The brainstem-vermis and brainstem-tentorium angles allow accurate categorization of fetal upward rotation of the cerebellar vermis

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Short title: BT and BV angle in posterior fossa malformations

ABSTRACT

Objective: To evaluate the role of the brainstem-vermis (BV) and brainstem-tentorium (BT) angles in the differential diagnosis of upward rotation of the fetal cerebellar vermis.

Methods: the BV and BT angles were measured retrospectively on median sonographic views of the brain in 31 fetuses at 19-28 weeks' gestation with upward rotation of the cerebellar vermis because of Blake's pouch cyst (12 cases), Dandy Walker malformation (12 cases) and cerebellar vermian hypoplasia (7). Eighty normal fetuses at 20-24 weeks were included as controls.

Results: In the control group BV and BT angles were 9.1° $\pm$ 3.5 (range 4-17) and 29.3° $\pm$ 5.8 (range 21-44) respectively. The BV angle was found to be progressively and significantly increased in the three subgroup of anomalies: Blake's pouch cyst (23° $\pm$ 2.8, range 19-26), vermian hypoplasia (34.9° $\pm$ 5.4, range 24-40) and Dandy-Walker malformation (63.5° $\pm$ 17.6, range 45-112). The BT angle had a similar pattern but there was overlap among the different groups

Conclusion: The BV angle and to a lesser degree the BT angle are simple and reproducible measurements that provide valuable additional information for the categorization of upward rotation of the fetal cerebellar vermis. From midgestation, a BV angle > 45° degrees is strongly suggestive of a Dandy-Walker malformation while a measurement < 30° favours the diagnosis of a Blake's pouch cyst.

Key Words: fetus, ultrasound, prenatal diagnosis, congenital anomalies, Dandy-Walker malformation, Blake's pouch cyst, vermian hypoplasia

Introduction

Fetal posterior fossa fluid collections associated with an upward rotation of the cerebellar vermis range from benign asymptomatic conditions to severe abnormalities associated with neurological impairment.[1-9] The most frequent of these anomalies, namely Blake's pouch cyst, vermian hypoplasia and Dandy-walker malformation have a similar sonographic appearance but a much different prognosis.[4] A specific diagnosis with either ultrasound or magnetic resonance imaging is possible but is frequently difficult and relies mostly upon subjective criteria[1, 4-9]

We aimed at evaluating the diagnostic contribution of an objective approach based upon the brainstem-vermis (BV) angle and the brainstem tentorium (BT) angle, that we have previously demonstrated to be feasible and reproducible sonographic measurements.[10]

Methods

The BV and BT angle were measured retrospectively in 2 referral centers for prenatal diagnosis, in fetuses with posterior fossa fluid collections associated with upward rotation of the cerebellar vermis (study group) retrieved from a series previously reported[4] and prospectively in normal fetuses at midgestation consecutively evaluated (controls). Measurements were obtained from median views of the fetal brain as previously described (Figure 1).[10] Inclusion criteria for the study group were the availability of digital images and/or ultrasound volumes of good quality as well as a detailed postnatal follow-up. In the study group three-dimensional (3D) ultrasound volumes and two-dimensional (2D) digital images demonstrating a median view of the brain were used for the measurements, utilizing *4D View 9.0* (GE Healthcare, Milan, Italy) and *Adobe Photoshop 6.0* (Adobe Systems Incorporated, San Jose, USA) respectively. In the control group, the BV and BT angles were always measured from ultrasound volumes. All measurements were performed by two operators (EC, PV). Statistical analysis was performed by calculating means and standard deviations. Groups were compared using the U-Mann Whitney test.

Results

A total of 31 fetuses ranging from 19 to 28 weeks' gestation with posterior fossa fluid collections (12 with Blake's pouch cyst, 12 with Dandy-Walker malformation and 7 with vermian hypoplasia) were included into the study group (Figure 2). Eighty normal fetuses at 20-24 weeks' gestation were used as controls. The measurements of the BV and BT angles are reported in Table 1. Controls always had a BV angle <18° and a BT angle <45°. The BV angle was progressively and significantly increased in the three subgroups of anomalies (Figure 3, Table 2). The BT angle demonstrated a similar pattern, but there was more overlapping among groups (Figure 4, Table 2).

Discussion

Our results suggest that the measurement of the BV angle discriminates accurately posterior fossa fluid collections associated with an upward rotation of the cerebellum.

