

Relations between fetal head descent and cervical dilatation during individual uterine contractions in the active stage of labor

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Abstract

The relationship between instantaneous changes in fetal head station and cervical dilatation within the individual contraction during the active stage of labor were studied and an index of labor progress was suggested. Cervix dilatation and fetal head station were measured continuously in 30 nullipara women (mean age 27.5, standard deviation 4.8). The continuous measurements enabled the analysis of each variable and the analysis of the relations between these two variables. The relationship between the head station and the cervical dilatation were demonstrated by plotting one against the other during a contraction. This led to the definition of a contraction vector that integrates the interaction between the two variables. The angle of this vector, that indicates this relation, was plotted against mean head station to demonstrate change along the delivery process regardless of time to normalize the progress and allow comparison between different women with different labor durations. This plot showed a sharp change from almost zero into a steep curve at about zero head station. A zero angle indicates that the cervix dilates during a contraction with little effect on head station while a steep angle indicates a significant effect of cervical dilatation on head station during the contraction. The contraction-vector angle reflects the changing intra-contraction relationship between head station and cervical dilatation. The angle of this vector may serve as an indicator of labor progress.

Key words: individual contraction analysis, labor management, labor physiology.

Introduction

Uterine contractions result in both cervical dilatation and fetal head descent. Contractions affect each of these variables differently throughout the course of labor. Attempts to measure these variables continuously were limited in the past due to the lack of suitable technology. In 1954 Friedman introduced the partogram that presents manually measured values of cervical dilatation and fetal head descent as functions of time.^{1,2} His work was continued and expanded by Philpott,³ Studd⁴ and Impey *et al.*⁵ Partograms show the

trend of cervical dilatation and head descent measured normally between contractions, as functions of time. The errors of these manual examinations are large. Even experienced hands were shown to exhibit a variability of up to 2 cm in the estimation of cervical dilatation.^{6–9} Assessment of fetal head station is even more subjective and suffers from large errors.^{10,11} Several instruments were designed for accurate measurements of cervical dilatation based on a variety of physical principles.^{12–15} Technologies for assessing fetal head descent were described by Wolfson¹⁶ and by Sallam *et al.*¹⁷ None of these were accepted clinically.

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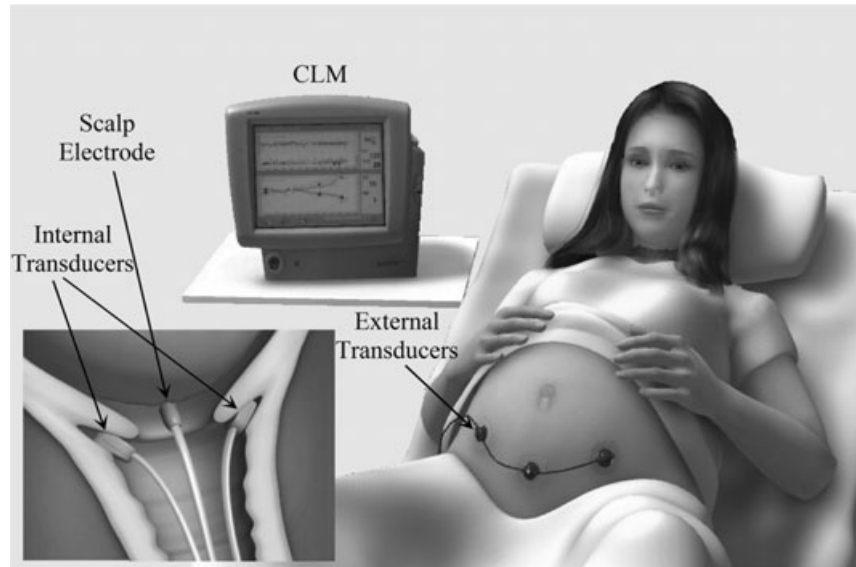


Figure 1 Illustration of the system. The system includes three external transducers on the abdomen and three internal transducers: two for measurement of cervical dilatation and two for fetal head station. CLM, computerized labor monitor.

Partograms presenting digital measurements do not include information regarding the dynamics of individual contractions. Such data may provide further insight into the physiology of labor and provide information on the efficiency of the single contraction and its effect on labor progress. Recent technological advances¹⁸ provide new opportunities for continuous data acquisition of the instantaneous values of both cervical dilatation and fetal head station. It has therefore become possible to study the dynamic relationship between head descent and cervical dilatation during each individual contraction along the course of labor.

In this paper we present graphical representations of labor mechanics that combine dynamics of head descent and cervical dilatation into one graph. These data provide further insight into labor physiology, thereby complementing the Friedman curve. This may provide new parameters for assessing labor progress.

