# STUDY OF SHORT TERM VARIABILITY INDEXES IN CORRESPONDENCE OF FETAL HEART RATE DECELERATIONS

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**Abstract: Cardiotocography is the most widely used diagnostic technique to monitor fetal health. Generally, clinicians interpret cardiotocographic tracings (CTG) by means of eye inspection. The validity of this diagnostic procedure is still limited by the lack of objectivity and reproducibility. Therefore, more objective methods for CTG interpretation are of crucial importance. To this end, great interest has been dedicated to the Variability of the Fetal Heart Rate (FHRV). In particular, this work aims to study the characteristics of the Short Term Variability (STV) patterns in correspondence of FHR decelerations. STV reflects changes in consecutive beat-to-beat intervals and, in general, reflects autonomic nervous system (ANS) functioning. We focused our attention on decelerations because they represent a suffering episode for the fetus. In this work, CTG corresponding to both physiologic and pathologic conditions were studied and 5 different computerised STV indexes were utilised and compared. Preliminary results concerning healthy CTG showed that STV values progressively increase in correspondence of a deceleration, returning to the rest value afterwards. With reference to pathologic CTG, at moment, it is not possible either to clearly distinguish different STV patterns or to surely correlate the entity of the STV variation with any specific pathology.**

## Introduction

Cardiotocography is the most widely used diagnostic technique, in clinical practice, to monitor fetal health, both in antepartum and in intrapartum period (usually from the 34th week of gestation to delivery).

Fetal Heart Rate (FHR) and Uterine Contractions (UC) are simultaneously recorded by means of two probes placed on the maternal abdomen (an US Doppler probe for FHR signal and a pressure transducer for UC signal).

To record FHR and uterine activity, direct (e.g. intra-uterine pressure with internal catheter and direct fetal scalp ECG) techniques can be also used. Direct measurements provide more precise results, but they can only be used during labour, after spontaneous or induced membrane rupture. Therefore, indirect methods are mostly and successfully employed. Since its introduction, in the '60s, electronic fetal monitoring led to a considerable reduction of perinatal morbidity and mortality.

Nevertheless, important conditions such as fetal distress are determined from the cardiotocographic (CTG) data, generally by means of eye inspection of clinicians, who evaluate specific clinical signs. The validity of this diagnostic procedure is still limited by the lack of objectivity and reproducibility of CTG tracings interpretation [1]. Moreover, important physiological mechanisms, like thermoregulatory oscillations, maturational changes with advancing gestational age, fetal behavioural states and maternal drugs [5, 6] can influence FHR and make CTGs interpretation more and more difficult.

To overcome this limit, more objective methods for CTG interpretation are of crucial importance; therefore, several analysis methodologies have been proposed in recent years [2]. For example, the introduction of computerised classification systems led to a partial reduction of intra- and inter-observer variation. Moreover, great interest has been dedicated to the Variability of the Fetal Heart Rate around its baseline, namely FHR Variability (FHRV), which can support more detailed and objective analyses [3].

The aim of this work is to study the characteristics of the Short Term Variability (STV) patterns in correspondence of FHR decelerations. STV or beat-to-beat variability is the index that concisely takes into account oscillations of the FHR around baseline (generally variations of 5-10 bpm). This variability permits to investigate fetal reactions to internal or external stimuli. In general, large variability reflects a healthy autonomic nervous system (ANS), and chemoreceptors, baroreceptors and cardiac responsiveness [4]. For this reason, STV can represent a valid support to diagnose fetal health (it is worth to remember that a flat baseline is one of the most important ominous characteristic of the FHR signals) [4].

STV of the entire CTG recording is considered an important clinical parameter but we focused our attention on decelerations because they emphasize a suffering episode for the fetus (generally as reaction to the strong stimulus represented by UC) and could be


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interesting to distinguish between transient and pathologic distress.

In this work, intrapartum cardiotocographic recordings corresponding to both physiologic and pathologic conditions (intrauterine growth retard –IGR-, oligoamnios –OA-, gestational hypertension –GH-, placentar senescence –PS-, pre-term delivery risk –PTDR-, fetal malformations –FM-, gestosis –G-) were analysed to study possible prognostic value of the STV.

It is difficult to evaluate STV by a simple eye inspection of CTG signals [5], therefore computerised indexes were employed (also to overcome the poor reproducibility of visual analysis). In particular, 5 different STV indexes, cited in literature [6], were utilised and compared.

**Materials and Methods**

Cardiotocographic recordings were provided by the "Dept. of Obstetrical-Gynaecological and Urological Science and Reproductive Medicine", University "Federico II", Naples, Italy. They were acquired during clinical routinely monitoring using HP-M1351A cardiotocographs.

