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Effects of the individual uterine contraction on fetal head descent and cervical dilatation during the active stage of labor

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ABSTRACT

Objective: To evaluate the effects of individual uterine contractions on instantaneous values of cervical dilatation and head station along the active stage of labor.
Study design: Cervix dilatation and fetal head station were measured continuously using a labor monitor that is based on ultrasonic triangulation. The relations between the two variables in response to each contraction were analyzed. The relative effect of the contraction on head station and on cervical dilatation was demonstrated by plotting one against the other during the contraction and quantified by two indices: (a) the *contraction vector* that integrates the maximum effect of uterine contraction on both variables and (b) the *efficiency vector* that indicates the contribution of each contraction to labor progression. The amplitude and angle of each vector were calculated. Correlation between the waveforms of head station and cervix dilatation during contractions was also calculated. These indices were plotted against cervix dilatation and head station at different stages in labor progress.
Results: Effects of uterine contractions on cervix dilatation and head station varied during labor. The amplitude of the contraction vector and efficiency vector increased to a maximal value at cervical dilatation of 6 cm. The angle of the contraction vector increased with the progress of labor. Correlation between cervical dilatation and head station was maximal at the engagement zone of the birth canal. High variability was observed between subjects for all indices measured.
Conclusion: The contraction vector and the efficiency vector exhibited distinct behavior during labor. These vectors may serve as indicators for normal and abnormal progress of labor. More data are required to obtain statistical significance.

1. Introduction

Fetal head station (HS) and cervical dilatation (CD) are the two main physiological parameters for assessing the progress of labor. Fetal head station is the position of the tip of the presenting fetal scalp relative to an imaginary line connecting the two boney ischial spines. HS is measured blindly, solely by palpation. The position of the head ranges from −5 cm to +5 cm. This range is divided into high station (−5 cm to 0) mid-pelvis station (0 to +3) and low or outlet (lower then +3). During labor, cervical dilatation is assessed by inserting two fingers, through the vagina into the cervix and spreading them until they touch the opposite sides of the cervical os. Cervical dilatation ranges from 0 cm prior to labor to 10 cm at full dilatation. Clinicians translate their assessment of both CD and HS into a numerical value. These estimated values are used for the assessment of labor progress, and are often presented graphically by a partogram that plots CD and HS against time as introduced by Friedman [1]. Recent comparative studies with ultrasound cast serious doubt on the accuracy of the digital examination [2,3]. Uterine contractions result in increase in both CD and HS, with maximal affect during the peak of contraction. However, since continuous monitoring of CD and HS within the individual contraction has been introduced only recently, the exact effect of uterine contractions on CD and HS is still poorly understood.

The physiology of individual contractions has been extensively studied at both the cellular and molecular level, as well as the

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hormonal regulation of the process [4]. More specifically, the relation between the profile of the uterine pressure and the force produced by the uterine activity was investigated [5]. It was shown that the progress in labor is correlated to the development of high pressure between the fetal head and the cervix [6]. By measuring the head-to-cervix pressure in response to the intrauterine pressure generated by contractions, investigators gained some knowledge about the mechanism by which the uterine effort is transmitted to the cervix, resulting in cervical dilatation.

Devices intended to measure cervical dilatation and head station were developed based on a variety of physical principles in an effort to monitor labor progress and investigate the physiology of the uterine contractions [7,8,9,10]. These attempts did not result in an accepted clinical device. Recently, an ultrasonic labor monitor was developed [11]. The new device enables continuous monitoring of cervical dilatation and fetal head station during the active stage in labor.

In this study we investigated the simultaneous waveforms of CD and HS during contractions and analyzed the effects of the single contraction on the instantaneous values of CD and HS, along the active stage of labor. One objective was to quantify the incremental effect of each contraction on the resting value of CD and HS. The other objective was to characterize the mutual dynamics of cervical dilatation and head station in mathematical terms of amplitudes and angles of a contraction vector.

2. Materials and methods

Cervical dilatation and fetal head station were continuously measured in women during labor using a continuous labor monitor (BirthTrack Inc., Andover, MA, USA). The device is based on an ultrasonic technique where pulses are transmitted by three external abdominal transducers that form a triangle. These acoustic pulses are received by three sensors, two located on opposite sides of the cervix and one incorporated into the fetal ECG scalp electrode. The time between transmission and reception of the acoustic pulses is measured and converted to distance. A triangulation algorithm uses these data to compute fetal head station and cervical dilatation. Head station baseline is set by the physician at the beginning of the session. A detailed description of the system was previously published [11]. The system was FDA cleared and received the European CE mark.

