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A Novel Algorithm for the Real-time Analysis of Uterine Contraction Status ⋆

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Abstract

Against the problems of existing uterine contraction identification algorithms, mainly in the inapplicability to real-time identification of the characteristic points of uterine contraction wave, a novel method based on a series of criteria for real-time analysis is proposed in this paper. After confirming the beginning, end and peak of the analyzed segment, a series of criterion are used to identify the status of current uterine contraction point. Meanwhile, the status of current uterine contraction point is corrected by a buffer mechanism to ensure accuracy. The experiments show that the conformity between the real-time analysis results and two experts' analysis results are high, and the kappa coefficients are as high as 0.874 and 0.872. Moreover, the time required for the analysis of a uterine contraction point is only 0.0032 ± 0.0002 (mean $\pm$ SD) seconds, which is far less than the acquisition and output time of a uterine contraction point by pressure probe. Therefore, the proposed method can meet the requirements of real-time analysis in both accuracy and efficiency.

Keywords: Uterine Contraction Status; Real-time Analysis; Characteristic Point

1 Introduction

Uterine Contraction (UC) is an important characteristic of labor. Medical staffs can evaluate the progress of active labor according to the contraction activity. The uterus is expected to contract regularly, and usually accompanies pain during labor. Clinically, the most commonly used method for uterus activity monitoring is tocography (TOCO), namely the pressure exerted on the maternal abdomen by the uterus is measured via a pressure probe positioned over the maternal fundus [1–3]. As shown in Fig. 1, the UC tracing, which is obtained by the TOCO probe, is mainly divided into the period of contraction and period of relaxation. In addition, the period of contraction can be subdivided into three stage: the increment, acme and decrement. The normal UC has obvious biological rhythmicity, which varies from weak to strong, and the situation will continue for some time, then from strong to weak. For a contraction, there are

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three characteristic points: the beginning, the peak and the end of contraction. The UC can also be described from the intensity (increased uterine pressure above baseline tone), the duration and the period [4–7]. With the progress of labor, the intensity of UC gets stronger gradually, meanwhile the duration of UC increases and the period of relaxation gradually gets shorter.

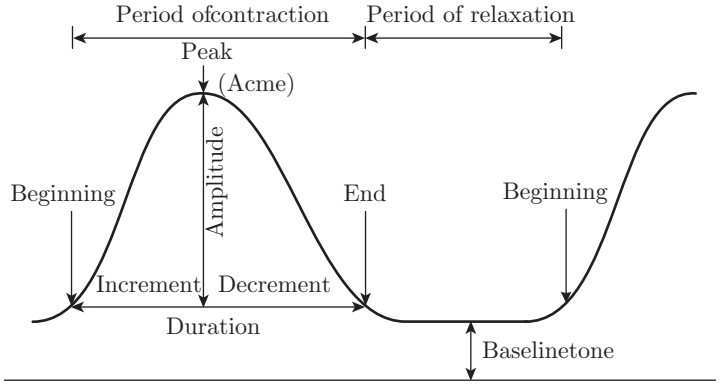

Fig. 1: The UC tracing

The contractions of the uterus is an important factor of labor pain [8]. The estimation of the extent of labor pain was generally based on the intensity of contractions in traditional obstetric analgesia methods [9]. However, the level of pain varies considerably from woman to woman even with the same contraction intensity due to individual differences. For these problems, Deng et al. [10] developed a bio-feedback analgesia therapy system that uses uterine pressure and maternal hand pressure to modify the waveforms of stimulation signals. The system has obtained a good performance. However, it was also found that the degree of labor pain is more relevant to UC status than the uterine pressure in clinical observation.

For now, the studies as to UC focus mainly on the recognition of UC wave. Existing algorithms generally adopted the method of experience threshold, namely by judging whether the difference between the contractions signal and the baseline tone satisfied the threshold conditions. Horoba et al. [11] calculated the frequency distribution of UC values in a moving average window to obtain the baseline tone value. And then the identification of UC is based on the threshold method after subtracting the baseline tone value. Georgieva et al. [12] improved the Cazares's algorithm [13] and put forward a method with novel meta-heuristic mechanisms for UC identification. Liang et al. [14] used Finite Automaton (FA) principle to extract the characteristic points of UC tracing, and thus identify the UC wave. Yang et al. [15] identified contractions waveform based on the curve of wavelet energy value and contractions pressure indicators. Wei [16] proposed a UC identification algorithm based on four indicators: UC amplitude, duration, baseline variation and morphology. This kind of method has simple principle and high computational efficiency. However, all of them just make holistic judgments for the UC tracing, and only identify the UC waves, namely the UC tracing is simply divided into two parts: the period of contraction and period of relaxation. Van De Laar et al. [17] also studied the real-time identification of contractions status, and proposed an automatic analysis algorithm for contraction activities. But it could only determine the parameter of contraction signals over a time period. Therefore, the research on extraction and real-time analysis of uterine activity characteristic parameters contributes greatly to the realization of the automatic delivery analgesia in labor and has high practical value.

In conclusion, the existing UC analysis methods have failed to solve the problem of real-time