Fetal Head Position Measurement Based on Freehand Three-Dimensional Ultrasound

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Abstract

Fetal head position is an important parameter in the labor process, and abnormal fetal head position is a major cause of dystocia. A clear understanding of the fetal head position during labor is important for reducing maternal complications and unnecessary cesarean section. In this paper, a new method of fetal head position measurement based on freehand three-dimensional ultrasound was proposed. The Bland-Altman consistency analysis showed that the fetal head position measurement based on our method is highly consistent with the gold standard, and all points falled within the consistency range, indicating that the fetal head position based on our method has high accuracy. The qualitative experimental results of the brain-midline mode showed that our method effectively measured the fetal head position parameter and met various measurement modes.

Keywords

Freehand three-dimensional ultrasound, Fetal head position,Labor monitoring.

1. Introduction

During labor, ultrasound imaging is used to observe fetal delivery status and assess dynamic parameters such as fetal position, allowing the obstetrician to detect abnormal birth conditions and make correct interventions and decisions. For the measurement of the fetal head position in the labor process, the measurement methods of translabial ultrasound and transabdominal ultrasound are mainly used.

The work of the researchers [1] showed that ultrasound examination is a scientific and objective method for measuring the parameter of fetal head position. Researcher [2,3,4] compared measurement of fetal head positon during the first stage of labor and the second stage of labor by traditional vaginal examination to abdominal ultrasound. Wiafe et al [3] found that ultrasonography had higher success rate than digital vaginal examination. Shetty et al [4] found that only 31.5% of the vaginal finger test results in the first stage of labor were consistent with the results of transabdominal ultrasound measurements. The results of vaginal examination were consistent with those measured by transabdominal ultrasound. All the studies above have proved that the vaginal finger test is highly inaccuracy, and the abdominal ultrasound examination greatly improve the quality of labor monitoring.

With the significant importance of maternal and fetal measurement of delivery parameters in the labor process, however the traditional vaginal finger examination used in obstetrics is highly inaccuracy[5]. Frequent vaginal finger examination increases the maternal discomfort and even increases the possibility of infection. Traditional ultrasound examination of the delivery parameters requires examiner to mark the fetal head features on the ultrasound images and construct the spatial positional relationship between the fetus and the pelvis in the mind, highly dependents on the clinical experience of the examiners, which is subjective. With the aim to solve the problems above, the purpose of this thesis is to propose a method of automatic measurement of the fetal head position by combining

electromagnetic positioning technology and ultrasound imaging technology, namely freehand three-dimensional ultrasound technology.

2. Freehand three-dimensional Ultrasound

2.1 System review

This research was based on electromagnetic positioning freehand three-dimensional ultrasound system. The freehand three-dimensional ultrasound system of this subject consisted of six main parts: an electromagnetic positioning unit, an ultrasound system device, a PC host, an electromagnetic transmitter and an integrated ultrasound probe which fixed with an electromagnetic positioning sensor.

2.2 Coordinate transformation

We recorded the coordinate system of the electromagnetic transmitter as *W* (hereinafter referred to as the world coordinate system), the coordinate system of the sensor attached to the probe was denoted by *P*, and the ultrasound image coordinate system was denoted by *I*. For arbitrary point in the image where the pixel coordinates is *I(u, v)*, its coordinates *W(x, y, z)* in the world coordinate system can be solved by the following formula:

$$\begin{pmatrix} x \\ y \\ z \\ 1 \end{pmatrix} = TRAN_{s \to w} TRAN_{i \to s} \begin{pmatrix} r_u u \\ r_v v \\ 0 \\ 1 \end{pmatrix} \tag{1}$$

where r_u and r_v are the actual size of each single pixel of the lateral and vertical resolutions of the two-dimensional ultrasound image, respectively. According to the six degrees of freedom data *(x, y, z, a, e, r)* obtained by the electromagnetic positioning sensor, $TRAN_{s \to w}$ can be solved by:

$$TRAN_{s \to w} = \begin{pmatrix} \cos(e)\cos(a) & \cos(e)\sin(a) & -\sin(e) & x \\ -\cos(r)\sin(a) & \cos(R)\cos(a) & \sin(r)\cos(e) & y \\ +\sin(r)\sin(e)\cos(a) & +\sin(r)\sin(e)\sin(a) & & \\ \sin(r)\sin(a) & -\sin(r)\cos(a) & \cos(r)\cos(e) & z \\ +\cos(r)\sin(e)\cos(a) & +\cos(R)\sin(e)\sin(a) & & \\ 0 & 0 & 0 & 1 \end{pmatrix} \tag{2}$$

after performing a process called probe space calibration[6], $TRAN_{i \to s}$ results as:

$$TRAN_{i \to s} = \begin{pmatrix} -0.0456 & 0.9935 & 0.1042 & 64.1313 \\ -0.9985 & -0.0485 & 0.0253 & 134.1750 \\ -0.1029 & 0.0302 & 0.9942 & 12.2573 \\ 0 & 0 & 0 & 1 \end{pmatrix} \tag{3}$$

3. Fetal Head Position Measurement

3.1 Pelvic positioning

The spatial position of the pelvis is measured by an abdominal ultrasound probe which fixed with an electromagnetic positioning sensor. When the ultrasound image shows the pelvic features, the ultrasound plane positioned at that time is reconstructed. The specific steps are as follows:

Ⅰ. Scan the pelvis using a freehand three-dimensional ultrasound probe. When the pelvic feature points are clearly displayed in the ultrasound image, the ultrasound image and the electromagnetic positioning system are frozen.

