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Original article

Evaluation of choroid plexus with fetal magnetic resonance imaging: What happens in ventriculomegaly?

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Abstract

Objectives: Diagnosis of ventriculomegaly (VM) and identification of choroid plexus (CP) can be challenging with fetal magnetic resonance imaging (MRI). Our aim is to create an adjunct method for supporting the diagnosis of VM by investigating the CP-ventricular wall separation distance in fetuses with and without VM (nV) with fetal MRI.

Methods: T2-weighted fetal MRIs of 154 fetuses were retrospectively evaluated. The CP separation was defined as the distance between the medial wall of the dependent ventricle and distal tip of the CP glomus. The measurement was performed at the same plane with the dependent ventricle measurement by two blinded readers.

Results: 41 fetuses with VM (mean gestational age 27 (19–35 weeks), and 44 nV fetuses (mean gestational age 28 (20–39 weeks) were included. Interobserver reliability was excellent for ventricle diameters ($R = 0.99$, confidence interval (CI) 95%) and the separation of CP ($R = 0.98$, CI 95%). Mean distance of CP separation was 10.7 mm ± 4.2 mm and 3.0 ± 1.6 mm in VM and nV fetuses, respectively ($p < 0.001$). The distance of CP separation to differentiate VM cases was 6.5 mm (sensitivity: 0.98, specificity: 0.98). Separation of CP was correlated to ventricle diameter in cases with ($R = 0.674$) and without VM ($R = 0.805$). For the cut-off value >0.65 cm for the distance between the medial wall of the dependent ventricle and the medial border of choroid plexus sensitivity is 97.56, specificity 95.45, positive predictive value (PPV) 95.20, negative predictive value (NPV) 97.70, and likelihood ratio (LR) (+) is 21.46.

Conclusion: Fetal CP can be efficiently evaluated with MRI, and the increase of CP-ventricular wall separation distance in correlation with the ventricle diameter is a reliable sign in the diagnosis of fetal VM.

Keywords: Choroid plexus; Ventriculomegaly; Magnetic resonance imaging; Fetus; Ultrasonography

1. Introduction

Choroid plexuses (CP) are villous vascular structures, which develop from the dorsal roof of the ventricular system and form one of the blood-brain barriers. Shortly after the closure of the neural tube, CPs develop in the roof of the neural tube at the 4th, both lateral, and 3rd ventricles. The lateral CPs are thin, leaf-like, villous, vascular structures, which are located at the dorsal roof of the inner ventricular surface as folds of pia mater [1]. The narrow cleft, to which the choroids plexus is attached in the ventricles, is defined as the choroidal fissure [2].

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Ventriculomegaly (VM) is relatively common in pregnancies with the incidence ranging from 3.6 to 7.8/10,000 [3–5], and it is the most common central nervous system (CNS) abnormality identified on prenatal sonography (US). In the prenatal population, VM is diagnosed when the atrium of the lateral ventricle is ≥10 mm [6–9]. Ventricle diameter values within the 10–15 mm range are classified as mild VM, while values greater than 15 mm indicate severe VM [10–12]. Majority of neonates diagnosed with the isolated form of mild VM in the fetal period develop normally [13], but some may have transient or permanent cognitive, motor and psychosocial developmental delay [14–16]. Severe VM is generally accompanied by other CNS and non-CNS abnormalities and in such cases, poorer outcomes are to be expected [12].

The body of the CP fills the lateral ventricular space between its medial and lateral borders. In VM cases, the CP of the dependent lateral ventricle separates from the medial wall and so-called 'dangles' into the lumen. Separation of the CP from the medial ventricular wall by ≥ 3 mm with the US has been associated with an abnormal outcome like an association with trisomy 21 or developmental problems [17]. In recent years magnetic resonance imaging (MRI) has gained increased value in diagnosing VM and analyzing possible associated CNS abnormalities, which can be occult on prenatal US [18,19]. Fetal MRI has higher contrast resolution than the prenatal US and allows better differentiation of normal from abnormal tissue [20]. The 10-mm rule, described on a sonographic axial view of the fetal atrium is used as the upper limit of normal on MRI [21]. In a study comparing ventricular measurements on US and MRI, there was no significant difference in fetuses with VM [22]. The outcome of VM depends on the cause and degree of ventricular enlargement. Fetal MRI is particularly helpful in demonstrating associated anomalies and in showing the multiplanar detailed anatomy.

CP separation is a well-documented and widely used finding in the prenatal assessment of VM with the US, however the evaluation of the CP is almost ignored in fetal MRI reports in the routine clinical practice. Although there are number of studies, which define VM and associated anomalies with MRI along with the follow-up results, the MRI appearance of fetal CP in normal and dilated ventricles has not been reported so far in the English literature to our knowledge. The familiarity with the normal CP and awareness of its appearance in VM would contribute to the diagnosis and further evaluation of fetuses. In the antenatal period, diagnosis of VM solely depends on ventricle diameter measurements. Thus, we hypothesized that documenting CP position may provide valuable data in the diagnosis of VM, if used with ventricle measurement. In this study, our aim is to create an adjunct method for supporting the diagnosis of VM by investigating the CP-ventricular wall separation distance in fetuses with and without VM (nV) with fetal MRI.

2. Subjects and methods

2.1. Patient selection and MRI technique

In this IRB-approved study (no: 2012-502), fetal cranial MRIs from our database of 154 fetuses were retrospectively evaluated. Waived consent is obtained before all fetal MRI procedures performed in our institution to use data for research. MRI was performed using a 1.5 Tesla (T) system (Magnetom Symphony, Siemens Healthcare, Erlangen, Germany) with a body array coil during free maternal breathing. The mothers were supine during the examination and they were examined with our routine fetal MRI protocol, including HASTE sequences. The images were obtained in fetal orthogonal planes with the following parameters: one signal acquired, slice thickness: 3 mm, no intersection gap, rectangular field of view matrix: 240 × 256, and field of view: 26 to 35 cm (optimized for GA of each fetus), acquisition: 1, time to echo: 78 ms, repetition time: 1000 ms, flip angle: 150 degrees, echo train length: 179, bandwidth: 230 Hz/pixel. No sedation was used.

For the evaluation of CP separation from the medial ventricular wall, the angle (θ) between the interventricular septum of the fetal brain and imaginary horizontal line of MRI table was assessed. In the included cases; the θ angle between the interventricular septum of the fetal brain and imaginary horizontal line of MRI table was between 0 and 45 degrees to observe the gravitational separation of CP from the medial ventricle wall (Fig. 1a). If the θ angle was 45 to 90 degrees the fetus was excluded from the study (Fig. 1b). For VM cases, ≥10 mm of atrial diameter of the dependent lateral ventricle was sought. The fetuses whose interventricular septum, ventricle walls, and choroid plexus could clearly be delineated were included (n = 85).

69 fetuses that did not meet those criteria due to motion artifacts, improper cranial position (θ > 45 degrees), and CNS anomalies were excluded from the study.

2.2. Measurement technique

Two radiologists experienced in fetal MRI (U.O 16 years and S.U 5 years) reviewed all the MR images blinded to patient data using picture archiving and communication system workstations (Siemens Medical Systems) on monochrome LCD monitors (RadiForce GS521, EIZO). Dependent lateral ventricle atrium was identified on the axial plane at thalamic/suprathalamic level, and all measurements were obtained at that level. The CP separation distance was defined as the distance between the medial wall of the dependent ventricle and

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