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Research article

Three-dimensional magnetic resonance pelvimetry: A new technique for evaluating the female pelvis in pregnancy

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ABSTRACT

Objective: To describe three-dimensional (3D) magnetic resonance imaging (MRI) pelvimetry methods and to establish the pelvimetric reference in a large population of Chinese females at term pregnancy.

Methods: Three-hundred one pregnant women at term who underwent MRI were included. Three-dimensional pelvic models were reconstructed using Mimics. 10.0 software based on MRI data sets, and measurements of these models were made. Pelvimetric results according to delivery modality were presented. Additionally, the previously described CT 3D pelvimetry method for predicting cephalopelvic disproportion (CPD) was used to validate its accuracy.

Results: Two hundred ten women underwent vaginal delivery, and 13 underwent caesarean delivery for CPD. 3D modelling of the pelvis of pregnant women was feasible using MR data sets. Pelvimetric parameters in the vaginal delivery group were as follows: transverse diameter, 134.7 mm ± 7.5; obstetric conjugate, 126.9 mm ± 8.3; interspinous distance, 113.4 mm ± 8.2; sagittal midpelvis, 117.8 mm ± 8.1; intertuberous distance, 127.1 mm ± 10.4; sagittal outlet, 110.2 mm ± 8.9, and posterior sagittal outlet, 59.7 mm ± 8.1. According to the previously described CT 3D pelvimetry method for predicting CPD, 67.6% (142/210) of women in the vaginal delivery group were diagnosed with CPD.

Conclusion: 3D MR pelvimetry is a novel method for determining pelvic dimensions at term pregnancy. A prospective trial is needed to establish a useful value for predicting CPD in Chinese females at high risk of CPD.

1. Introduction

Pelvic dimensions are crucial variables in the labour process, and pelvimetry has been used to detect women at risk of dystocia due to a contracted pelvis or cephalopelvic disproportion (CPD) for more than two hundred years [1–3]. Various pelvimetry imaging modalities, including X-ray, computed tomography (CT) and magnetic resonance imaging (MRI), have been suggested to provide more accurate measurements than digital examination [4–6]. However, neither X-ray nor CT pelvimetry is considered an ideal imaging method for pregnant women, as both expose the foetus to ionizing radiation and increase the risk of childhood cancer [7,8]. MRI may be a promising imaging modality, with pelvimetric errors of approximately 1% [6]. Moreover, unique advantages of MRI reported from clinical examinations to date include its ability to produce high-quality images of both bone and tissue with no radiation exposure or foetal harm [9,10].

Cross-sectional MRI has been described to accurately measure most pelvic parameters, except for intertuberous distance and sagittal outlet, as it is difficult to exactly determine bony landmarks for measurements [11]. The introduction of CT pelvimetry based on 3D models promises improvements over previous pelvimetric modalities, and an earlier feasibility study of 3D CT pelvimetry showed good accuracy and better precision than 2D CT [5]. Compared to cross-sectional pelvic images, 3D models can provide improved anatomical views for accurately choosing the measurement point. However, to date, few studies have focused on pelvic modelling during pregnancy. Attempting to predict CPD using a synthesized 3D pelvis based on several parameters of pregnant women yielded promising results, but the predictive accuracy was limited by the measurement values [12].

Lenhard reported the first and only CPD prediction analysis using 3D CT pelvimetric results of postpartum women, although no prospective data were available to validate the predictive accuracy of the analysis [3]. Additionally, several studies have demonstrated racial differences in the pelvis [13,14]; however, to our knowledge, few

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studies have focused on Chinese female pelvis of childbearing age [15,16]. Therefore, it is uncertain whether these criteria are suitable for the Chinese population. The purpose of this study was to validate pelvimetry based on 3D models from 2D MRI of women's pelvises at term pregnancy and to establish an MR pelvimetric reference in a Chinese population.

2. Materials and methods

This study was approved by the medical ethics committee of Southern Medical University. All subjects provided written consent. This was a single-institution prospective cross-sectional study conducted at the Department of Radiology and Obstetrics and Gynecology of Nanfang Hospital, Southern Medical University, Guangzhou, Guangdong, China.

This report is a secondary analysis of a prospective cohort study of The Establishment of Digital Three-dimensional Pelvic and Fetus Models and Its Significance in the Cephalic Delivery (Registration number ChiCTR-DDD-16009075). All consecutive pregnant women were recruited in the clinic by trained researchers between Jan 2014 and Dec 2016 to participate in the study. Women were eligible if they had a viable singleton intrauterine pregnancy at ≥37 weeks gestation, vertex presentation and planned to attempt vaginal delivery without indications for caesarean section and if they had a short size, suspected macrosomia evaluated by ultrasound, adnexal cysts, suspected cephalopelvic disproportion (CPD), no complicated prenatal record for the foetus, and no contraindications on MRI examination. Women were excluded if they had multiple gestations, breech presentation, planned caesarean delivery, or other maternal contraindications to vaginal delivery. A more detailed abstraction of the prenatal records of women who agreed to participate was collected in the clinic.

