Reproducibility of Measurement of Pulsatility Index by Doppler Ultrasound of the Anterior Cerebral Artery of Preterm Infants

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SUMMARY: Ten preterm infants were each studied by three observers using a commercial duplex Doppler ultrasound scanner, in order to determine the intra-observer and inter-observer variability in the measurement of pulsatility index (PI) of the anterior cerebral artery. There was considerable difference in estimates of PI, with a mean range of 0.11 between the three observers for each infant. Intra-observer variability exceeded inter-observer variability and had a coefficient of variation of 8.4%.

The five observers involved in this study had less than six months experience of duplex scanning. The results suggest that the PI can be measured with acceptable reproducibility by personnel with limited experience.

Introduction

Haemorrhagic and ischaemic complications are common in very low birthweight (VLBW) infants, and may lead to death or neurodevelopmental delay¹. Cerebral lesions can be detected using real time ultrasound imaging, which is non-invasive and easily performed at the cotside². Duplex ultrasound scanners combine real-time imaging with Doppler systems, allowing cerebral artery blood flow velocities to be studied, using the anterior fontanelle as an acoustic window. In 1979 Bada *et al.* observed that transcutaneous Doppler flow velocity recordings from anterior cerebral arteries were helpful in the evaluation of intracranial haemorrhages³. Ultrasound Doppler measurements have since been shown to correlate well with cerebral blood flow as measured using xenon 133 clearance techniques⁴.

The pulsatility index (PI), or Pourcelot's resistance index

$$\frac{\text{Systolic-Diastolic}}{\text{Systolic}} = \frac{\text{S-D}}{\text{S}}$$

is a ratio which is independent of the effect of the angle between the ultrasound beam and the long axis of the blood vessel and is a commonly used Doppler index of flow velocity. A low PI in infants with birth asphyxia has been associated with an adverse outcome⁵.

Because of the serious implications of an abnormal PI, it is important to establish the accuracy of the measurement, especially as duplex Doppler scanning systems are now widely available commercially.

The purpose of this study was to determine the intra-observer and inter-observer variability in the measurement of PI, as performed by members of the clinical and research staff of a neonatal intensive care unit, using a commercially available duplex scanner.

Patients and Methods

Ten preterm infants in stable clinical condition were studied using an Ultramark 4 Scanner (Advanced Technical Laboratories). Clinical details of these infants are shown in Table 1. The brain was imaged through the anterior fontanelle in a sagittal plane using a 7.5 MHz transducer. Flow velocity waveforms (FVWs) were obtained from the anterior cerebral artery as it curved around the corpus callosum to become the pericallosal artery⁶ (Fig. 1). At least five waveforms were obtained on each occasion and stored on hard copy (Fig. 2). The duration of the examination was recorded. The study was immediately repeated by the same observer and a further hard copy obtained. The same infant was then studied independently by two other observers in the same way. Each infant was studied by three or five observers according to the plan shown in Table 2. The five observers were clinical staff from the nursery, with varying degrees of expertise and experience in ultrasound. No measurements were made at the time FVWs were recorded. Hard copies were stored until all ten infants had been studied. Each observer then measured by ruler the PI from each of the 12 FVWs he had recorded from 6 infants, without knowing which

Table 1
Patient details

	Range	Median
Gestation	27-36	28 weeks
Birthweight	685-2316	945 grams
Age of study	15-70	29 days
PI	0.67-0.95	0.81
Study duration*	60-155	119 secs

*Time taken for an individual observer to make a single recording of PI.

Fig 1: Sagittal section of the brain showing intracranial arteries. The transducer is placed over the anterior fontanelle.

FVWs had originated from the same patient. This indirect method of measuring PI, which is less accurate than using the electronic calipers on the scanner screen, was necessary to obtain some measurement of intra-observer variability.

The maximum frequency during systole (S), and diastole (D) was measured on each waveform to the nearest millimetre, and the PI was calculated as $(S-D)/S$ from the mean values of at least 3 FVWs.

The data resulting from this "balanced incomplete block" design⁷ were analysed by analysis of variance. This enabled estimates to be made of both the intra-observer and inter-observer variability, as measured by standard deviation (SD) and coefficient of variation (CV). The CV was calculated as SD/mean expressed as a percentage.

All of the hard copies were then re-examined by a single observer (BM) in order to determine whether the inter-observer variability in PI measurement was due to observer variability in the quality of Doppler waveforms

Fig 2: Ultrasound image and Doppler velocity waveform obtained from the anterior cerebral artery using a duplex scanner. Peak systolic (X) and diastolic (+) velocities are indicated.

Table 2
Study design

Observer Patient	1	2	3	4	5
1	*	*	*		
2	*	*		*	
3	*	*			*
4	*		*	*	
5	*		*		*
6	*			*	*
7		*	*	*	
8		*	*		*
9		*		*	*
10			*	*	*

obtained, or in the measurements made from those spectra.

Results

Each of the infants studied had six Doppler recordings, two by each of three observers. The median time for each Doppler examination was 119 seconds. The mean PI for each infant was 0.67-0.95 (median 0.81). The mean difference between highest and lowest estimates for PI for the ten infants was 0.11 (range 0.02-0.18). On two occasions individual observers reported a PI of 1.0 signifying absent diastolic flow, the mean PI of all three observers in these cases were 0.88 and 0.94.

