

# Doppler ultrasonography of the fetoplacental circulation — normal reference values

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## Summary

Normal reference values for the resistance index, A/B ratio and pulsatility index of the umbilical artery obtained by Doppler ultrasonography are presented. The resistance index and A/B ratio values are very similar to those previously published, indicating no need to formulate normal values for different populations. The pulsatility index differed from other published values, probably reflecting different calculation methods built into the spectrum analysers rather than differences in waveforms. The resistance index had the lowest coefficient of variation and showed least inter-observer variation. For routine use the resistance index is preferable to other indices.

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Doppler ultrasonography has enabled the obstetrician to study the fetoplacental circulation in a simple, non-invasive way. This new area of research holds much potential for the obstetrician. However, before its potential can be evaluated, the range of normal reference values must be defined. Few ranges have so far been established<sup>1-4</sup> and no data are available about the advisability of using reference values obtained in one population for a different population. A set of reference values for the coloured population of the western Cape was established in an attempt to address these issues.

## Patients and methods

Patients included in the study had no obstetric risk identifiable at the first visit and consented to undergo the Doppler examinations. The gestational age of all fetuses was confirmed by early ultrasonography. The patients were seen at 20, 24 and 28 weeks' gestation and fortnightly thereafter. Doppler ultrasonography of the umbilical artery was performed at each visit. The resistance index (RI) (also known as the Pourcelot ratio<sup>5</sup>), the A/B ratio<sup>6</sup> and pulsatility index (PI)<sup>7</sup> were calculated for the umbilical artery velocity waveforms (Fig. 1). For each patient the mean of 5 velocity waveforms was used to calculate each index. Readings from the umbilical artery were only taken if the umbilical vein velocity waveform was also visible and while the fetus was quiet and apnoeic. If a mother developed pregnancy complications or delivered a baby weigh-

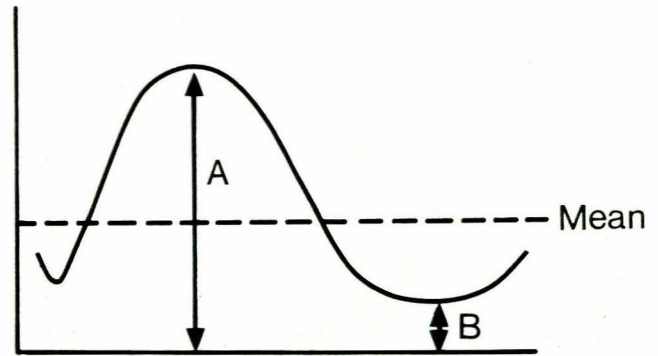


Fig. 1. Definitions of three velocity waveform indices — RI, A/B ratio and PI (A = peak systolic Doppler shift; B = end-diastolic Doppler shift; mean = mean Doppler shift over one cardiac cycle, RI = A-B/A; A/B ratio = A/B; PI = A-B mean).

ing less than the tenth centile for its gestational age using the curves of Lubchenco *et al.*,<sup>8</sup> she was excluded from the study.

Doppler ultrasonographic measurements were performed on two machines — a Doptek 9000 continuous wave Doppler apparatus (4-MHz transducer and 200-Hz wall filter) or an ATL Ultramark IV ultrasound system combining high-frequency imaging with pulsed Doppler flowmetry and real-time spectral analysis (3-MHz transducer and 150Hz wall filter). The latter machine cannot calculate the PI. When the continuous wave machine was used the umbilical artery was identified by pattern recognition. If difficulty was experienced, the umbilical cord was localised by real-time ultrasonography.

Inter-observer variability was tested using 10 patients, each scanned consecutively by the 3 operators. Two operators used the Doptek machine and the third used the ATL Ultramark IV. The design of the experiment thus necessitated regarding each operator and machine as a unit. For each index an analysis of variance was carried out to assess the inter-unit variability. The correlations between the readings resulting from the different units were also computed. Intra-observer variability was tested using two groups of 10 mothers. Each group was scanned twice by an operator within 1 hour (a different operator was assigned to each group). For each index, the variability of repeat readings was assessed using an *F*-test and the correlation between repeat readings was determined.

