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ORIGINAL ARTICLE /*Research and new developments*

Can three-dimensional pelvimetry using low-dose stereoradiography replace low-dose CT pelvimetry?

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Abstract
Purpose: To evaluate the reliability of pelvimetric measurements performed using stereoradiographic imaging (SRI), and to assess maternal and fetal radiation doses compared to low-dose computer tomography (CT) pelvimetry.
Materials and methods: Thirty-five pregnant women (mean age, 29.6 ± 5.5 [SD] years; range: 20—41 years) were prospectively included. All women underwent simultaneous frontal and lateral low-dose SRI and low-dose CT examination of the pelvis. Pelvimetry measurements were obtained from both examinations and radiation doses obtained with the two techniques were compared.
Results: SRI-CT correlation (Pearson coefficient correlation [*r*]; mean bias [mb]) was strong for transverse inlet diameter ($r = 0.92$; mb = −0.09 cm), anteroposterior diameter of the pelvic inlet ($r = 0.92$; mb = 0.47 cm), maximal transverse diameter ($r = 0.9$; mb = 0.21 cm), sacrum length ($r = 0.9$; mb = 0.09 cm). Correlation was good. Correlation was good for the sacrum depth ($r = 0.75$; mb = 0.06 cm) and Magnin's index ($r = 0.7$; mb = 0.5 cm). Correlation was moderate for anteroposterior diameter of pelvic outlet ($r = 0.6$; mb = 0.52 cm). The fetal dose was 13.1 times lower using SRI (87 ± 26 μGy) than CT (1140 ± 220 μGy, $P < 0.0001$). The effective maternal dose was 3.1 times lower using SRI (97 ± 21 μSv) than CT (310 ± 60 μSv; $P < 0.0001$).

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Conclusion: Pelvic inlet measurements using SRI are reliable. Compared to CT pelvimetry, SRI leads to a significant decrease in fetal and maternal radiation doses. These findings should prompt physicians to use SRI as the first-line approach for pelvimetry.

Estimation of the various diameters in the pelvis before birth is important to evaluate obstetrical prognosis, and this evaluation is primarily performed by clinical examinations during the pregnancy. In certain cases, manual pelvimetry is not enough accurate for the measurement of obstetrical diameters, particularly the pelvic inlet. For these reason, radiographic pelvimetry has been widely developed and has made it possible to better prevent and manage risks related to delivery, thus impacting on obstetrical prognosis [1]. Several imaging modalities are used, including conventional x-ray pelvimetry, pelvic computed tomography (CT), and magnetic resonance imaging (MRI) of the pelvis [2,3]. Initially conventional x-ray pelvimetry was the method of choice to allow indirect measurements and appreciate the overall shape of the pelvis. However, CT of the pelvis is now the standard of reference [4]. Indeed, CT yields a better estimate of obstetrical diameters of the pelvic inlet, and reduces the radiation dose to the mother and fetus [5]. Magnetic resonance imaging (MRI) is a non-irradiating imaging technique that also yields reliable pelvic measurements [6,7], and although it seems to be a good alternative, the use of MRI remains limited by availability issues.

Low-dose stereoradiographic imaging (SRI) (EOS®, EOS Imaging SA, Paris, France) allows simultaneous acquisition of high-quality frontal and lateral radiographic images, while limiting the radiation dose absorbed by the patient. Radiographic images can be acquired in the standing position, in a single scan, without the need for image reconstruction, without vertical distortion and on a 1:1 scale. This system is currently used in the evaluation of spine curvature disorders [8—11], and the upper [12] and lower limbs [13,14], particularly in children. Recently, Sigmann et al. [15] showed that there was a good correlation between manual measurements, CT and SRI for the internal diameters of the bony pelvis. Inter-observer agreement was excellent for all diameters measured by CT and SRI, suggesting excellent degrees of reliability for SRI [15]. However, the work by Sigmann et al. was performed on bony pelvises, and without correction for three-dimensional (3D) distortion in the measurements [15].

The main objective of this study was to demonstrate in a prospective study in vivo in pregnant women, the reliability of SRI for the measurement of internal obstetric diameters of the pelvis, as compared to pelvic CT. Secondary objectives were to compare maternal and fetal radiation doses with both SRI and CT, and to evaluate the impact of pelvic parameters and maternal weight on the reliability of SRI measures.

Materials and methods

This study was approved by the local ethics committee and by the French Health Products Safety Agency. It was registered with ClinicalTrials.gov under the number NCT02834897. All patients provided written informed consent. All authors had access to the study data.

Study population

Subjects were included prospectively over a period of 12 months from June 2015 to June 2016. Inclusion criteria were: age $\geq$ 18 years, in the 8th month of pregnancy, with a clinical indication for pelvic CT (breech presentation, clinically asymmetrical or small pelvis, fetal macrosomia, a history of dystocia, pelvic trauma or caesarean section indicated due to pelvic anomalies). All patients had to be affiliated to a social security system or be a beneficiary thereof. Patients who were legally incapacitated or with limited legal capacity, unlikely to adhere to the study procedures or those within the exclusion period after another study were excluded.

Measures

The following data were recorded: the participant's weight, height and body mass index (BMI), the number of weeks of amenorrhea at the time the examinations were performed, and subsequently, the weight and height of the baby at birth.

Participants successively underwent on the same day a pelvic CT and pelvimetric SRI. The diameters measured were anteroposterior diameter of the pelvic inlet (APDPI); transverse inlet diameter (TID), maximal transverse diameter (MTD), transverse outlet diameter (TOD), bispinous diameter (BSD), anteroposterior diameter of the pelvic outlet (APDPO), sacrum depth (SD) and length (SL) (Fig. 1). Magnin's index was also calculated by summing APDPI and TID.

Pelvic CT examinations were performed while the patient was lying down. A frontal topogram was obtained, followed by helical acquisition from the anterosuperior iliac spine to the crotch. Following CT manufacturer recommendations, images were acquired at a thickness of 1.5 mm with the constants held at 100 kV and 20—25 mA, and pitch 0.8 (Somatom Sensation®, Siemens Healthineers, Erlangen, Germany). The different obstetrical diameters of the pelvis were measured in a blinded fashion on a dedicated com-

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