Placenta 43 (2016) 35–40

Contents lists available at ScienceDirect

Placenta

journal homepage: www.elsevier.com/locate/placenta

Uterine artery pulsatility and resistivity indices in pregnancy: Comparison of MRI and Doppler US

R.A. Hawkes [a,*], A.J. Patterson [a], A.N. Priest [a], G. Harrison [b], S. Hunter [a], J. Pinney [a], P. Set [a], N. Hilliard [a], M.J. Graves [a], G.C.S. Smith [c], D.J. Lomas [a]

[a] Department of Radiology, Cambridge University Hospitals NHS Foundation Trust, United Kingdom
[b] City University London, United Kingdom
[c] Department of Obstetrics and Gynaecology, University of Cambridge, NIHR Cambridge Comprehensive Biomedical Research Centre, Cambridge, United Kingdom

ARTICLE INFO

Article history:
Received 10 January 2016
Received in revised form
20 March 2016
Accepted 4 April 2016

Keywords:
Phase contrast
Magnetic resonance imaging
Uterine artery Doppler
Fetal growth restriction
Pre-eclampsia
Pulsatility index
Resistivity index

ABSTRACT

Objective: The aim of this work was to evaluate whether the uterine arteries (UtA) could be identified and their flow profiles measured during a fetal MRI examination. A comparison was performed against same day sonographic Doppler assessment.

Methods: 35 normal, healthy, singleton pregnancies at 28–32 weeks gestation underwent routine Doppler examination, followed by MRI examination. The resistivity index (RI) and pulsatility index (PI) of the left and right UtA were measured using phase contrast MRI. Bland Altman statistics were used to compare MRI and ultrasound results.

Results: Sixty-nine comparable vessels were analysed. Six vessels were excluded due to artefact or technical error. Bland-Altman analysis demonstrated the ultrasound indices were comparable, although systematically lower than the MRI indices; Right UtA RI bias −0.03 (95% limits of agreement (LOA) −0.27 to +0.20), and left UtA RI bias −0.06 (95% LOA −0.26 to +0.14); Right UtA PI bias −0.06 (95% LOA −0.50 to +0.38), Left UtA PI bias −0.11 (95% LOA −0.54 to +0.32). The inter-rater agreement for the MRI derived PI and RI analysis was good.

Conclusion: This study demonstrates that in the majority of early third trimester pregnancies, the uterine arteries can be identified, and their flow profiles measured using MRI, and that the derived PI and RI values are comparable with Doppler ultrasound values.

1. Introduction

Prior to pregnancy, the uterine circulation is high resistance. As the placenta develops in the first and second trimesters, extravillous trophoblast invades the walls of the resistance vessels in the myometrial layer of the uterus, and the vascular resistance of the uterine circulation declines [1]. This physiological process is mirrored by an increasingly low resistance pattern of flow in the uterine arteries [2]. Failure of trophoblast invasion of the uterine resistance vessels is implicated in a number of the major complications of pregnancy such as pre-eclampsia and fetal growth restriction [3]. Consistent with this, the presence of a high resistance pattern of UtA Doppler flow in mid-gestation is associated with an increased risk of these complications [4]. UtA Doppler flow velocimetry has been shown to provide useful prediction of the risk of pre-eclampsia and stillbirth [5]. However, its use is generally confined to women who are high risk. Currently, the primary method for assessing the vascular resistance of the uterine circulation is ultrasonic Doppler flow velocimetry of the uterine arteries [6]. Commonly measured indices include the pulsatility index (PI) and the resistivity index (RI) [7,8]. PI describes the variability of blood velocity across the cardiac cycle; peak systolic velocity (S), minus minimum diastolic velocity (D), divided by the time averaged mean (M) ((S-D)/M), while RI is calculated from (S-D)/S [9,10].

MRI (magnetic resonance imaging) is becoming more widely used in fetal imaging, and in placental studies [11,12], It is particularly valuable when ultrasound is technically problematic due to maternal body habitus, fetal position or advanced gestational age [13–15]. Previous studies of placental MRI have reported that high

* Corresponding author. Department of Radiology, Addenbrooke's Hospital, Cambridge, CB2 0QQ, United Kingdom.
E-mail address: rebecca.hawkes@addenbrookes.nhs.uk (R.A. Hawkes).

http://dx.doi.org/10.1016/j.placenta.2016.04.002
0143-4004/

UtA Doppler PI is associated with a smaller placental volume [16], however, there is little literature on whether PI and RI are reproducible using MRI, and whether MRI could provide more detailed information on placental function [17].

An initial small-scale study reported difficulty in UtA localisation, where MRI blood flow measurements were not successfully obtained [18]. Phase-contrast methods have been developed for measuring arterial blood flow [19,20] and Issa et al. were the first to describe successful UtA blood flow measurements using phase-contrast MRI [21]. To our knowledge, there are no MRI studies estimating UtA PI and RI during pregnancy, however, studies in sheep have proved that phase-contrast methods demonstrate high inter-operator agreement and good reproducibility when calculating flow velocities and when compared with Doppler ultrasound [22].