The centile charts were constructed using density based centile estimates in preference to non-parametric estimates, since the former generally lead to more stable estimates (being based on all data, rather than the one or two points at a particular centile location as is the case with non-parametric estimates). For each index and each week of pregnancy studied the available data were assessed to determine whether their distribution could be regarded as being normal (Gaussian). The statistical analysis system (SAS) procedure, PROC UNIVARIATE, was used for this purpose and involved calculation of the Shapiro-Wilk statistic for sample sizes  $\leq 50$  and the Kolmogorov D statistic was used for larger samples.<sup>9-11</sup> The umbilical artery RI and PI data up to and including week 30 were significantly different from normal in their distribution, but thereafter the distribution did not differ from normality.

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(The term significant refers throughout to  $P < 0,05$  for the associated hypothesis test.) The distribution of the A/B ratio differed from normality for all weeks of pregnancy considered. Because the distribution of the indices could not be regarded as normal throughout, the centile curves were drawn up by the fitting of the flexible four-parameter Johnson family of distributions,<sup>12</sup> with smoothness constraints applied to the parameters, so that the centiles changed smoothly from week to week.

**Results**

Sixty mothers were initially selected for the study. Of these, 15 had to be excluded because 8 developed pre-eclampsia, 2 abruptio placentae, 3 had small-for-gestational-age babies, 1 developed pyelonephritis and preterm labour, and 1 was started on low dose aspirin. The average age of the 45 mothers in the study was  $27,4 \pm 5,7$  years and 13 were primiparous and 32 multiparous. Most delivered between 38 weeks and 40 weeks (average gestational age at delivery  $39,2 \pm 1,3$  weeks). Eighteen mothers delivered at or after 40 weeks, a number too small to establish reliable reference values in this range.

An analysis of variation for each index showed no significant inter-observer variability. However, there was poor correlation ( $r = 0,36$ ;  $P = 0,35$ ) between measurements on the two machines used. The RI showed the lowest coefficient of variation of all the indices (Table I). The highest coefficient of variation for the RI was 20%, whereas the lowest for the PI and the A/B ratio were 27% and 25% respectively. In assessing the intra-observer variability, the variation between readings for the observers was found not to differ significantly. The repeat readings for one observer showed poor correlations per index, e.g.  $r(\text{RI}) = 0,59$ ;  $P = 0,07$ ), but on retesting of this observer good correlations per index were found, e.g.  $r(\text{RI}) = 0,86$ ;  $P = 0,001$ ).

Observer	RI	A/B ratio	PI
1	$0,66 \pm 0,10$	$3,27 \pm 1,00$	$1,06 \pm 0,29$
2	$0,64 \pm 0,13$	$3,13 \pm 0,98$	$1,14 \pm 0,41$
3	$0,63 \pm 0,10$	$2,92 \pm 0,73$	—

The umbilical artery RI, A/B ratio and PI normal reference values are shown in Figs 2-4. The values for the RI are shown in Table II.

Week	WEEKS' GESTATION		
	5th centile	50th centile	95th centile
20	0,60	0,73	0,85
24	0,56	0,70	0,83
28	0,53	0,67	0,80
30	0,51	0,65	0,79
32	0,49	0,63	0,77
34	0,47	0,61	0,75
36	0,45	0,59	0,72
38	0,42	0,56	0,69

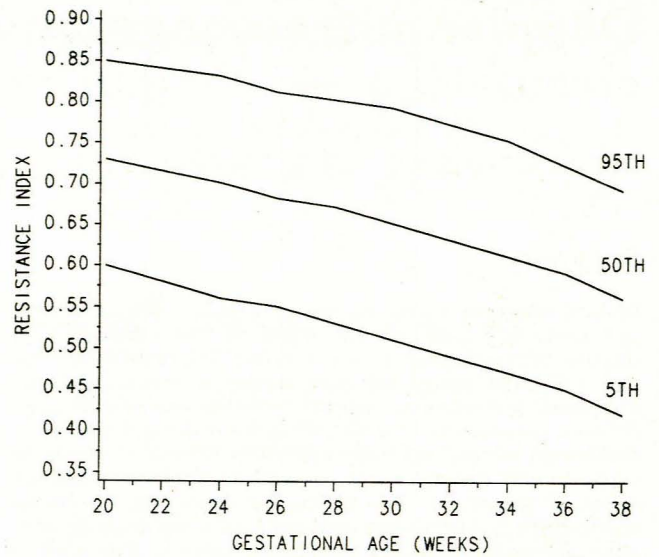


Fig. 2. Reference values for the RI of the umbilical artery.

