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RESEARCH ARTICLE

# The significance of meeting Dawes–Redman criteria in computerised antenatal fetal heart rate assessment

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**Abstract**

**Objective:** To investigate the significance of not meeting Dawes–Redman criteria on computerised cardiotocography in high-risk pregnancies.

**Design:** Retrospective observational study.

**Setting:** UK university hospital.

**Population:** High-risk pregnancies undergoing antenatal assessment.

**Methods:** We interrogated the database for records of computerised fetal heart rate assessment and pregnancy outcomes.

**Main outcome measures:** Neonatal outcome and stillbirths.

**Results:** Excluding duplicate assessment in the same pregnancy, 14 025 records with complete information on the criteria of normality having been met and the outcome of the pregnancy were available. Criteria were not met for 907 records (6.46%). The gestational age of assessment was lower in the group not meeting criteria of normality. Overall, 32 stillbirths occurred in normally formed fetuses (2.28/1000). Stillbirths were more frequent in the group not meeting criteria (odds ratio [OR] 8.78, 95% CI 4.28–18.02). This finding persisted even after records with abnormally low short-term variation (STV) were excluded. The confidence intervals around the rate of stillbirth in the two groups overlapped beyond an STV of 8 ms.

**Conclusions:** Approximately 1:16 pregnancies do not meet the criteria of normality. The criteria are not met more often at preterm gestation than at term. The risk of stillbirth was higher in the group not meeting criteria of normality, even if cases with low STV are excluded. Cases not meeting criteria should be followed up closely, unless the STV is ≥8 ms. Stillbirths still occurred in the group meeting criteria, but the rate was lower than in the general population.

**KEYWORDS**
antenatal fetal assessment, computerised cardiotocography, stillbirth

## 1 | INTRODUCTION

Electronic fetal heart rate monitoring is a commonly used test for antenatal assessment of fetal wellbeing in the setting of high-risk pregnancy.[1] The initial use of the antenatal fetal heart rate monitoring utilised visual interpretation of the fetal heart trace. However, considerable inter- as well as intraobserver variability has been reported with visual interpretation.[2] The latest Cochrane review does not support the use of visual interpretation of antenatal fetal heart rate analysis for the assessment of fetal wellbeing in high-risk pregnancies.[3]

Computer-aided analysis of the antenatal cardiotocography (CTG) was developed by the group of Dawes and Redman from Oxford in the 1980s. Criteria for normality were developed, and a detailed description of these has been

published.[4,5] An antenatal CTG trace is deemed to be normal if the Dawes–Redman criteria for normality are met.[6] When the criteria of normality are not met, a review with an experienced clinician is suggested. Although it is reassuring when criteria are met, the significance of not meeting them is not entirely clear. For example, absence of accelerations is physiological in the preterm fetus and is seen not infrequently in normal pregnancies.[7] Short-term variation (STV) on the computerised cardiotocography (cCTG) was recorded in a large study on growth-restricted fetuses[8] and the STV value was used to develop triggers of elective intervention. However, it has been argued that STV is not the only significant feature of the fetal heart rate analysis and that fetuses not meeting criteria with a normal STV are still at a higher risk of fetal compromise.[9] This statement was based on unpublished data. We investigated the significance of not meeting criteria on cCTG assessment in high-risk pregnancies.

## 2 | METHODS

Computer-aided analysis is the preferred mode of assessment of fetal wellbeing using the CTG at St George's hospital for several years. We used the Sonicaid Team3 system and its older versions for computer analysis of the CTG (Huntleigh Healthcare Ltd Diagnostic Products Division, 35 Portmanmoor Road, Cardiff, CF24 5H, Wales, UK). We retrieved all records of antenatal fetal assessment performed between the years 2000 and 2020. The outcome of the pregnancy was also retrieved from the maternity database of the hospital. The fetal outcome was recorded as live birth, neonatal demise or stillbirth. All records of stillbirths were checked to explore whether the stillbirth was associated with a chromosomal or structural abnormality. These records were removed. Records of neonatal demise were combined with those of live births. Records of late pregnancy termination were also excluded. All FHR recordings were obtained when the woman was not in labour. Expected birthweight for the gestational age was calculated using the method described by Mikolajczyk et al.[10] and corresponding percentiles of birthweight were computed.