Labour dystocia for CPD was diagnosed in women who experienced cervix arrest over 2 h with normal uterine contractions since cervix dilated to at least 4 cm, and who had protracted descent.at least 2 h after the cervix dialated to 10 cm. All these women underwent caesarean delivery. The practitioners managing labour were blinded to the MRI results.

2.1. Available MR data

MR imaging was performed with 1 fast spin echo T_2-weighted scan (FSE) and 1 fast imaging employing steady-state acquisition (FIESTA). A 1.5 and 3.0 T GE Signa magnet (Signa EXCITE HD System, GE Company, American), a torso coil, and an abdominal coil were used. For the 1.5 T system, the FSE was an axial 3-mm acquisition without gap, field of view (FOV) 260 mm, TR10040 ms, TE48 ms, matrix 192 × 288, number of excitations (NEX) 3; FIESTA was a sagittal 4-mm acquisition without gap, FOV 400 mm, TR4.0 ms, TE1.7 ms, matrix 192 × 256, NEX 1. For the 3.0 T system, the FSE was an axial 3-mm acquisition without gap, FOV 340 mm, TR3000 ms, TE102 ms, matrix 512 × 512, NEX 4; FIESTA was a sagittal 4-mm acquisition without gap, FOV 40 mm, TR4.2 ms, TE1.4 ms, matrix 224 × 224, NEX 1,

The FIESTA sequence incorporated the entire gravid uterus and pelvis, an average of 40–50 images were acquired. The FSE sequence averaged 70–80 images, which incorporated the maternal pelvis. Total examination time was 10 min or less without requiring patients to hold their breath or sedation.

2.2. Three-dimensional reconstruction

To create 3D pelvic models, MRI datasets were imported into Mimics 10.01 (Materialise's Interactive Medical Image Control System, Version 10.01, Materialise Company, Belgium). MR-based pelvic reconstruction should be first done by manual segmentation. The outline of the pelvis should be drawn layer by layer to generate a new pelvic mask (Fig. 1). Bone cortex is characterized by low signal and is distinguishable from the surrounding soft tissue. To make up for the lack of the cortex, we used the dilate function to increase the outline drawn by one pixel. After reconstruction, the cutting plane function was used to divide the pelvis into two halves. 3D models were exported to Standard Template Library (STL) format for 3D pelvimetry. All 3D reconstructions were completed by two junior doctors who had been trained to make the measurements and were supervised by a radiologist.

2.3. 3D pelvimetry

Measurements were performed retrospectively in a virtual reality environment using engineering software UG NX 6.0 (Siemens PLM Software, Germany). To prevent interobserver variability, the standardized pelvic diameters were measured by the same observer on the respective sections, as described by Lenhard. The posterior sagittal diameter of the pelvis was from the middle of the transverse diameter to the same point of the sagittal diameter on the sacrum of the respective plane (Fig. 2).

Measurement results were not available to the clinicians managing labour, and investigators were not informed of the delivery outcomes.

To compare pelvic dimensions in the dystocia group and the vaginal delivery group, 26 women who underwent vaginal delivery, controlled for birthweight in dystocia, served as the controls.

2.4. Statistical analysis

Continuous variables are given as the mean ± standard deviation. Differences between pelvimetric dimensions were tested for significance using the Student's *t*-test and the Mann-Whitney *U* test.

CPD is present if the sagittal midpelvic diameter is equal to or less than 121 mm. The predictive outcome was compared with regard to delivery outcome.

Statistical tests were conducted using SPSS 20.0 software. P values < 0.05 were considered significant.

3. Results

A total of 301 pregnant women gave their consent to participate in this study. No participant complained of major discomfort. One woman delivered at another hospital, and delivery information was not available. Of the remaining 300 patients, 210 women underwent vaginal delivery, and 90 women underwent caesarean delivery. Of the vaginal deliveries, there were 5 vacuum extractions for foetal stress, no forceps deliveries and no use of anaesthetics. Of the caesarean deliveries, 77 did not have an adequate labour trial for maternal request, oligohydramnios and foetal distress, etc., and these women were excluded; the remaining 13 deliveries were dystocia. Thus, the results of 210 vaginal deliveries and 13 cases of labour dystocia are reported here.

Table 1 shows the maternal and neonatal demographic characteristics for the three groups.

All women were primipara. There were no significant demographic differences between the dystocia and the control groups.

3.1. The three-dimensional reconstruction of the pelvis

It is feasible to reconstruct a pregnant woman's pelvis based on MR data sets acquired with the T2-weighted single-shot fast SE sequence (Fig. 2). The bony pelvis was clearly identified, although there were artefacts caused by foetal movement (Fig. 1). All conventional parameters can be measured using the models, particularly the posterior sagittal diameter of the pelvis, which cannot be derived from 2D images. However, segmentation of the pelvis had to be performed manually and took up to 25 min for each case.

Table 2 shows the results of the total vaginal delivery women's pelvic measurements and a comparison of selected pelvic