

# Repeatability of measurement of uterine artery pulsatility index using transvaginal color Doppler

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## ABSTRACT

**Objective** To assess the repeatability of measuring the pulsatility index of the uterine arteries using transvaginal color Doppler at 23 weeks of gestation.

**Patients and methods** The pulsatility index was measured in 100 women with singleton pregnancies attending for routine transvaginal Doppler examination of the uterine arteries at 23 weeks. To assess the repeatability of different components of variability, six measurements of the uterine artery pulsatility index were made on one of the uterine arteries in each patient.

**Results** Six measurements of the pulsatility index were successfully measured in all 100 patients, resulting in a total of 600 measurements. The repeatability was unrelated to the pulsatility index. On 95% of occasions the intraobserver, interobserver and waveform tracing repeatability was less than 0.24, 0.27 and 0.14, respectively.

**Conclusions** Measurement of the pulsatility index using transvaginal color Doppler is highly reproducible when the examination is carried out by well-trained operators.

## INTRODUCTION

A series of Doppler ultrasound screening studies have demonstrated that increased impedance to flow in the uterine arteries at 18–24 weeks of gestation is associated with an increased risk for subsequent development of pre-eclampsia, fetal growth restriction and perinatal death<sup>1</sup>. In addition, women with normal impedance constitute a group that have a low risk of developing obstetric complications related to uteroplacental insufficiency. Most of these studies have been carried out by transabdominal ultrasound. We have recently reported a large study examining transvaginal uterine artery Doppler in the prediction of pre-eclampsia and fetal growth

restriction<sup>1</sup>. The aim of this study was to assess the repeatability of transvaginal measurement of the pulsatility index (PI) in the uterine arteries.

## MATERIALS AND METHODS

At King's College Hospital, London, all women attending for routine antenatal care are offered two ultrasound scans during pregnancy. The first is carried out at 12 weeks and the aims are to determine viability and gestational age, diagnose major fetal defects, determine nuchal translucency thickness as part of screening for chromosomal abnormalities and determine chorionicity in multiple pregnancies. The second scan is at 23 weeks and includes measurement of fetal growth, examination for fetal abnormalities and the option of a transvaginal scan to measure both cervical length, as a method of screening for preterm delivery, and PI of the uterine arteries, as a method of screening for pre-eclampsia and intrauterine growth restriction.

The study was approved by the local ethics committee. A total of 115 consecutive women attending the research clinic were invited to take part in the study of repeatability and 100 women accepted. Written informed consent was obtained in all cases. The women were asked to empty their bladders and were placed in the dorsal lithotomy position. Transvaginal sonography using a 5-MHz transducer (Aloka 1700, Aloka Co. Ltd, Tokyo, Japan) was carried out by both sonographers (A.P., M.T.), who were well-trained and had similar experience, and the uterine artery PI was measured successfully in all 100 women.

The order in which the operators performed the scans was determined by computer-generated randomization. The first operator placed the probe in the sagittal plane in the anterior fornix of the vagina and cervical length was measured as previously described<sup>2</sup>. The probe was then moved into the lateral fornix and the uterine artery was identified using color Doppler at the level of the internal cervical os. Pulsed wave Doppler was then used to obtain three similar consecutive

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waveforms, and the same was then repeated for the contralateral uterine artery.

To assess repeatability of different components of variability, six measurements of the uterine artery PI were made on one of the uterine arteries in each patient. The first operator generated the appropriate image, measured the PI and then generated a new image and repeated the measurement (intraobserver repeatability). This second image was frozen on the screen but the waveform trace for measurement of the PI was removed and the second operator measured the PI (assessment of waveform tracing repeatability). The process was repeated with the operators reversed (interobserver repeatability). Thus a sequence of six measurements was obtained: A1, A2, BT, B1, B2 and AT, where A and B represent the two operators, 1 and 2 indicate the two normal measurements, and T indicates the measurement that involved only tracing of the waveform and measurement of the PI. Numerical displays on the screen were covered so that the operators were blinded to the actual measurement and were unaware of results obtained by the previous operator; the ultrasound probe was returned to the midline after each measurement, but was not actually withdrawn from the vagina.