### 2.1 | Statistics

The data were expressed as mean (SD) or median (IQR) as appropriate depending on the data distribution. Proportions were expressed as percentages. An unpaired *t*-test or Mann–Whitney *U* test was used to compare continuous data as appropriate. A chi-square test was used to compare proportions. Mantel–Haenszel common odds ratio estimate was obtained to quantify the differences of proportions between the two groups. The 95% confidence intervals (CI) were calculated for the proportions of stillbirths from the properties of binomial distribution. SPSS V 28.0.1.1 (IBM corp, www.ibm.com) was used for the statistical analysis.

## 3 | RESULTS

A total of 21 231 records were retrieved. Although performed for a variety of indications, the most common indications for antenatal fetal heart rate monitoring were post-date assessment and women presenting with reduced fetal movements. In the initial period, the primary indication for performing the cCTG assessment was not systematically recorded. The most common indications in the last 12 months can be seen in Table S1. Duplicate records from the same pregnancy and those with missing Dawes–Redman analysis as well as outcome were excluded. In cases of duplicate records from the same pregnancy, only the record closest in time to the delivery date was retained. Please see Figure 1 for details. Data were cleaned to remove data entry errors (negative gestational ages, for example). In all, 14 019 records were complete, with information on the criteria having been met and the outcome of the pregnancy. Of these, the criteria were not met for 907 records (6.46%). Characteristics of the participating women are shown in Table 1. There was not difference in maternal. Median gestational age at assessment was significantly lower in the group not meeting criteria for normality, as was the median monitoring duration (Table 1). Median gestational age at assessment was significantly lower in the group not meeting criteria for normality, as was the median monitoring duration. The baseline heart rate was significantly lower. Outcomes of the cases are shown in Table 2. The birthweight centiles in the group not meeting criteria were lower by 9.82 percentile points (95% CI 7.64–11.99).

Stillbirth was more frequent in the group not meeting criteria (odd ratio [OR] 8.78, 95% CI 4.28–18.02). Criteria may not have been met because of an abnormal STV. To account for this, cases with STV <3.5 ms were excluded ($n = 44$) and the analysis repeated. Stillbirth was still more frequent in the group not meeting criteria (OR 7.62, 95% CI 3.57–16.33). The cut-off of 3.5 ms was used in the TRUFFLE study as the criterion for intervention in the CTG arm.[8]

Table 3 and Figure 2 show the details of the cases categorised according to the short-term variation. We calculated the number of pregnancies with a short-term variation above cut-offs stating from 2.7 ms up to 12 ms in the two groups and the proportion of them experiencing a stillbirth. Only the lower CIs for the group not meeting criteria and the upper CIs for the group meeting criteria have been shown to explore an overlap. The rate of stillbirth in the group not meeting criteria of normality was comparable to that for the group meeting criteria for STVs beyond 8 ms because the confidence intervals overlap beyond this cut-off (Figure 2, $p = 0.072$ using Fisher's exact test).

## 4 | DISCUSSION

In this dataset we have shown that in the group of women with pregnancies perceived at a high risk of utero-placental insufficiency, Dawes–Redman criteria are not met in 6–7% of records. In those records not meeting criteria, the gestational

