Ultrasound in Med. & Biol., Vol. 35, No. 3, pp. 360–366, 2009

0301-5629/09/$–see front matter

ELSEVIER

doi:10.1016/j.ultrasmedbio.2008.09.006

● *Original Contribution*

LATERAL VENTRICULAR SIZE IN EXTREMELY PREMATURE INFANTS: 3D MRI CONFIRMS 2D ULTRASOUND MEASUREMENTS

SANDRA HORSCH,*‡§ JOHAN BENGTSSON,† ANDERS NORDELL,† HUGO LAGERCRANTZ,† ULRIKA ÅDÉN,* and MATS BLENNOW‡

*Department of Woman and Child Health, Karolinska Institutet Stockholm, Sweden; †Department of Medical Physics, Karolinska University Hospital, Stockholm, Sweden; ‡Department of CLINTEC, Karolinska University Hospital, Stockholm, Sweden; and §Department of Neonatology, Sophia Children's Hospital, Rotterdam, The Netherlands

(*Received* 19 *March* 2008; *revised* 24 *August* 2008; *in final form* 5 *September* 2008)

Abstract—Ventriculomegaly at term age is an important predictor of neurologic outcome in preterm infants. Previous studies have found only poor correlations between two-dimensional (2D) cranial ultrasound (US) measurements of lateral ventricles and volume measurements using three-dimensional (3D) magnetic resonance imaging (MRI). Paired cranial MRI and US scans in a population based cohort of 28 extremely preterm infants were obtained at term equivalent age. A 3D MRI volume and five different 2D ultrasound measurements were assessed for each lateral ventricle. Correlations and interobserver variability were calculated. Reliability of US measurements and correlations between MRI volumes and US measurements of the frontal horns and ventricular midbody were consistently good. The highest correlation was achieved by combining the coronal frontal horn measurements to a frontal horn product (r^2 = right 0.94, left 0.95). Our study underlines the value of cranial ultrasound measurements in neonatal care and follow-up. (E-mail: s.horsch@gmx.de) **© 2009 World Federation for Ultrasound in Medicine & Biology.**

Key Words: **Brain imaging, White matter damage, Sonography, Outcome, Preterm infants, Ventriculomegaly.**

INTRODUCTION

The presence of cerebral ventriculomegaly at term equivalent age is an important and independent predictor of adverse cognitive and motor development in preterm infants (Ment et al. 1999). It can be easily detected by cranial two-dimensional (2D) ultrasound at the cotside. To quantify ventricular size, a variety of ultrasound measurements have been suggested by different authors (Davies et al. 2000; Govaert and de Vries 1997; Levene 1981; London et al. 1980; Ment et al. 1999). In our experience, the width of the frontal horns in the coronal plane and the width of the ventricular midbody in the sagittal plane are the most commonly used parameters in daily routine on neonatal intensive care units. However, there is no consensus as to which is the best parameter to use. Furthermore, interobserver variability has been a matter of concern, as well as correlation of 2D measurements with actual ventricular volume (Anderson et al. 2004). In the present study, we hypothesized that the frontal horn area correlates well to the total lateral ventricle volume. However, area measurements are not easily performed with all ultrasound devices. Therefore, we decided to measure an estimate of the frontal horn area (called frontal horn product) by multiplying two perpendicular linear measurements of the frontal horns, the short and the long axis of the frontal horn.

Ventricular volume can be accurately measured by three-dimensional (3D) magnetic resonance imaging (MRI), which is an established and valid method to assess brain tissue and fluid volumes (Harris et al. 1991; Kohn et al. 1991). One previous study has compared the two methods and found only limited correlation between 2D ultrasound measurements of ventricular size and cerebrospinal fluid (CSF) volume assessed by 3D MRI (Anderson et al. 2004). However, in this study, CSF volume was not subdivided into extra- and intraventricular CSF volume.

Therefore, the aim of the present study was to correlate five common linear 2D ultrasound measurements of lateral ventricular size (in the coronal plane:

Address correspondence to: Sandra Horsch, MD, Neonatal Research Unit, Q2, 07, Astrid Lindgrens Childrens Hospital, 17176 Stockholm, Sweden. E-mail: s.horsch@gmx.de

short and long axis of the frontal horn, in the parasagittal plane: the height of the frontal horn, the width of the ventricular midbody and the thalamo-occipital horn distance) and the frontal horn product to the lateral ventricular volume assessed by 3D MRI and thereby to determine the best ultrasound parameter to use in clinical practice to quantify ventricular size.