For this study, the following definition was hold to automatically select the FHR decelerations: transient decreases of the FHR below the baseline level of at least 10 bpm lasting at least 30 s [7]. In order to analyse isolated decelerations a minimum delay of 10 minutes was accepted for consecutive decelerations.

About 900 cardiotocographic recordings, of minimum duration of 20 minutes, were screened, searching for decelerations. From that database, 42 CTG tracings with good quality of the FHR signals were chosen and 60 decelerations selected.

Cardiotocographic data was previous classified as normal or pathologic, also specifying the type of disease, by a team of obstetrics and gynaecologists.

This classification produced 11 decelerations corresponding to oligoamnios, 4 corresponding to intrauterine growth retard, 9 corresponding to pre-term delivery risk, 2 corresponding to placentar senescence, 3 corresponding fetal malformations and 2 corresponding to gestosis.

Early, late and variables decelerations (with respect to the correspondent uterine contraction) were further separated within the healthy group (see table 1 for the defnitions). In this case, we obtained 18 late decelerations, 3 early decelerations and 8 variable decelerations.

From literature [6], different formulas to compute STV were selected (Arduini, Corometrics, Dalton, Organ, Yeh) and then used in data processing (see table 2).

To follow the time course of the deceleration, STV indexes were computed using a sliding temporal window of an opportune length and a considerable overlap. Therefore, the time-varying evolution of the STV indexes can be represented along with the FHR and UC signals.

Table 1: adopted definitions for decelerations [1].

| **Type of deceleration** | **Definition** |
|---|---|
| Early | This type of deceleration has a uniform shape, with a slow onset that coincides with the start of the contraction and a slow return to the baseline that coincides with the end of the contraction. Thus, it has the characteristic mirror image of the contraction. They generally last 20 – 90 s. |
| Late | A late deceleration is a symmetric fall in the fetal heart rate, beginning at or after the peak of the uterine contraction and returning to baseline only after the contraction has ended. The descent and return are gradual and smooth. |
| Variable | Variable decelerations are shown by an acute fall in the FHR with a rapid downslope and a variable recovery phase. They are characteristically variable in duration, intensity and timing. They resemble the letter "U," "V" or "W" and may not bear a constant relationship to uterine contractions. |

Table 2: employed STV indexes. $T_i$ = istantaneous beat-to-beat interval [s], Fi = istantaneous herat beat [bpm].

| **Index's name** | **Formula** |
|---|---|
| Dalton | $\sum_{1}^{n} \lvert T_i - T_{i-1} \rvert / 2$<br>n = # of beats in 60 s |
| Arduini | $\frac{\sum_{1}^{n-1} \lvert T_{i+1} - T_i \rvert}{n-1}$<br>n = # of samples in 60 s |
| Organ | $\sum_{1}^{n} \lvert F_{i+1} - F_i \rvert / n$<br>n = # of beats in 30 s |
| Corometrics | $\frac{1}{n} * \sum_{1}^{n-1} \lvert D_{ave} - D_i \rvert$<br>$D_{ave} = \frac{1}{n} * \sum_{1}^{n-1} D_1$<br>$D_i = 4096 * \frac{T_i - T_{i+1}}{T_i + T_{i+1}}$<br>n = 256 beats |
| Yeh | $\sum_{1}^{n-1} \sqrt{(D_i - D_{ave})^2} / (n-2)$<br>$D_i = 1000 * (T_i - T_{i+1}) / (T_i + T_{i+1})$<br>$D_{ave} = \frac{1}{n-1} * \sum_{1}^{n-1} D_i$<br>n = # of beats in 60 s |


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In order to highlight common features of STV time-courses, all available homogenous data (belonging to the same CTG group) were synchronously averaged. The start of the deceleration was considered as the time reference. In this case segments of 5 minutes (heuristically chosen in order to surely include a whole deceleration and also signal tracts just before and after the deceleration) were analysed.

**Results**

Concerning healthy CTGs, STV values progressively increase in correspondence of a deceleration, returning to the rest value afterwards (fig 1a). Roughly, the average time-varying STV shape, computed with 3 indexes (Arduini, Dalton, Organ), frequently employed in clinical practice, appears as a mirrored version of the corresponding FHR deceleration. Accordingly to their physiological meaning, early decelerations show a higher STV variation with respect to the other groups (late and variable).

The detected increase in STV values is in accordance with other studies carried out in uncomplicated labours [8].