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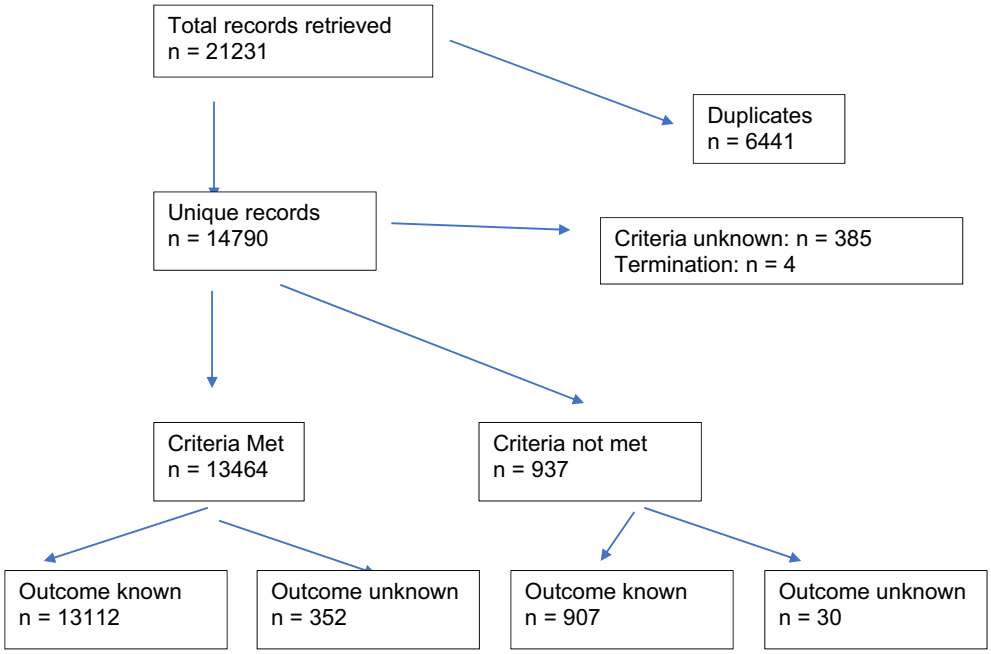


**FIGURE 1** Selection of records.

**TABLE 1** Characteristics of participating women and their fetuses.

| | D-R criteria met ($n$ = 13 112) | D-R criteria not met ($n$ = 907) | Significance |
|---|---|---|---|
| Maternal age in years | 31.5 (5.9) | 31.4 (5.7) | 0.33 |
| Gestational age of recording | $40^{+0}$ ($37^{+0}$–$41^{+2}$) | $36^{+3}$ ($30^{+6}$ to $40^{+2}$) | <0.001 |
| Preterm at recording | 3183 (24.3%) | 479 (52.8%) | <0.001 |
| Duration of recording in minutes | 28 (20–38) | 60 (56–60) | <0.001 |
| % signal loss | 3.0 (1.0–9.0) | 9.0 (2.6–21.0) | <0.001 |
| Baseline HR (BPM) | 136 (10.5) | 143 (13.7) | <0.001 |
| FHR accelerations/h | 11.7 (3–18) | 4.0 (1–8) | <0.001 |
| High variation/h | 30 min (18–46) | 19 min (10–32.5) | <0.001 |
| Median STV (ms) | 9.7 (7.9–11.9) | 6.6 (5.2–8.6) | <0.001 |

*Note*: Numbers represent mean (SD) or median (IQR). D-R, Dawes–Redman.

age of assessment is significantly lower as compared with those meeting criteria. This information has been reported previously by the group from Liverpool Women's Hospital. Roberts et al.[7] from Liverpool reported that criteria are often not met at preterm gestation and that the accelerations are often have a smaller increase in the fetal heart rate.

The risk of stillbirths in the cohort not meeting the criteria of normality was significantly higher than in those meeting criteria. This risk was not completely related only to abnormal short-term variation on the FHR because the elevated risk persisted even after exclusion of cases with abnormally low STV. There is a case for a closer follow-up of cases not meeting criteria. It is unclear whether a closer follow-up will prevent adverse outcomes and this question will not be answered by retrospective studies such as the present one. Another explanation for the higher stillbirth risk is that criteria are not likely to be met in the preterm period, and these pregnancies are exposed to the potentially risky conditions for a longer duration. It has previously been shown that the prospective risk of stillbirth is 0.2–0.5/1000 ongoing pregnancies/week.[11,12] The denominator of stillbirth/1000 births represents a 'rate' and that stillbirths/1000 ongoing pregnancies represents 'risk'.[12] Stillbirth rates are not cumulative, as the pregnancies have ended, but stillbirth risks are cumulative. Therefore, the longer the pregnancy continues, the longer the cumulative risk. Even then, the extent of the increase (eight- to nine-fold increase) is out of proportion to that expected by a longer exposure time (median of 4 weeks).