The repeatability of PI measurements and interobserver comparisons were assessed using the four normal measurements on each patient (A1, A2, B1 and B2). Intraobserver variation was analyzed by calculating the standard deviation (SD) of the differences between the 200 pairs of measurements made by the same observer. Interobserver variation was analyzed by calculating the SD of the differences between the means of pairs of measurements made by two observers on one patient ( $n = 100$ ). This value was then multiplied by  $\sqrt{2}$  to get the corresponding value for single measurements. Waveform tracing repeatability was assessed from the SD of the 200 pairs of interobserver differences A2 – BT or B2 – AT<sup>3</sup>.

**RESULTS**

Both operators measured uterine artery PI successfully in all 100 cases. A total of 600 measurements were made.

**Distribution**

The distribution of the uterine artery PIs (using the average value over the four measurements A1, A2, B1 and B2) is shown in Figure 1. The mean PI was 0.99, and three patients had a PI above 1.63, which was the 95th centile in a previous study involving 7851 pregnancies<sup>1</sup>.

**Intraobserver repeatability**

There was no significant association between uterine artery PI and measurement error (Figure 2); therefore the repeatability can be expressed by using the SD of the difference. The SD of the differences between measurements one and two of each observer (pooled across both observers) was 0.12; thus, on 95% of occasions two readings by the same observer would not differ by more than  $\pm 0.24$  from the true PI.

**Interobserver repeatability**

There was no significant association between uterine artery PI and differences between observers (Figure 3). The interobserver SD was 0.096 for the mean of two measurements. Consequently, on 95% of occasions single readings by two different observers would not differ by more than  $\pm 0.27$  from the true PI ( $2SD \times \sqrt{2}$ ). If each observer takes two measurements, then the mean of the two measurements of the two observers would not differ by more than  $\pm 0.20$ .

**Waveform tracing repeatability**

The SD of the difference between the two observers in tracing the frozen picture of the waveform was 0.07, i.e. on 95% of occasions the two readings would not differ by more than

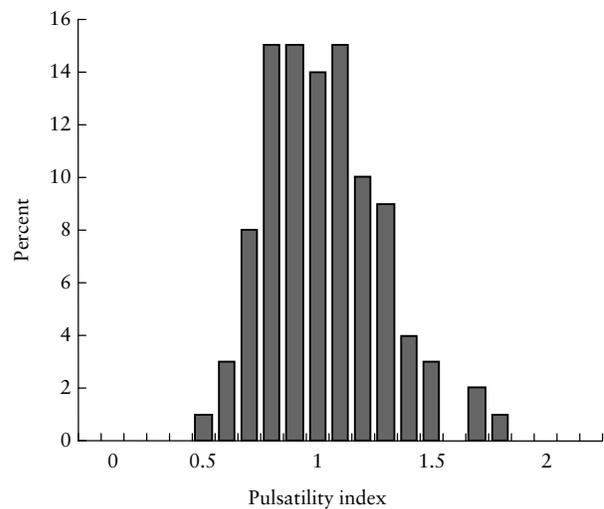


Figure 1 Distribution of the 'true' uterine artery pulsatility index in the 100 cases, calculated by using the average value over the four normal measurements (A1, A2, B1 and B2).