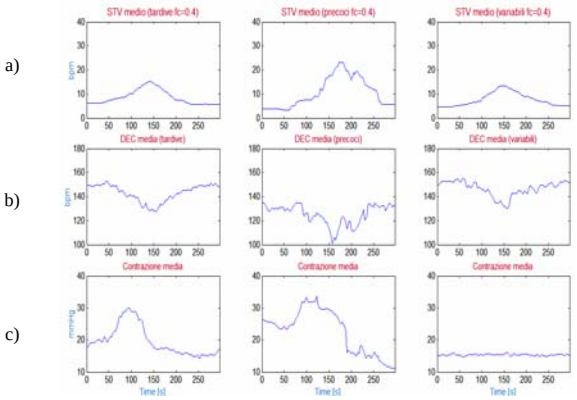
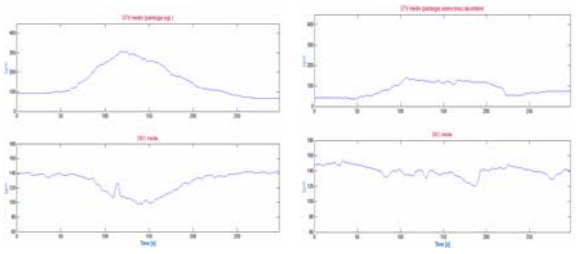
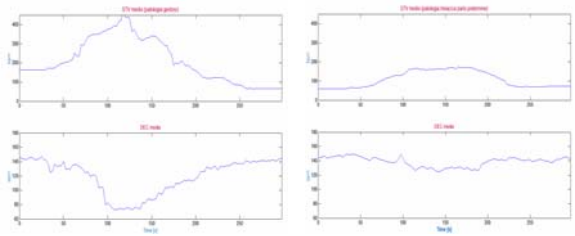



Figure 1: healthy CTGs: from the top: average of the STV time courses (a), average of the decelerations (FHR signals) (b) and average of the UC signals (c). In the columns (from the left): late, early and variable decelerations, respectively. Arduini's index is represented in this figure.



a) b)

Figure 2: from the top: average of the STV and average of decelerations, cases of IUGR (a) and of PS (b). Dalton index was employed for this figure.



a) b)

Figure 3: from the top: average of the STV and average of decelerations, cases of G (a) and of PTDR (b). Dalton index was employed for this figure.

With reference to pathologic CTGs, we detected again an increase of STV values during decelerations. This increase seems to be reduced with respect to healthy for specific pathologies (i.e. OA, PTDR, PS). In the figures 2 and 3 are reported some examples of the preliminary results obtained. In particular, cases of IUGR and PS (Fig. 2) and G and PTDR (Fig. 3) are graphically compared.

However, at moment, concerning pathologic CTGs, it is difficult to clearly distinguish different STV patterns and, mainly, it is not possible to highlight particular prognostic value of the analysed STV indexes.

**Discussion and Conclusions**

Cardiotocography is the most used prenatal technique in clinical practice to diagnose fetal well-being or distress.

Usually, clinicians evaluate CTG traces by means of eye inspection. Of course, it can be very useful to achieve more objective and reproducible analysis methodologies. For this purpose, several techniques and indexes, both in time-domain and in frequency-domain, have been proposed in recent years [2].

In particular, great interest has been dedicated to the Variability of the Fetal Heart Rate, which could be a base for a more detailed analysis [3]. Changes in the variability are thought to be secondary to ANS alteration. This concept is supported by observations that drugs which depress autonomic reflexes also tend to decrease FHRV. Maturation of the fetal central nervous system is also a determinant; variability increases and become more cyclic and predictable with advancing gestational age [9].

The variability of FHR can be concisely studied both in terms of Short Term Variability (STV), which reflects differences in sequential beat-to-beat intervals and Long Term Variability (LTV), which reflects changes over a longer period of time [6, 9]. STV has been considered more useful in CTGs tracings interpretation but it is very difficult to detect beat-to-beat changes only by eye inspection. Therefore, many indexes were proposed to quantify STV. These indexes can be classified into categories depending upon the theoretical mathematical basis (for example statistic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indexes, indexes based on frequency analysis, etc.) [6]. In this work, five STV indexes were selected and compared among those reported in literature and used in clinical practice, in order to study their eventual prognostic value.

In physiological cases, obtained results showed a higher STV variation for early decelerations respect to the other groups (late and variable), in accordance with their more favourable meaning (normally, early decelerations are not associated with fetal distress [4]).

In pathological cases, instead, at moment, it is not possible either to clearly distinguish different STV patterns or to surely correlate the entity of the STV variation with some pathology.

Many factors could explain these uncertain results. The low sampling frequency of FHR signals (equal to 0.4 Hz for our CTGs signals), which could affect the estimation of the beat-to-beat variability. The little number of decelerations involved in the analysis relative to the different kind of signals (i.e. healthy, IGR pathology, etc.) could affect characteristics of the averages. Absence, in the analysed database, of cases showing very poor neonatal outcome (e.g. very low Apgar score, neonatal asphyxia, need of neonatal intensive care, etc.) excludes the presence of extremely serious condition (fetuses condition were not so bad).

However, preliminary results seem to show the potential value of studied STV indexes in highlighting fetal distress. Therefore, future developments foresee the application of this methodology to a wider database with different characteristics.

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