Stillbirths still occurred in the group meeting criteria, although the rate was much lower (20/13 118 = 1.52/1000) even though this was a group with complicated pregnancies. Figure 2 shows that the rate of stillbirths is not related to the short-term variability in the group meeting criteria. Therefore, one can conclude that once criteria for normality have been met, further analysis of the short-term variability is not warranted. In the group not meeting criteria, the rate of stillbirth gradually decreases with increasing STV. For STVs beyond 8 ms the rate of stillbirth was comparable to

**TABLE 2** Outcome of cases.

| | D-R criteria met ($n$ = 13 112) | D-R criteria not met ($n$ = 907) | Significance |
|---|---|---|---|
| Gestational age of delivery in weeks | $41^{+0}$<br>$39^{+2}$–$41^{+5}$ | $39^{+1}$<br>$35^{+6}$–$41^{+1}$ | <0.001 |
| Birthweight in grams | 3429 (584) | 2844 (1068) | <0.001 |
| Birthweight centile | 45.93 (28.03) | 36.11 (31.90) | <0.001 |
| APGAR score at 5 minutes <7 ($n$) | 149/8184 (1.82%) | 29/543 (5.34%) | <0.001 |
| Preterm birth (<$37^{+0}$ weeks) | 652 (4.97%) | 268 (29.55%) | <0.001 |
| Mechanical ventilation | 133 (1.01%) | 73 (8.05%) | <0.001 |
| Intrauterine demise | 20/13 112 = 1.52/1000 | 12/907 = 13.2/1000 | <0.001 |
| Interval between assessment and birth (days) | 4 days (2–12) | 3 days (1–21) | 0.014 |

*Note*: Numbers represent mean (SD) or median (IQR). D-R, Dawes–Redman.

**TABLE 3** Correlation of short-term variation (STV) and stillbirth.

| | Criteria met ($n$ = 13 112) | | Criteria not met ($n$ = 907) | |
|---|---|---|---|---|
| STV | Live births | Stillbirths | Live births | Stillbirths |
| All | 13 092 | 20 | 895 | 12 |
| ≥2.7 ms | 13 092 (100%) | 20 | 884 (98.77%) | 11 |
| ≥3 ms | 13 092 (100%) | 20 | 876 (97.88%) | 11 |
| ≥4 ms | 13 084 (99.94%) | 20 | 832 (92.96%) | 9 |
| ≥5 ms | 12 990 (99.22%) | 20 | 711 (79.44%) | 9 |
| ≥6 ms | 12 501 (95.55%) | 19 | 548 (61.33%) | 6 |
| ≥7 ms | 11 432 (87.32%) | 17 | 394 (44.02%) | 5 |
| ≥8 ms | 9671 (73.87%) | 14 | 277 (30.95%) | 2 |
| ≥9 ms | 7834 (59.84%) | 10 | 195 (21.79%) | 2 |
| ≥10 ms | 6087 (46.49%) | 7 | 138 (15.42%) | 1 |
| ≥11 ms | 4461 (34.07%) | 6 | 104 (11.62%) | 1 |
| ≥12 ms | 3216 (24.56%) | 6 | 75 (8.38%) | 1 |
| ≥13 ms | 2260 (17.26%) | 2 | 62 (6.93%) | 1 |
| ≥14 ms | 1569 (11.98%) | 2 | 48 (5.36%) | 1 |
| ≥15 ms | 1083 (8.27%) | 2 | 38 (4.25%) | 0 |