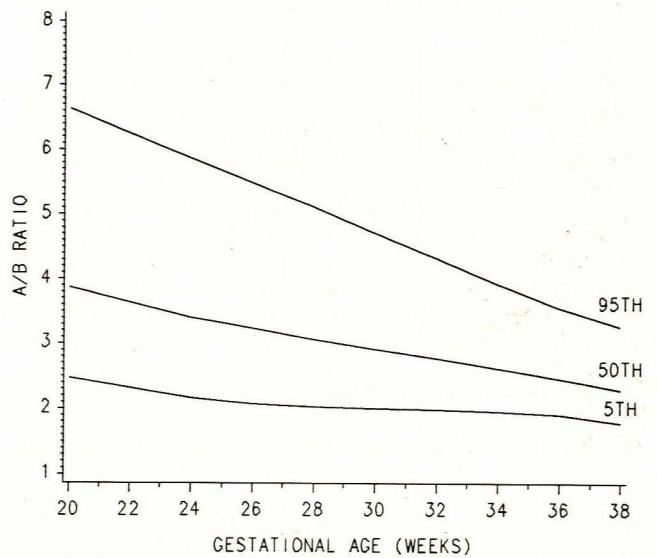


Fig. 3. Reference values for the A/B ratio of the umbilical artery.

**Discussion**

Reference values for the fetoplacental waveform indices are presented. The values for the RI and A/B ratio are very similar to those previously published,<sup>1-3</sup> indicating that different populations do not differ with respect to these indices. Thus maternity units do not have to establish their own reference values before starting a study.

There were differences between the PI values obtained here and those from other centres. However, there are also differences between PI values obtained between these centres. For the calculation of the PI, the spectrum analyser has an in-built program that automatically calculates the mean Doppler shift and then the PI. Machines differ with respect to the programs incorporated to calculate the mean Doppler shift. This probably explains the differences between our and other PI reference values. An alternative explanation could be that the velocity waveforms differ in shape.

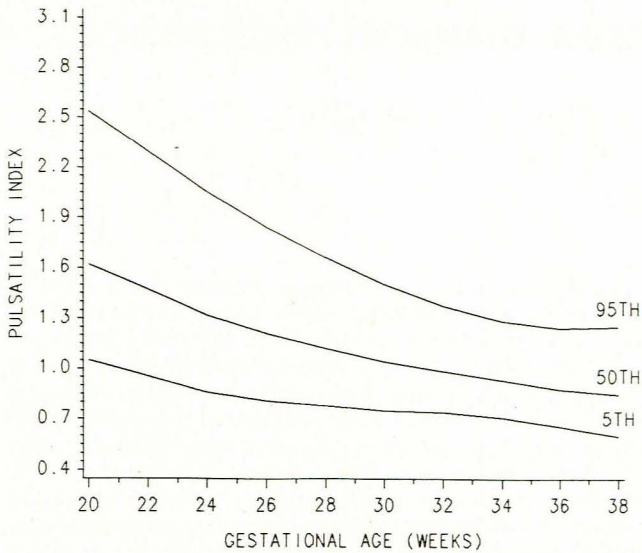


Fig. 4. Reference values for the PI of the umbilical artery.

The RI has the lowest coefficient of variation of all the indices, and least inter-observer variability. This has also been found in other centres.<sup>2,13</sup> The error in calculating the A/B ratio increases as the A/B ratio increases, whereas the converse holds for the RI and PI.<sup>13</sup> Thompson *et al.*<sup>13</sup> found that the three indices give the same information, so that only one need be calculated. The RI appears to be the most useful index because it is simple to calculate, has the least inter-observer variability, the lowest coefficient of variation and can be used to compare data from different centres.

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