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Transcranial color Doppler sonography on healthy pre-school children: Flow velocities and total cerebral blood flow volume

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Abstract

Transcranial color Doppler sonography (TCCD) is a useful tool for intracranial investigation. Using TCCD to calculate total cerebral blood flow volume (TCBFV) can be a useful indicator for intracranial hemodynamic status. We performed a series study of TCCD on 60 healthy kindergarten students. Peak-systolic, end-diastolic, and mean blood velocities of major cerebral arteries, and depth of flow waves were measured. We also collected Gosling pulsatile index (PI) and Pourcelot resistance index (RI) of the arteries. TCBFV was calculated from the mean blood flood velocity and vessel chamber size of the internal carotid artery (ICA) and basilar artery (BA). Fifty children completed the examinations. The TCBFV was 1538 ± 416 ml/min with mean cerebral blood flow volume of 571 ± 241 ml/min for the ICA system and 983 ± 343 ml/min for the BA system. PI, RI, and the velocities of A1, A2, M1, M2, BA, ICA, and TCBFV were not significantly different between girls and boys in this age group. In this study, we used TCCD to determine the normal data of main cerebral arteries and TCBFV of pre-school children in Taiwan. The reference data of velocities and other parameters of main cerebral arteries from our study may serve as a guide for additional pediatric cerebral hemodynamic studies.

Keywords: Transcranial color Doppler sonography; Total cerebral blood flow volume; Cerebral hemodynamic

1. Introduction

Transcranial color Doppler sonography (TCCD) is a useful tool for intracranial investigation. It provides direct sonographic imaging of intracranial vessels and brain parenchyma. It is also a noninvasive, reproducible and bedside mobile device for evaluating the cerebral hemodynamics, including blood flow direction, flow velocities, and other abnormal vascular lesions [1]. Some reference data, focusing on pediatric patients, have been reported by several investigators [2–5]. Nevertheless, it is still a technical issue concerning the poor cooperation of pre-school children in clinical practice without sedation of the children. It might be the reason that no normal data of this age group are available in Taiwan. Total cerebral blood flow volume (TCBFV) is an important yet largely unknown factor in the treatment of neurologically intensive care patients suffering, for example, from cerebrovascular disorders and/or intracranial hypertension. Until now, the quantitative measurement of TCBFV has been possible by exposing patients to invasive or to radionucleotide technique [6–9]. Apply TCCD on calculating TCBFV can be a noninvasive and useful elucidation of intracranial hemodynamic status [6]. The goal of this study was to record normal data of flow velocities and waveform parameters of basal cerebral arteries and to measure TCBFV via TCCD in healthy pre-school children.

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2. Materials and methods

We performed studies of TCCD on 60 healthy kindergarten students, aged from 4 to 6 years old (30 females, 30 males), without headache or systemic disease. The volunteers were recruited from the kindergarten in Chang Gung Medical Village. Written informed consent was obtained before the examination from parents of all the children receiving procedure. We performed the sonographic examinations in the pediatric neurosonographic exam room in Chang Gung Children's Hospital. It took 45 min to complete the whole procedure in each subject, including 15 min for environment adaptation and 30 min for sonographic procedure.

A computed sonography system (128XP; Acuson, a Siemen Company, Mountain View, CA) with a 2.0-MHz transducer (for intracranial arteries) and a 7.0-MHz linear transducer (for extracranial arteries) were used for the examination. Before the examination, we played with the children for 15 min. The room was rich in kid songs, colorful pictures and interesting toys in order to increase compliance of the subjects. The examination began after 5 min of rest in a supine position with the parents by the child's beside (for consolation). The probe was applied to the transtemporal window, supraorbital window [10], and carotid area (for internal carotid artery, ICA) when the volunteer was supine, and the suboccipital window (for basilar artery, BA) when in the left decubitus position. We studied in B-mode first and then in color Doppler mode to present the course of arteries. The color Doppler of blood flow toward the transducer was shown in red and flow away from the transducer was shown in blue. We surveyed the M1- and M2-segments of the middle cerebral artery (MCA) and the A1-segment of the anterior cerebral artery (ACA) through the transtemporal window, the A2-segment of the ACA through the supraorbital window. We surveyed the BA 1.5 cm distal to the junction of the vertebrobasilar system through the suboccipital window with mild head bending posture, and the ICA 1.5 cm distal to the common carotid artery through the carotid window. The site of measurement was set 1.5 cm distal to the junction to ascertain the circular lumen. We paid special attention to prevent turbulent flow at the site of Doppler recordings.

We collected data on age, sex, body weight (BW), body length (BL), and systolic and diastolic blood pressures (BP) before the examination. We measured peak-systolic (PS), end-diastolic (ED), and mean blood velocities of the right and left ACA-A1, A2; MCA-M1, M2; ICA; and BA, and depth of flow detected. Color Doppler measurements were taken only when the signal was stable for at least 5 s. We also collected Gosling pulsatile index (PI) and Pourcelot resistance index (RI) of the above arteries [11], and the diameters of the right and left ICA and BA so we could calculate TCBFV from the mean blood flow velocity and vessel chamber size. We searched the vessels by color Doppler mode. The diameters of vessels were calculated by real-time B-mode sonography without Doppler coded. The diameters were calculated at systolic phase. We calculated the intravascular flow volume as the product of time-averaged mean flow velocities and the cross-sectional area of the vessel. We defined TCBFV as the blood flow through the right and left ICA and BA. We used the Student's *t*-test and analysis of variance (ANOVA) with post hoc test for statistical analysis with a significant *p*-value less than 0.05 for all parameters.

3. Results

Ten children did not complete the sonographic procedure because of irritability and emotional intolerance. Thus, a total of 50 healthy children (8 – 4-year-old, 19 – 5-year-old, and 23 – 6-year-old children) was included in this study, including 25 girls and 25 boys. Their mean BP was 103.1 ± 12.0 over 62.3 ± 10.1 mm Hg. Their mean BW and mean BL were 21.3 ± 5.0 kg and 114.5 ± 7.3 cm, respectively (Table 1). There was no significant difference between the girls and boys in age, BW, or BP, either systolic or diastolic. All parameters of the main cerebral arteries by TCCD recording are summarized in Table 2. There was no significant difference between the right- and left-sided study in PS, ED, or mean of PI, RI of A1, M1, and M2 groups (*t*-test; $p > 0.05$). There was also no significant difference in the cerebral blood flow velocities between the boys and girls (Fig. 1). No significant difference was found between the right and left ICA in either PS, ED, mean velocity, PI, or RI, but a significant difference was detected in depth (*t*-test; $p = 0.004$). No statistically significant difference distinguished the group of age 4 from age 6 children in PS, ED, and mean velocities (ANOVA with post hoc test; $p > 0.05$). Neither did PI and RI of the main cerebral arteries differ significantly among

Table 1
The profiles of 50 children receiving transcranial Doppler sonography

Age (years)	
4 year, *n*	8
5 year, *n*	19
6 year, *n*	23
Sex	
Male:Female	25:25
Blood pressure (mm Hg)	
Diastolic pressure	62.3 ± 10.1
Systolic pressure	103.1 ± 12.0
Body height (mean ± SD, cm)	114.5 ± 7.3
Body weight (mean ± SD, kg)	21.3 ± 5.0

SD, standard deviation.