that for the group meeting criteria because the confidence intervals overlap. Therefore, we conclude that cases where criteria are not met and the STV is >8 ms, the risk of stillbirth is no different from those meeting criteria. In those fetuses where criteria are not met and the STV is <8 ms, we suggest a closer monitoring rather than just attributing the result to a lower gestational age. We acknowledge that the confidence intervals for the stillbirth rates are wide because the event rate is so low. However, this is the best evidence-based advice we can offer in the absence of larger data with tighter confidence intervals. This cut-off may change in the future if larger datasets become available.

Stillbirths have many causes but not all of them are evident, even after extensive investigations including an autopsy.[13] It would take a leap of faith to believe that antenatal CTG can predict all stillbirths. It is unlikely that cCTG would be able to predict future accidents such as placental abruption.

The overall incidence of stillbirth in this dataset was 32/14 025 = 2.28/1000. This is slightly lower than that reported in the 2020 UK CEMACE report[14] (3.33/1000, 95% CI 3.19–3.46/1000). The most likely reasons for this are that the cases deemed to be complicated pregnancies were under surveillance. It has been shown that prenatal identification of small fetuses is associated with a lower risk of adverse fetal outcome compared with unidentified small fetuses.[15] All stillbirths related to chromosomal and structural abnormalities as well as late terminations have been excluded. Intervention before fetal demise may have averted at least a few potential stillbirths in this high-risk cohort. Another reason is that cCTG is indicative of the fetal status at the time of recording the fetal heart rate trace. The baseline heart rate was significantly lower, likely due to the earlier gestation at assessment in the group not meeting criteria of normality, as the baseline heart rate reduces with increasing gestational age. Table 2 shows the median interval between

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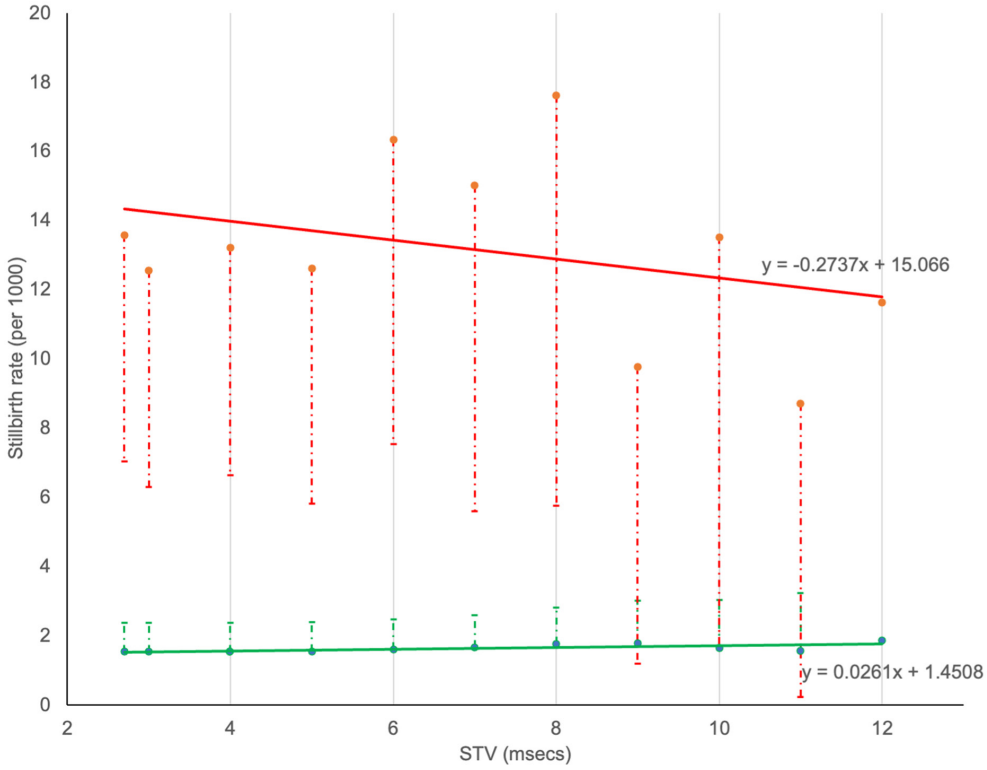