Ⅱ. Mark the coordinates of the feature points in the ultrasound image, and record the information of the six degrees of freedom data of the sensor.

Ⅲ. Record the image coordinates data of the four corner points of the ultrasound image and a center point as a set of auxiliary points.

Ⅳ. Calculate the transformation matrix from the sensor coordinate system to the world coordinate system according to the formulas (2).

Ⅴ. Calculate the coordinates of the image point set in the world coordinate system according to the formula (1).

Ⅵ. Reconstruct the pelvic plane by the point set achieved above.

3.2 Fetal head positioning

The specific fetal head positioning process is: scan the fetal head at different angles and positions using the freehand three-dimensional ultrasound probe, when the ultrasound image clearly shows the fetal anatomical features such as the brain-midline, froze the ultrasound image and electromagnetic positioning data. Recording the two marked points which are the end points of the brain-midline. At the same time, as described in chapter 3, the coordinates of the marked points in the world coordinate system in the image are calculated using the coordinate transformation matrix. The directed line segment between the marked points is recorded as the fetal head vector.

4. Results and Analysis

In this paper, the fetal head position was measured by the brain-midline mode. The brain-midline and pubic symphysis feature points were marked by transabdominal and translabial ultrasound scans, as shown in Fig. 1. We used Bland-Altman [7] to evaluate the consistency between the proposed fetal head position measurement method and the gold standard. If 95% of the points in the graph fall within the consistency range, which is within the range $\bar{d}+1.96S_d$, then the two measurements are considered to be consistent. The consistency of the fetal head position measurement results with the gold standard is shown in Fig. 2, all points were within the consistency range, which indicated that our method and gold standard were highly consistent

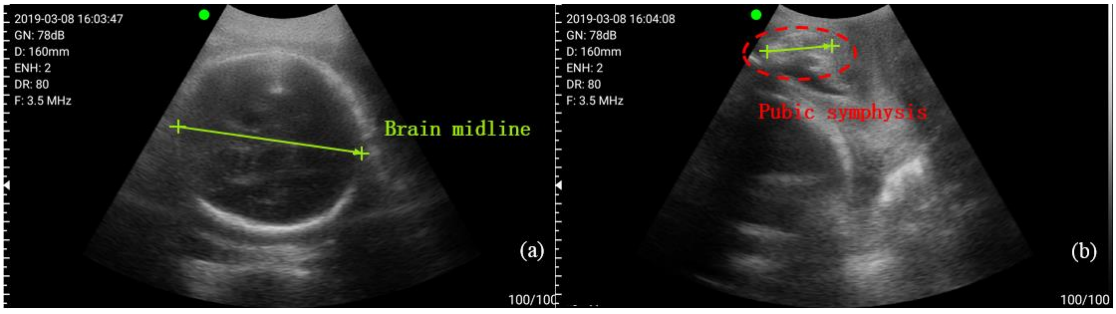

Fig.1 fetal head position measurement by brain-midline mode

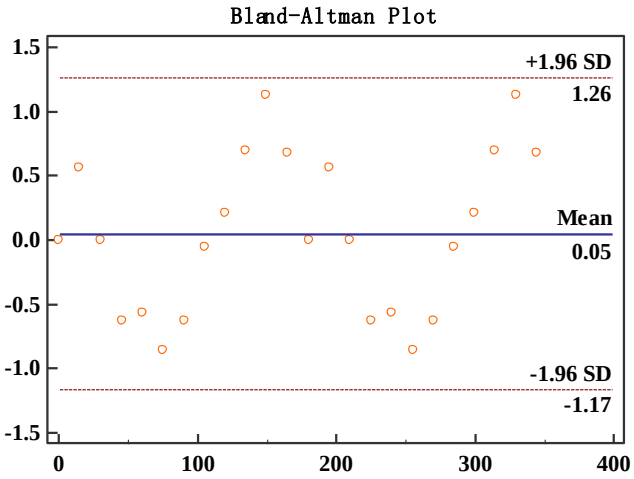

Fig.2 Bland-Altman consistency analysis

5. Conclution

The Bland-Altman consistency analysis shows that the measurement method of the fetal head position based on the freehand three-dimensional ultrasound we proposed is highly consistent with the gold standard, and all the points fall within the consistency range, indicating that our measurement method of the fetal head position is highly accuracy. This measurement method provide an objective quantitative measurement of the fetal head position, which overcomed the deficiencies of vaginal fingering and traditional two-dimensional ultrasound evaluation, and is the development direction of fetal head position measurement in the future.

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