* that uses a database of 73,802 antepartum traces.

DAWES-REDMAN CTG ANALYSIS™ since 1999, improved versions of Sonicaid FetalCare, now strong of well over 100,000 CTG traces.

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