**FIGURE 2** Cumulative stillbirths in the two groups. Stillbirth rate in the group meeting criteria (green) and not meeting criteria (red). Only upper confidence interval for the group meeting criteria and lower confidence interval for the group not meeting criteria have been shown to explore an overlap. Confidence intervals are much larger for the group not meeting criteria due to a smaller number of cases.

obtaining the trace and outcome was still 3 days, and that deterioration of the fetal status could have taken place after a cCTG that met the criteria of normality before a repeat recording was obtained. It may be argued that the prognostic value of cCTG is limited. However, in 23 of the 32 stillbirths, the interval between the recording and birth was 14 days or less. It is conceivable that some stillbirths were not delivered for some time, so that the interval between recording and occurrence of a stillbirth may be shorter.

### 4.1 | Strengths and weaknesses

According to our knowledge this is the first large study reporting the outcome of pregnancies where the criteria of normality for cCTG were not met. The number of pregnancies included is reasonably large. There were 32 stillbirths of normally formed fetuses in this dataset. Stillbirth is an uncommon outcome of a pregnancy, particularly when the pregnancy has been flagged up as a high-risk pregnancy and is under surveillance. The results of the computerised fetal assessment were available to the clinicians. This introduces intervention bias. However, given the available information on the value of antenatal CTG assessment it is not ethical to blind the clinicians to the reports of the cCTG assessment. It is interesting that the stillbirth rate was still higher in the sub-group not meeting criteria, even when the results were available to the caregivers. There is reason to believe that the rate might have been even higher, had the results been concealed. Neonatal deaths were included in the group of live births. Therefore, clinician intervention is unlikely to have influenced the higher stillbirth rate in the group not meeting the criteria of normality. Outcome of the pregnancy was not available for some of the pregnancies. This weakness should be acknowledged. However, all stillbirths are reported and investigated in the UK. Therefore, it is unlikely that some stillbirths may have been unknown to us from either of the groups where the outcome of the pregnancy was not available.

## 5 | CONCLUSION

We conclude that criteria of normality are not met in approximately one of 16 pregnancies undergoing antenatal CTG. The criteria are not met more often at preterm gestation than pregnancies at term. The risk of adverse perinatal outcome is eight to nine times higher in the group not meeting criteria than when the criteria are met. This finding persists even if cases with low short-term variation are excluded. The cases not meeting criteria should be followed up more closely, particularly when the STV is below 8 ms. Stillbirths still occurred in the group meeting criteria, but the rate was lower than in the general population.

## AUTHOR CONTRIBUTIONS

AB: conceived the idea, retrieved the data, analysed and interpreted data, wrote the paper. AM: retrieved the data, analysed and interpreted data, revised the paper. AF: analysed and interpreted data, revised the paper. BT: interpreted the data, revised the paper. All the authors approved the final article.

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No specific funding was available for this study.

## CONFLICT OF INTEREST STATEMENT

Amarnath Bhide and Basky Thilaganathan work with Biorithm Inc. on non-invasive fetal ECG monitoring. Biorithm are manufacturers of an antenatal fetal monitor using fetal ECG signals. The work in the manuscript is not influenced by this collaboration.

## DATA AVAILABILITY STATEMENT

Data available for sharing by contacting the corresponding author.

## ETHICS APPROVAL

This was a retrospective analysis of routinely collected data. The NHS health research authority deemed the study a 'health surveillance' and so formal review by the research ethics committee was not necessary for this study.

## PATIENT CONSENT

This was a retrospective analysis of routinely collected data. Patient consent was not sought.

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## SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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