Materials and Methods

Cervical dilatation and fetal head station were continuously measured in women during labor using a computerized labor monitor (CLM, Barnev LTD., Netanya, Israel). The device is based on ultrasonic technique where pulses are transmitted by three external abdominal transducers that form a triangle (Fig. 1). These acoustic pulses are received by three internal sensors (Fig. 1), two located on opposite sides of the cervix and one incorporated into the fetal electrocardiogram (ECG) scalp electrode. The scalp electrode is

attached to the scalp of the presenting part of the fetal head following membrane rupture. The time between transmission and reception of the acoustic pulses is measured and converted to distance. A triangulation algorithm uses the data to compute fetal head station and cervical dilatation. Head station may be manually calibrated by the physician at the beginning of the session. A detailed description of the system has been published previously.¹⁸ The system was cleared for clinical use by the Food and Drug Administration and received the Conformité Européene (European CE) mark. The study was performed at Lis Maternity Hospital in Sourasky Tel Aviv Medical Center. The study was approved by the Institutional Review Board. All participating women signed an informed consent form before participating in the study.

Data from 30 nullipara who agreed to take part in this study are presented. Their ages ranged between 19 and 41 (mean 27.5, standard deviation 4.8). Two women had a previous elective cesarean section. All had uncomplicated singleton pregnancies with vertex presentation. Women with significant medical history were excluded. All had epidural analgesia prior to the insertion of the sensors. The monitoring of all women started in the active part of the first stage of labor (defined as cervical dilatation of more than 3 cm and the presence of regular uterine contractions that have changed cervical dilatation).

Measurements included continuous and simultaneous data of fetal head station (HS) and cervical dilatation (CD). The relationship between these two

variables was studied directly in the HS–CD plane using 456 contractions (i.e. by plotting the HS waveform during a contraction against the CD waveform during the same contraction).

Data analysis

Data recorded in the active phase of the first stage of labor, starting at CD = 3 and ending with birth, were analyzed. The data included continuous signals for HS and CD as functions of time (as illustrated in Figure 2 – top panel). In each of these two signals, the change during each individual contraction (HS and CD waves) was identified and delineated. In each delineated segment, containing a single contraction, the head descends and returns to the contraction baseline plus an increment while the cervix opens and returns to its baseline plus an increment. Such segment pairs of HS and CD waves for each contraction were plotted HS against CD – HS on the y axis and CD on the x axis (illustrated in Figure 2 – bottom panel). This resulted in

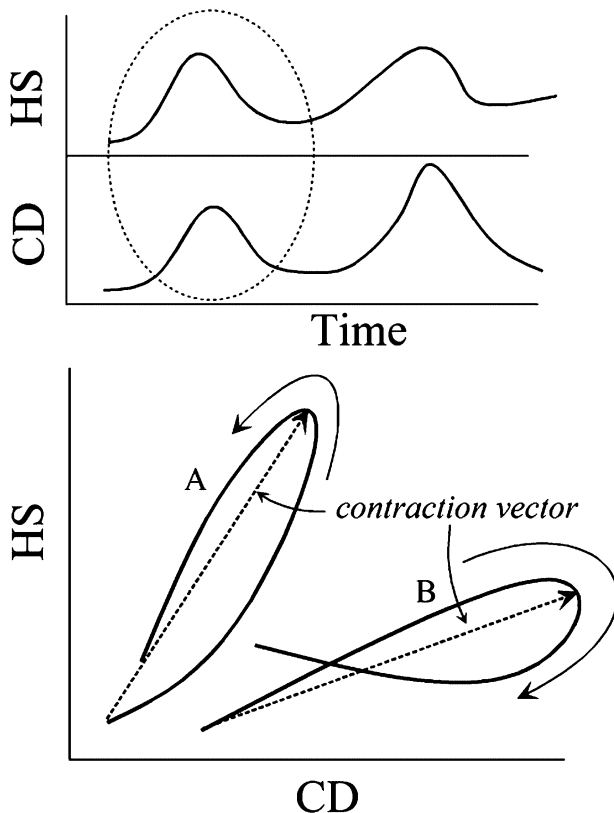


Figure 2 Illustration of cervical dilatation (CD) and head station (HS) as functions of time (top panel) and HS plotted against CD for one contraction (bottom panel).

a single plot for each contraction that shows how the instantaneous value of station is related to the instantaneous value of dilatation during each contraction. Many such contraction-loops were constructed along the time course of labor using an automatic program implemented in a MATLAB (The Mathworks Inc. Natick, MA). Each pair of HS and CD waves that were plotted during a contraction created an elongated loop of different shapes depending on the relative intensity and timing of each variable. This is demonstrated in the illustration in Figure 2. The loops may go in a counter-clockwise trajectory, indicating that CD begins increasing before HS or in a clockwise trajectory, indicating that the descent of the head descending precedes cervix dilatation. A line was drawn from the point at the beginning of the contraction to the peak of contraction. This line was designated as the *contraction vector*. The angle of this vector indicates the relationship between the maximal effect of the contraction of CD and HS. Thus, the direction of rotation reflects a temporal effect while the angle of the contraction vector reflects relative intensity.