In the late first trimester, the fourth ventricle is large and a relatively small cerebellum is found on top of it. In the following weeks the cerebellum grows to enfold completely the fourth ventricle. However, a small finger-like appendage of the fourth ventricle, the Blake's pouch, is frequently seen protruding into the cisterna magna, caudally to the cerebellum.[8] It has been suggested that there is a continuum of anatomic anomalies involving the fourth ventricle-Blake's pouch complex.[8] The mildest of these anomalies is the Blake's pouch cyst, a persistence of the Blake's pouch that results in an isolated superior displacement of the cerebellar vermis. At the other end of the spectrum stands the Dandy-Walker malformation, where the upward displacement of a normal to hypoplastic vermis is associated with an enlargement of the cisterna magna. In vermian hypoplasia (previously referred to as Dandy-Walker variant) the cisterna magna is of normal size and the vermis is small and frequently (although not always) rotated upward. Distinguishing the three entities is important, because a Blake's pouch cyst is a risk factor for anatomic and chromosomal anomalies but when isolated is probably a normal variant. Conversely, Dandy-Walker malformation and vermian hypoplasia are true malformations frequently associated with abnormal neurodevelopment.[4] The differential diagnosis depends upon the visualization of the tentorium and/or torcular (normal position in Blake's pouch cyst and vermian hypoplasia, upward displacement in Dandy-Walker) and appearance of the vermis (intact in Blake's pouch cyst, hypoplastic in vermian hypoplasia, normal to hypoplastic in Dandy-Walker malformation.[1, 4-7] These findings can be demonstrated in utero with sonography and/or magnetic

resonance but they are subjective and even in expert hands may be difficult to interpret, particularly in early gestation[4]

In our series the BV angle discriminated accurately this group of anomalies. In normal fetuses at midgestation the angle was always < 18°. In fetuses with Blake's pouch cyst it was always < 30°, in those with Dandy-Walker malformation it was consistently > 45°, while vermian hypoplasia had intermediate values (Figure 3).

The BT angle was increased in the study group compared to controls, but there was overlapping among the different types of anomalies and this certainly limits the diagnostic value of this measurement (Figure 4).

We do acknowledge the limitations of our study. The number of abnormal cases was relatively small and they were investigated retrospectively. Further experience is certainly needed. Nevertheless the spread of measurements between normals and abnormals and among the different categories of abnormals suggest that the BV angle may reveal important in the differential diagnosis of fetal posterior fossa fluid collections, at least as in combination with the traditional criteria. [1, 4, 5, 7]After 20 weeks' gestation, a measurement > 45° is strongly indicative of a Dandy-Walker malformation. A value < 30° favours the diagnosis of Blake's pouch cyst. An intermediate value in our series was associated with vermian hypoplasia, however the number of cases was limited and caution is certainly warranted in making this difficult diagnosis.[4, 6]

In conclusion, we suggest that the BV angle and to a lesser degree the BT angle are objective findings useful to differentiate fetal entities that are sonographically similar but carry a different prognosis.

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Table 1. *Brainstem-vermis and brainstem-tentorium angles in the study population and in controls.*

Measurement	Ultrasound findings	Cases	Mean	Standard deviation	Range
BV angle (°)	Controls	80	9.1	3.5	4-17
	Blake's pouch cyst	12	23.0	2.8	19-26
	Vermian hypoplasia	7	34.9	5.4	24-40
	Dandy-Walker	12	63.5	17.6	45-112
BT angle (°)	Controls	80	29.3	5.8	21-44
	Blake's pouch cyst	12	42.2	7.1	32-52
	Vermian hypoplasia	7	52.1	7.0	45-66
	Dandy-Walker	12	67.2	15.1	51-112

***Table 2**. Comparison of brainstem-vermis (BV) and brainstem-tentorium (BT) angles in controls and fetuses with anomalies*

Measurements	Comparisons	P value (U-Mann Whitney test)
BV angle	Controls < Blake's pouch cyst	<0.00000005
	Controls < Dandy-Walker	<0.00000005
	Controls < vermian hypoplasia	<0.00005
	Blake's pouch cyst < Dandy-Walker	<0.00005
	Blake's pouch cyst < vermian hypoplasia	<0.005
	Vermian hypoplasia < Dandy-Walker	<0.0005
BT angle	Controls < Blake's pouch cyst	<0.000005
	Controls < Dandy-Walker	<0.00000005
	Controls < vermian hypoplasia	<0.00005
	Blake's pouch cyst < Dandy-Walker	<0.00005
	Blake's pouch cyst < vermian hypoplasia	= 0.01
	Vermian hypoplasia < Dandy-Walker	<0.005