The aim of this work is to establish if phase contrast MRI can identify the UtA, measure the PI and RI, and compare these with Doppler indices measured at same day ultrasound examination in the early third trimester.

2. Method

Ethical approval was obtained from the NRES Committee East of England-Cambridge Central, reference number 12/EE/0169. Participants provided written informed consent and between 1st May 2013 and 28th May 2014, 35 normal singleton pregnancies were recruited at routine 20–22 week ultrasound examination. Subjects with multiple pregnancies were excluded. All women then underwent routine fetal ultrasound examination between 28 and 32 weeks gestation followed by same-day MRI examination which was then analysed by two independent observers. This formed part of a larger study evaluating amniotic fluid measurements.

2.1. Ultrasound

Following routine biometry measurements, transabdominal colour Doppler US was used to identify each UtA. The in-room time was 20 min and the US examination was performed by a single investigator (RH) with 5 years obstetric ultrasound experience as guidelines and recent research state Doppler ultrasound is reproducible [23,24]. All the examinations were performed using the same GE Voluson E8 (GEHC, Waukesha, WI, USA) ultrasound machine with a 2–5 MHz multi-frequency curvilinear transducer adhering to the following standardised guidelines [24]. The Doppler measurement was taken 10 mm downstream to the point of apparent crossing of UtA and the external iliac artery (Fig. 1a) [24]. The sample gate was set at 3 mm to include the whole vessel, and an angle of insonation <40° was used. Pulse-wave Doppler US was used to obtain three separate UtA waveforms, and the inbuilt automatic waveform analysis calculated the mean UtA RI and PI [24–27]. The mean of three consecutive measurements was recorded (Fig. 1b).

2.2. MRI

All MRI examinations were performed using an 8-channel cardiac array coil and the same 1.5T MRI system (MR450), GE Healthcare, Waukesha, WI, USA). Initial breath-hold sagittal and axial imaging through the uterus was obtained with a fast-imaging employing steady-state acquisition (FIESTA) pulse sequence. Following these, an oblique coronal image plane was positioned immediately superior to, and parallel with, the external iliac arteries. A cardiac-gated cine phase-contrast study was performed using this plane, with the following parameters: TR/TE 6.45/3.1msec, slice thickness 7 mm, FOV 36 cm, matrix 192 × 256, flip angle 30°, retrospective gating with 60 cardiac phases, two views per segment, velocity encoding parameter (venc), 80–90 cm/s. The in-room total examination time ranged from 25 to 30 min.

2.3. Data analysis

A computer based imaging software ClearCanvas (ClearCanvas Inc, Toronto, ON) was used for vessel identification by co-locating the UtA between the phase-contrast image and reference images. Axial and sagittal FIESTA images and an oblique coronal phase-contrast image were used to identify each vessel (Fig. 2). Correct identification was based on the following features: the presence of one or more vessels passing through the plane in the expected location, flow predominantly in an anterior direction, and image correlation confirming that the vessel was positioned within the uterine wall rather than in adjacent structures such as fetal body parts, maternal bowel, or the umbilical artery. Vessels were excluded if they did not fulfil the criteria, or if the vessel could not be discretely identified owing to motion or blurring artefacts. If more than one artery was identified on each side of the uterus, both were evaluated, but the largest vessel was used for comparison with ultrasound as this was the criterion applied during routine ultrasound examinations.

An in-house flow analysis program was developed using Matlab (The Mathworks, Nattick, MA), and used to evaluate the phase-contrast images of the selected vessels. Two observers independently traced manual regions of interest (ROI) around each identified UtA, and an adjacent artefact-free area of stationary tissue to provide background correction. Velocity aliasing was also corrected by the program. A corresponding flow profile was generated, and from this a RI and PI value for each artery was calculated (Fig. 3b).

2.4. Statistical analysis

Bland Altman comparison statistics were used to investigate the

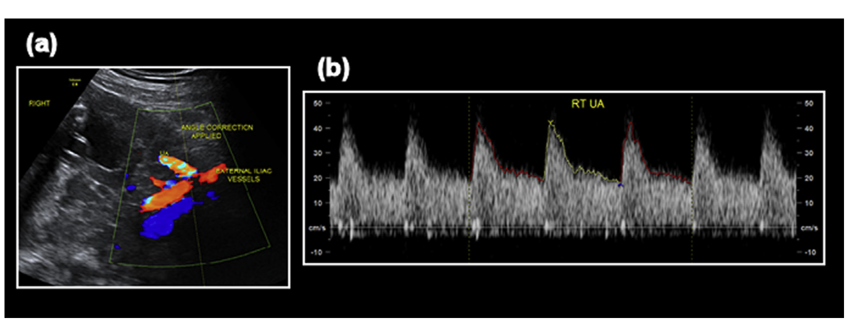

Fig. 1. Illustrates the UtA location on ultrasound (a), and the resulting waveform (b) at 30 weeks gestation.