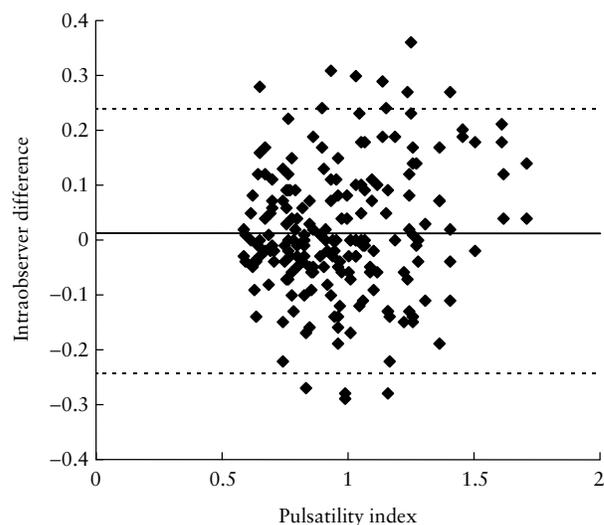
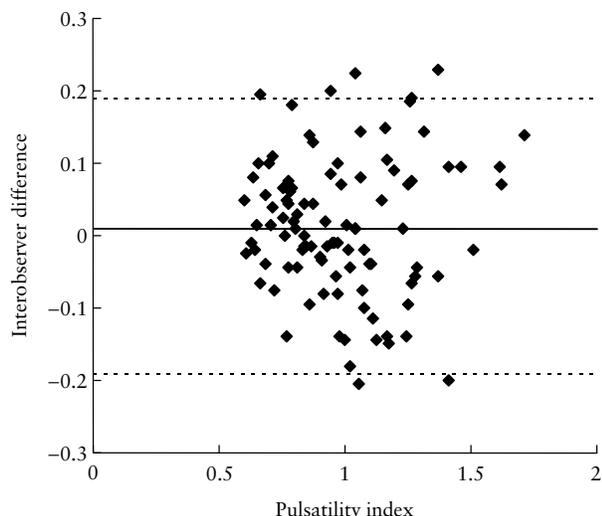
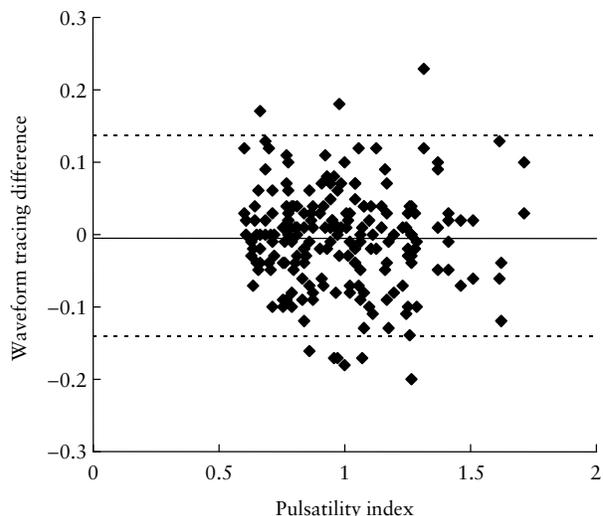


Figure 2 Scatter diagram showing the intraobserver differences against the mean of the 'true' uterine artery pulsatility index.



**Figure 3** Scatter diagram showing the interobserver differences of the mean of two measurements against the mean of the 'true' uterine artery pulsatility index.



**Figure 4** Scatter diagram showing the differences in tracing the same waveform against the mean of the 'true' uterine artery pulsatility index.

$\pm 0.14$  (Figure 4). Therefore, a significant proportion of the intraobserver and interobserver variability was due to tracing the waveform rather than to obtaining it.

**DISCUSSION**

The usefulness of a screening test depends not only on its predictive ability but also on its reproducibility. Most previous studies examining the repeatability of uterine artery Doppler

in pregnancy have concentrated on the transabdominal approach, examining small numbers of patients using different techniques and Doppler indices, and using different statistical methods to assess repeatability. It is therefore difficult to compare the results of the current study to those performed previously (Table 1). In assessing repeatability many of the studies have used the coefficient of variation or comparisons of differences. However, the method proposed by Bland and Altman<sup>3</sup> has been shown to be more appropriate for assessing