The study was performed at the Lis Maternity Hospital in the Tel-Aviv Sourasky Medical Center (Tel-Aviv, Israel), Sheba Medical Center (Tel Hashomer, Israel), Winthrop-University Hospital (New York, USA) and Hutzel Women's Hospital (Detroit, USA). The study was approved by the Institutional Review Board. All participating women signed an informed consent to participate in the study. Data from 61 women who agreed to take part in this study are presented. Subjects' ages were between 17 and 35 years (mean 27.0, SD 5.0). Thirty two of the women were nullipara and four had a previous caesarean section. All had uncomplicated singleton pregnancies with vertex presentation. Women with significant medical history were excluded. All women were in the active stage of labor (defined as cervical dilatation of more then 3 cm and presence of regular uterine contractions). Measurements included continuous and simultaneous waveforms for fetal head station and cervical dilatation as well as intermittent manual examination performed by the attending physician (as illustrated in Fig. 2, *top panel*).

The accuracy of the system was assessed by an analysis of agreement between the device and traditional manual measurements, as introduced by Bland and Altman [6]. For each pair of automatic and manual measurements, mean value of the two techniques and the measurement difference were calculated and analyzed.

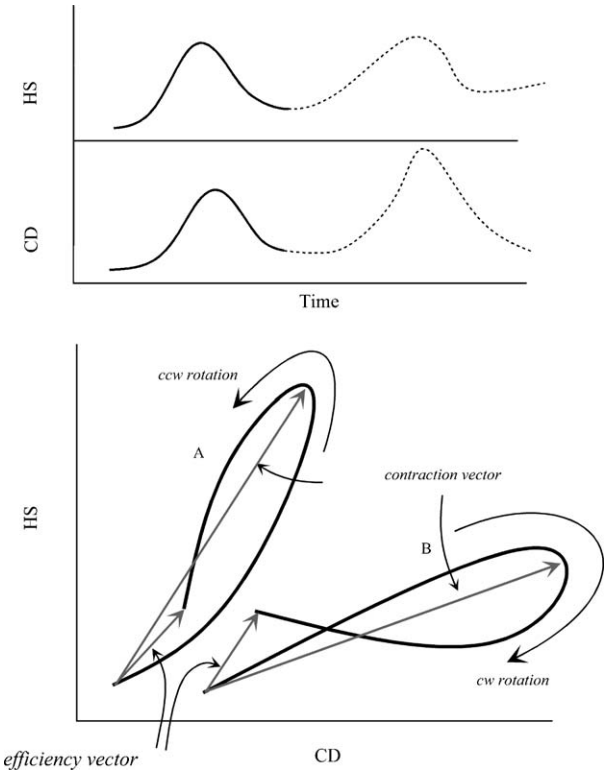

Fig. 1. *Top panel*: waveforms of cervical dilatation and head station. *Bottom panel*: contraction loops plotted on the CD-HS plane. The contraction in the left hand side illustrated a state where the increase in CD preceded the descent of the head, whereas the contraction on the right hand side illustrates the opposite dynamic. Contraction vectors and efficiency vectors are plotted in both contractions.

The relationship between CD and HS was studied in the CD-HS plane (i.e. by plotting the HS waveform during a contraction against the CD waveform during the same contraction). In each of these two signals, the change during each individual contraction (HS and CD waves) was identified and delineated. 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 Fig. 1, *bottom panel*). This resulted in a single plot for each contraction that showed how the instantaneous value of station was 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. 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 Fig. 1. The loops may be formed in a counter clockwise trajectory, indicating that CD started to increase before the descent of the fetal head; or in a clockwise trajectory, indicating that the descent of the head preceded the dilatation of the cervix.

Two vectors were defined to quantify the effects of the uterine contraction on the value of CD and HS. The *contraction vector* was defined as the vector that originated from the beginning of contraction and ended in its peak (see Fig. 1). The angle of this vector indicates the relationship between the maximal effect of the contraction of CD and HS. The *efficiency vector* was defined as the vector that originated from the beginning of the contraction and ended in the end of the contraction, indicating the progress in CD and HS due to the contraction. The angle of the efficiency vector indicated on the relative incremental effect of CD and HS. The