Results

Results of the analysis of a single labor process are shown, followed by averaged and normalized values of 30 nullipara women. The mean duration of the monitored labor processes was 4.06 h (standard deviation 1.75 h; min 2.03 h; max 8.0 h). Figure 3 shows CD and HS of a full labor process for a single patient measured with the CLM. The thin lines show the instantaneous dynamics while the thick lines show the trend of the contraction baseline (see Sharf *et al.* for more details). The thin lines show the effects of each contraction on head station and on cervical dilatation thereby creating the CD and HS waves. The figure demonstrates the measurement capabilities of the device and clearly shows the effect of each individual contraction on the baseline value.

Figure 3 also shows several numbered contractions for both HS and CD that were selected arbitrarily as examples. These contractions were numbered so they can be followed in subsequent plots.

Figure 4 shows an example of a single contraction. The HS signal of a single contraction from Fig. 3 is plotted against its related CD counterpart signal for that contraction, thereby creating a view of the contraction in the HS–CD plane where time is neutralized. The trajectory of the loop is a clockwise trajectory indicating that the HS wave precedes the CD wave. This may

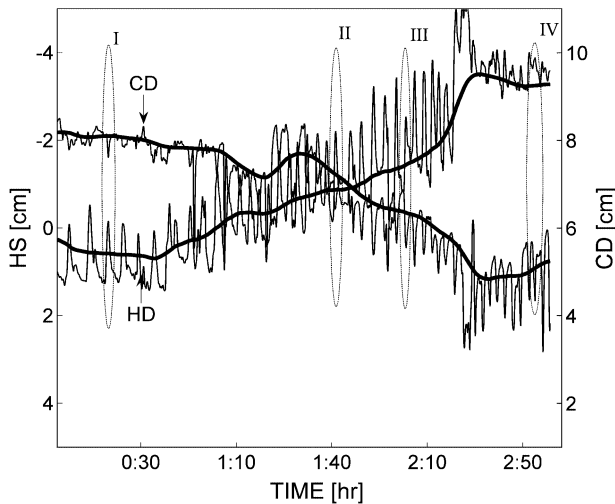


Figure 3 Head station (HS) and cervical dilatation (CD) as functions of time. The thin lines indicate the actual real-time measurement of HS and CD while the thick line indicates the trend of the signals' baseline (value between contractions) as a function of time.

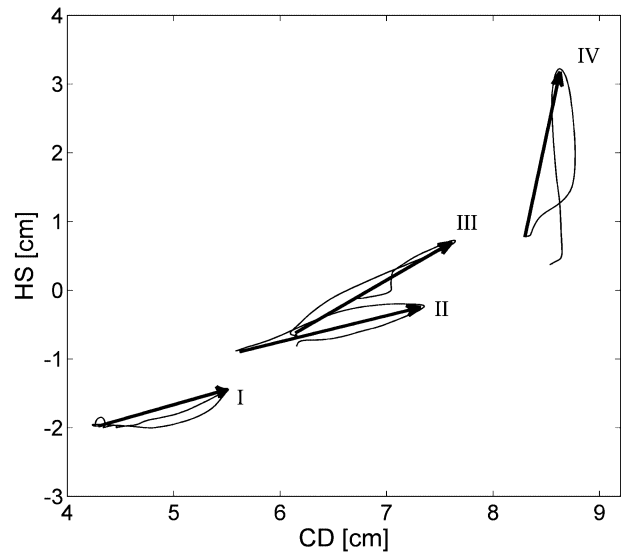


Figure 5 Numbered contractions of Fig.3 for one woman are plotted: instantaneous values of head station (HS) waves as a function of cervical dilatation (CD) waves during individual contractions along the course of labor.

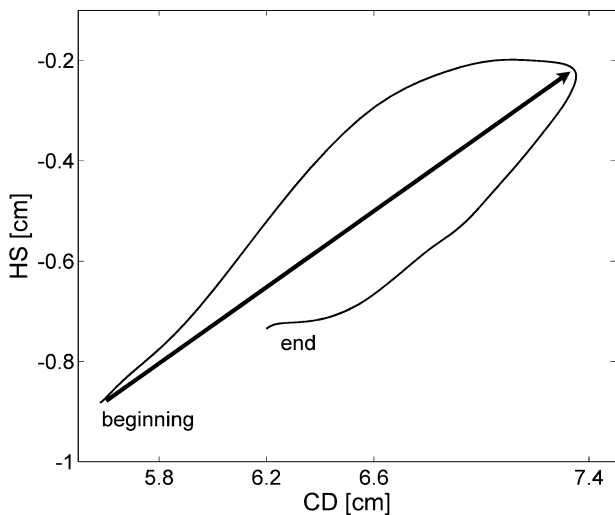


Figure 4 Head descent during a single contraction is plotted against the change in cervical dilatation at that time thereby creating a head station (HS) – cervical dilatation (CD) loop and the contraction vector.

indicate that the dilatation is in part affected by the pressure of the head on the cervix. The contraction vector that is shown represents an equivalent contraction intensity that combines the amplitudes of both CD and HS. The angle of the contraction vector relates the CD amplitude to the HS amplitude indicating a relative effect.