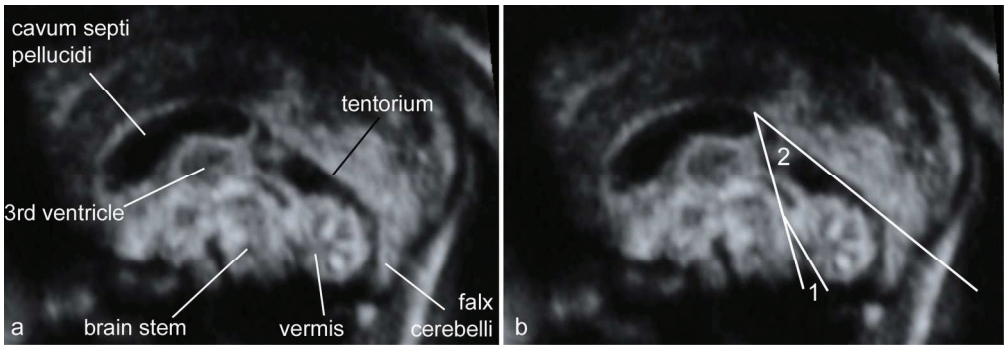
LEGENDS TO FIGURES

Figure 1. Measurement of the brainstem-vermis (BV) and brainstem-tentorium (BT) angles; a) a median view of the fetal brain is obtained (in this case after the acquisition of an ultrasound volume starting from an axial view) and the main anatomic landmarks are identified; b) a line is drawn tangentially to the dorsal aspect of the brain stem and a second line is drawn tangentially to the ventral contour of the cerebellar vermis; the interposed angle (1) is the BV angle; the BT angle is measured between the former line and a third line tangential to the lower edge of the tentorium (2).

Figure 2. Measurement of BV angle (1) and BT angle (2) in fetuses with Blake's pouch cyst (a); cerebellar vermis hypoplasia (b); Dandy-Walker malformation (c). The BV angles are 26°, 39°, 73° respectively. The BT angles 45°, 50°, 66° respectively. These images were obtained from 3D ultrasound volumes acquired originally by positioning the probe along the posterior fontanelle. Corresponding images from the same cases obtained by acquiring the volumes with a transabdominal axial approach are also provided (d,e,f), to demonstrate the excellent correlation between the two approaches.

Figure 3. Measurement of the BV angle in controls and in the different subgroups of anomalies

Figure 4. Measurement of the BT angle in controls and in the different subgroups of anomalies



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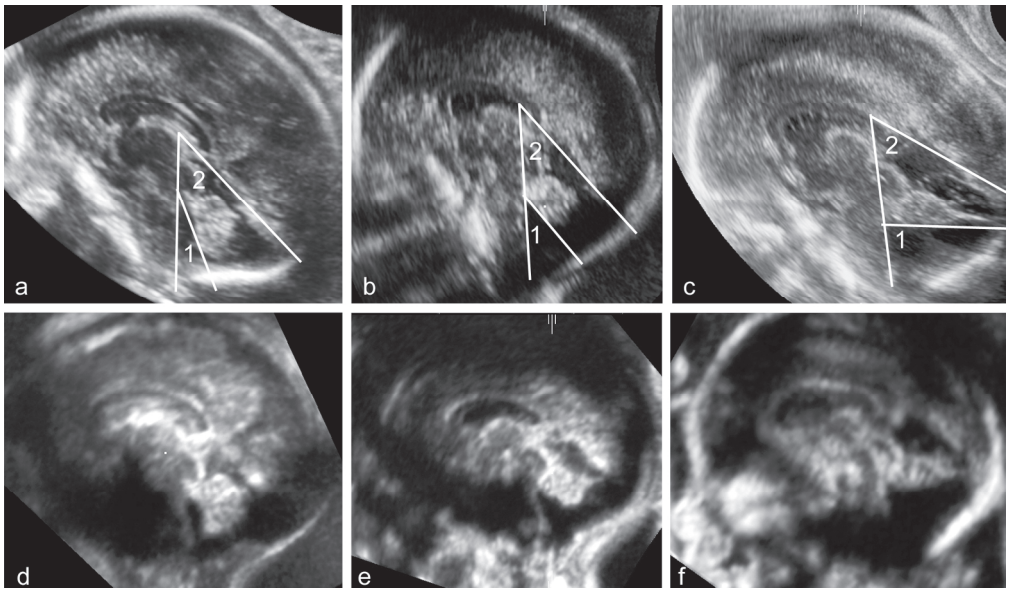

Figure 2 Measurement of BV angle (1) and BT angle (2) in fetuses with Blake's pouch cyst (a); cerebellar vermis hypoplasia (b); Dandy-Walker malformation (c). The BV angles are 26°, 39°, 73° respectively. The BT angles 45°, 50°, 66° respectively. These images were obtained from 3D ultrasound volumes acquired originally by positioning the probe along the posterior fontanelle. Corresponding images from the same cases obtained by acquiring the volumes with a transabdominal axial approach are also provided (d,e,f), to demonstrate the excellent correlation between the two approaches.