PATIENTS AND METHODS

Patients and perinatal data

From August 2004 to August 2005, all infants born with a gestational age below 27 weeks in the Stockholm region were included. An ultrasound and an MRI scan of the brain were performed at term equivalent age as part of clinical routine. For acquisition of MRI images that exceeded the clinical routine protocol, approval was given by the local ethical board. Informed consent was obtained from all parents of infants included in the study. Perinatal data and clinical courses were prospectively collected. Infants with chromosomal disorders, congenital abnormalities, congenital infections, and proven metabolic or malignant disorders were excluded from further analysis.

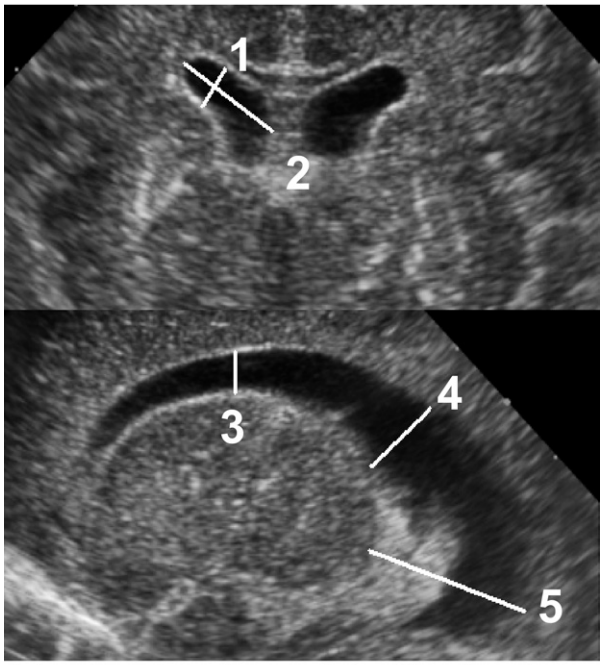
Cranial ultrasound

Cranial ultrasound was performed the same day as the MRI scan. Infants were scanned by an examiner experienced in neonatal cranial ultrasound (S.H.) using the ACUSON Sequoia ultrasound system (Siemens Medical Solutions, Germany) equipped with a multifrequency sector transducer (5 to 8 MHz). Ultrasound was performed in coronal and sagittal/parasagittal planes through the anterior fontanelle obtaining sequential sections according to Levene (1985). The images were stored digitally and the following five ventricular measurements obtained for the right and left lateral ventricle:

(1) in the coronal plane at the level of the third ventricle: width of the frontal horn in the long (measurement 1) and short axis (measurement 2) (Fig. 1); and (2) in the parasagittal plane: width of the frontal horn (measurement 3), width at the midbody (measurement 4) and the thalamo-occipital horn distance (measurement 5) (Fig. 1).

Furthermore, to get an estimate of the frontal horn area the short and long axis measurements of the frontal horn were multiplied resulting in the frontal horn product (frontal horn product = short axis measurement × long axis measurement).

To study the interobserver variability, and thereby the reliability of the ventricular measurement, the digitally stored images were reanalysed by a second independent observer (M.B.) for all patients.



1: frontal horn short axis 2: frontal horn long axis
3: frontal horn height 4: ventricular midbody
5: thalamo-occipital horn distance

Fig. 1. Ultrasound measurements.

MR imaging

All MR scans were performed at the Astrid Lindgren Children's Hospital at Karolinska University Hospital in Stockholm, Sweden, using a 1.5 Tesla magnetic resonance system (Philips Intera). A coronal T1 weighted 3D gradient echo sequence (TR 40 ms, TE 4.6 ms, Flip angle 30 degrees, NSA 2, scanning matrix 256 × 206, slice thickness 2 mm (1 mm spacing), FOV 180 mm, SENSE $r = 1.5$) was added to the standard protocol to allow exact volumetric measurements. According to our standard clinical protocol for neonatal MRI, infants were fed and given chloral hydrate (30 mg/kg p.o. or rectally) 15 to 30 min before the examination. Six infants did not receive chloral hydrate either because they were already deeply asleep before the examination (n = 4) or parents did not give consent to the application of sedative medication (n = 2).

MR image postprocessing

To segment the lateral ventricles, image-processing software was developed and implemented in Matlab 7.0 (Mathworks, MI, USA). The software uses a semiautomatic gradient vector flow active contour model (Kass et al. 1987; Xu et al. 1998) that is attracted to the ventricle edges. Dedicated software provided by Xu et al. (1998) was used to calculate the gradient vector flow field. Apart from reducing inter- and intraobserver variability com-