Each numbered contraction from Fig. 3 is presented in Figure 5 in the HS–CD plane in a manner similar to the example of Figs 2 and 4. This plot shows the relationship between HS and CD during the course of labor. Note the displacement along the CD axis and the change in angle and form of the HS–CD loop.

Figure 6 depicts the change from baseline of the contraction vector angle averaged for all women as a function of HS along the course of the active stage of labor. It shows that as the fetus descends, the contraction angle does not vary until station reaches a value of 0–1 cm. Beyond that point, the angle becomes steeper rapidly.

Discussion

The effect of the individual contraction can be analyzed to study its contribution to the progress of cervical dilatation and head descent. This study presents the dynamic relationship between fetal head station and cervical dilatation during each individual contraction over the course of the active part of the first stage as well as the second stage of labor. The data for cervical dilatation and head station were acquired simultaneously and continuously using a computerized labor monitor. CD and HS waves, representing the effect of the individual contraction on cervical dilatation and

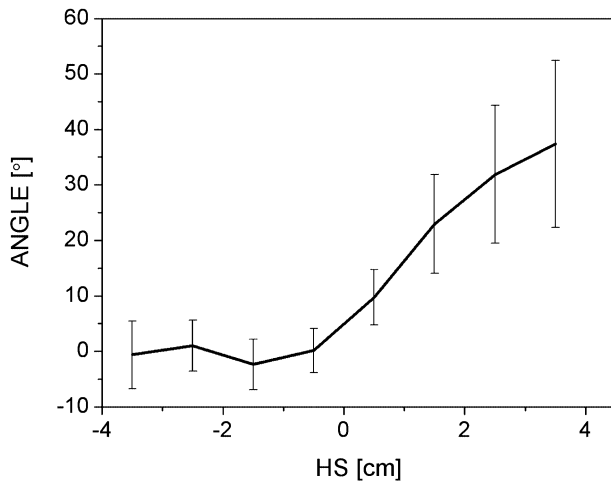


Figure 6 The change in angle is measured from baseline value of the contraction-vector angle (designated '0'). HS, head station.

head station, respectively, were extracted from the acquired data. Plotting HS waves as functions of CD waves reveals a new relationship that changes during the course of labor.

The changes during a single contraction in HS were plotted against the changes in CD during that contraction (Fig. 4) to demonstrate how these two variables are affected differently by the same contraction. This plot allows the observer to study the relationship between these two major variables. In most cases we observed a clockwise trajectory that indicates that either the HS wave precedes the CD wave or it is shorter. More complex forms were observed as shown in Figure 5 – contractions number III and IV for example. The HS-CD trajectory may loop clockwise or counterclockwise depending on the time delay between HS and CD in each contraction or on the duration of each wave.

As labor progresses, HS increases while CD starts with an increase followed by a decrease and finally vanishes due to full dilatation. This is reflected in the contraction vector angle that can be seen as a function of time in Figure 6. The angle becomes steeper as HS increases and CD decreases. When either the cervix achieves full dilatation or an arrest of dilatation occurs without an arrest in descent, the angle is expected to be 90°.

The angle-index that we have presented as a function of head station has several different implications for the physiology of labor. The effect of individual contractions on dilatation is different from the effect on descent at different times throughout the active part of

the first part of labor and the second part of labor. The angle of the contraction vector does not change much initially, indicating high dilatation activity with low activity in fetal head descent. The rapid change following HS 0-1 cm indicates increased activity in fetal head descent. In contractions following zero head station, it seems that the head descent is directly related to the effect on dilatation. This may indicate the engagement of the head to the cervix and may reflect a milestone in the progress of the labor process.

The ability to measure instantaneous values of both dilatation and descent during individual contractions may provide tools to study the physiology of the individual contraction as well as means for early diagnosis of non-progressive labor. In addition, it is possible that titrating oxytocin to achieve a normal pattern of individual contraction may provide better clinical guidance for both oxytocin induction and augmentation. This may result in better management of non-progressive labors leading to a reduction in cesarean rates. It may also lead to earlier cesarean sections in cases when increase in oxytocin titration will not result in a normal pattern of contractions. Further information on these parameters in normal and non-progressive labors is needed to validate or negate these hypotheses.

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