Table 3 shows that the best single-value estimate of the intra-observer variability of PI in terms of standard deviation (SD) is 0.067, and in terms of coefficient of variation (CV) is 8.4%. For the inter-observer variability the best estimates of SD and CV are both zero (in other words, the hypothesis that inter-observer variability is zero cannot be rejected at the 5% level,

using these data). Ninety-five percent confidence limits for all these estimates are shown in brackets in Table 3.

When the hard copy of all spectra were re-analysed by one of the observers (BM), the SD of the difference between initial analysis and re-analysis was 0.035. If all the variability of PI was attributable to spectral measurement, the expected SD would be $0.067 \times 2 = 0.095$. It is therefore likely that the majority of variability in PI measurement is due to the recording of the spectra and not the analysis.

Discussion

Several Duplex scanners are commercially available and are frequently used in neonatal nurseries to study the cerebral blood velocities for both clinical assessment and research projects. In order to assess the prognostic observations of poor outcome of low PI⁵, we undertook a project to study the reproducibility (inter and intra observer) of commonly used simple Doppler measurement of PI by various medical personnels of varying experience, of a busy neonatal unit. The anterior cerebral artery was chosen as it was easily identified and because the direction of blood flow is directly towards the transducer.

Reproducibility of the Doppler measurements have been previously reported by Murrill et al⁸ (CV10-12%) and Winberg et al⁹ (CV8-10%). Using continuous wave Doppler of the anterior cerebral artery in 10 neonates Hancock et al¹⁰ reported an estimated error of observations of 0.073. A CV of 8% for intra-observer variability was noted by us which was considered adequate for clinical purposes. It is possible that this CV of 8% could have been improved by using the electronic calipers, directly measuring on the scanner screen; but it was necessary in this study to use the hard copy and ruler to study the intra-observer variability. The intra-observer variability was thought to be due to the inherent random error of the technique or the 'noise' of the system. In the absence of the 'gold standard' it was impossible to assess whether any of the observers was more accurate than the others or whether previous experience or time taken to obtain a satisfactory spectrum was related to accuracy. The variability of PI measurement may be due to incomplete insonnation of the artery or to the physiological variation in the

Doppler waveform, from one heartbeat to another in a neonate who is crying or breathing asynchronously with mechanical ventilation¹¹.

One observer recorded absent diastolic flow and therefore a PI of 1.0, presumably due to incomplete insonnation of the vessel as the other observers recorded satisfactory diastolic flow. This source of error is of great clinical relevance in obstetrics scanning as the absent diastolic flow in the umbilical arteries is considered a poor prognostic sign of foetal well being¹². None of the observers noted a PI value of less than 0.55 which is associated with poor outcome in asphyxiated neonates⁵. It is unlikely that faulty technique could lead to an erroneously low PI but a more complete study on neonates with PI values at the lower end of the range is needed, where errors would be of great clinical significance.

None of the currently available techniques for early assessment of prognosis following severe birth asphyxia have adequate sensitivity or specificity to be used as a single predictive test. If the report⁵ suggesting that a low PI in the first few days of life carries a high risk of adverse outcome can be reproduced in a larger population, then Doppler assessment of cerebral artery velocity waveforms is likely to become a commonly used diagnostic and prognostic technique. This study suggests that an acceptable degree of reproducibility in the measurement of PI can be achieved by personnel with limited experience using commercially available equipment.

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Table 3

Variability of PI, as measured by the standard deviation and coefficient of variation for intra- and inter-observer differences. Values are single value estimates, with 95% confidence limits shown in brackets.

	Standard deviation	Coefficient of variation
Intra-observer variability	0.067 (0.050-0.100)	8.4% (6.3-12.6)
Inter-observer variability	0 (0-0.058)	0% (0-7.3%)

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REPORT OF A MEETING

ASSOCIATION OF SERVICE PHYSICIANS

The tenth annual meeting of the Association of Service Physicians was held at the Royal Army Medical College, Millbank, on 17 February 1989. Fifty two members attended and Major General M Brown, Director of Army Medicine, took the chair.

Following an opening introduction and welcome by Major General R Scott, Commandant and Postgraduate Dean, Royal Army Medical College, Squadron Leader P Mullen presented a paper on the detection of *Campylobacter pylori* in Gastric Mucosa, and recommended that a single biopsy from the peri-pyloric antrum would usually identify the organism. Major S P Sahi then gave a review of 107 cases of Deliberate Drug Overdose admitted to one military hospital in a four year period, with an analysis of the factors leading to self poisoning, and discussion of potential difficulties and shortcomings in medical management. The first session ended with a paper by Surgeon Commander R J Clark describing research he had undertaken at Hammersmith

Hospital using positron emission tomography to study white cell behaviour in acute lung injury.

The second session, with Air Commodore D H Hull, RAF Consultant Adviser in Medicine in the chair, took the form of a mini symposium on Diabetes Mellitus. Lieutenant Colonel G E Ratcliffe gave an analysis of the prevalence and outcome of diabetes in the three services in recent years; Surgeon Commander R H Taylor then described the considerable changes and improvements in the management of diabetes, especially insulin dependant type, that have occurred in the last few years, and finally Air Commodore Hull reviewed the current regulations regarding medical grading of diabetic servicemen including special groups such as aircrew and air traffic controllers. These papers predictably engendered considerable useful discussion, which was at times animated, but always good humoured!

The meeting concluded with lunch in the RAMC Headquarter Officers' Mess.

T B N OLDREY