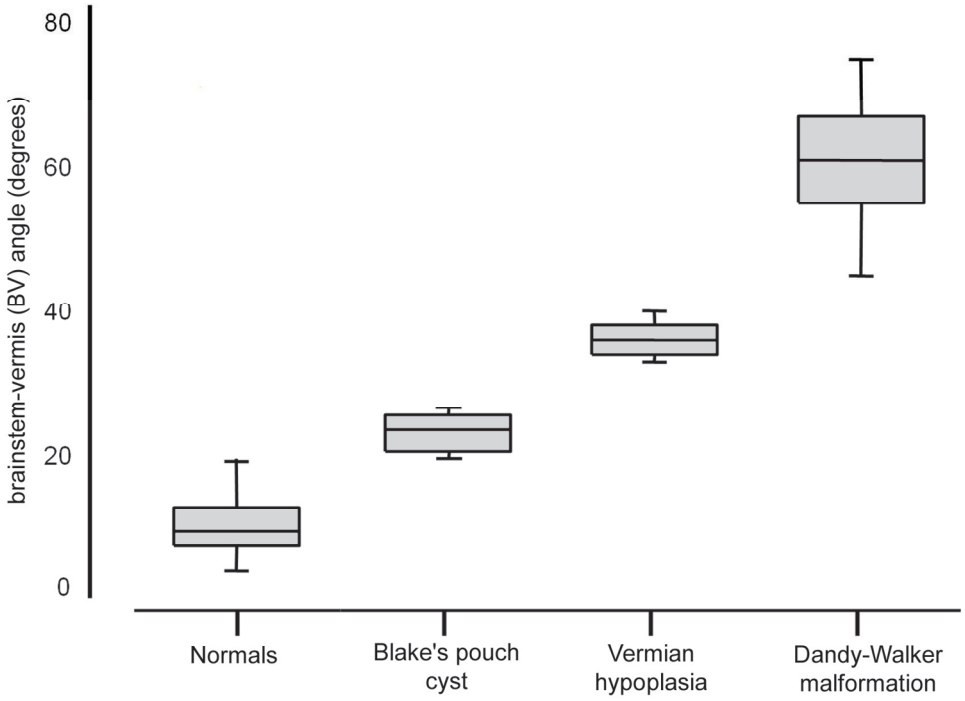

Figure 3 Measurement of the BV angle in controls and in the different subgroups of anomalies

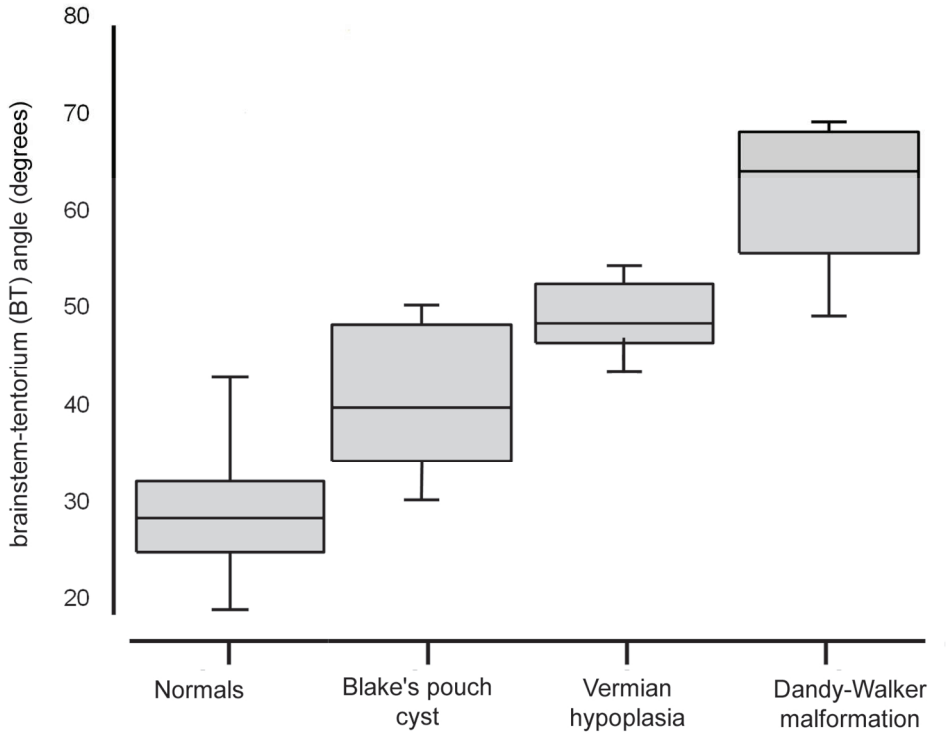

Figure 4 Measurement of the BT angle in controls and in the different subgroups of anomalies