**Table 1** Studies assessing repeatability of uterine artery Doppler during pregnancy

Reference	n	Doppler technique	Doppler index	Repeatability	Statistical method
<b>Intraobserver</b>					
Schulman <i>et al.</i> 1986 <sup>10</sup>	NR	CW	S/D	4%	NR
Mulders <i>et al.</i> 1988 <sup>11</sup>	21	PW	PI	6.4%	CV
Gagnon <i>et al.</i> 1988 <sup>12</sup>	11	CW	S/D	6.1%	CV
Long <i>et al.</i> 1988 <sup>13</sup>	20	CW	PI	6%	CV
Oosterhof <i>et al.</i> 1992 <sup>14</sup>	15	PW	PI	10.8%	CV
Bower <i>et al.</i> 1993 <sup>15</sup>	5	Color	RI	7%	CV
Ferrier <i>et al.</i> 1994 <sup>16</sup>	5	Color	RI	4%	CV
Weissman <i>et al.</i> 1995 <sup>8</sup>	20	TV, CW	S/D	5%	CV
Chan <i>et al.</i> 1995 <sup>17</sup>	9	CW	RI	5.9%	CV
Harrington <i>et al.</i> 1997 <sup>18</sup>	10	TV, Color	PI	2.6%	CV
Liberati <i>et al.</i> 1997 <sup>19</sup>	5	Color	RI	5.1%	CV
<b>Interobserver</b>					
Trudinger <i>et al.</i> 1985 <sup>20</sup>	10	CW	S/D	No difference	CV
Schulman <i>et al.</i> 1986 <sup>10</sup>	NR	CW	S/D	4%	NR
Mulders <i>et al.</i> 1988 <sup>11</sup>	13	PW	PI	11.1%	CV
Oosterhof <i>et al.</i> 1992 <sup>14</sup>	10	PW	PI	10.1%	CV
Bower <i>et al.</i> 1993 <sup>21</sup>	10	CW	RI	-0.24 to 0.28	95% prediction interval
Bewley <i>et al.</i> 1993 <sup>22</sup>	20	CW	RI	-0.18 to 0.22	95% prediction interval
Ferrier <i>et al.</i> 1994 <sup>16</sup>	8	Color	RI	6.6%	CV
Yan <i>et al.</i> 1995 <sup>23</sup>	20	Color	RI	-0.24 to 0.16	95% prediction interval
Weissman <i>et al.</i> 1995 <sup>8</sup>	20	TV, CW	S/D	8%	CV
Chan <i>et al.</i> 1995 <sup>17</sup>	8	CW	RI	13.6%	CV
Liberati <i>et al.</i> 1997 <sup>19</sup>	10	Color	RI	7.4%	CV

NR, not reported; CW, continuous wave; PW, pulsed wave; Color, color-flow Doppler; TV, transvaginal; S/D, systolic/diastolic ratio; PI, pulsatility index; RI, resistance Index; CV, coefficient of variation.

intra- and interobserver repeatability<sup>3-6</sup>. In this study we have used this statistical method to examine a large number of women, utilizing the transvaginal route and using color Doppler to image the vessel.

Examining uterine artery blood flow transvaginally offers a number of advantages over the transabdominal route. The uterine artery is a large-diameter vessel, which is easily identifiable using this approach, and this may improve repeatability over transabdominal sampling or using pulsed or continuous-wave Doppler. Furthermore, the vessel is studied at close proximity resulting in clearer waveforms with a reduction in the variability of impedance<sup>7,8</sup>. Finally, in contrast to the suboptimal angles often obtained by the transabdominal route, the angle of insonation to the uterine artery that can be achieved transvaginally is generally close to the optimal 0°<sup>9</sup>.

We demonstrated that on 95% of occasions the intra-observer and interobserver repeatabilities of measuring the uterine artery PI by transvaginal sonography were < 0.24 and 0.27, respectively. The repeatability was unrelated to PI, and is therefore likely to be similar for higher values of PI, although there were relatively few in this study.

Differences in repeat readings of PI can be due to the generation of a new image which may be at a different site or with a different angle of insonation; differences in tracing of the waveform; or actual temporal changes in uterine artery blood flow. We have shown that the waveform tracing repeatability was < 0.14 in 95% of occasions. This suggests that a large part of the intra- and interobserver variation can be accounted for by the tracing of the waveform. The study also shows that the repeatability of the mean of two measurements is lower than that of one measurement, so this could be improved by taking the mean of two good measurements rather than one. The findings of this study demonstrate that when uterine artery PI is measured by well-trained operators the measurement is highly reproducible.

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