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Appearance of the fetal posterior fossa at 11 + 3 to 13 + 6 gestational weeks on transabdominal ultrasound examination

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KEYWORDS: cisterna magna; first-trimester scan; fourth ventricle; prenatal diagnosis; spina bifida; TCD

ABSTRACT

Objectives *To describe the sonographic appearance of the structures of the posterior cranial fossa in fetuses at 11 + 3 to 13 + 6 weeks of pregnancy and to determine whether abnormal findings of the brain and spine can be detected by sonography at this time.*

Methods *This was a prospective study including 692 fetuses whose mothers attended Innsbruck Medical University Hospital for first-trimester sonography. In 3% (n = 21) of cases, measurement was prevented by fetal position. Of the remaining 671 cases, in 604 there was either a normal anomaly scan at 20 weeks or delivery of a healthy child and in these cases the transcerebellar diameter (TCD) and the anteroposterior diameter of the cisterna magna (CM), measured at 11 + 3 to 13 + 6 weeks, were analyzed. In 502 fetuses, the anteroposterior diameter of the fourth ventricle (4V) was also measured. In 25 fetuses, intra- and interobserver repeatability was calculated.*

Results *We observed a linear correlation between crown–rump length (CRL) and CM (CM = 0.0536 × CRL − 1.4701; $R^2 = 0.688$), TCD (TCD = 0.1482 × CRL − 1.2083; $R^2 = 0.701$) and 4V (4V = 0.0181 × CRL + 0.9186; $R^2 = 0.118$). In three patients with posterior fossa cysts, measurements significantly exceeded the reference values. One fetus with spina bifida had an obliterated CM and the posterior border of the 4V could not be visualized.*

Conclusions *Transabdominal sonographic assessment of the posterior fossa is feasible in the first trimester. Measurements of the 4V, the CM and the TCD performed at this time are reliable. The established reference values assist in detecting fetal anomalies. However, findings must be interpreted carefully, as some supposed malformations might be merely delayed development of brain structures.*

INTRODUCTION

Early diagnosis of malformations has long been a goal in fetal medicine[1,2]. Widespread implementation of nuchal translucency thickness (NT) measurement has led to increasing numbers of women undergoing ultrasound examination of their fetuses in the first trimester of pregnancy. Assessment of fetal anatomy has always been part of this early scan[3,4], and recent years have seen significant improvement in ultrasound technology, thus affording better resolution and hence the ability to visualize smaller structures.

Our study aimed to examine the structures of the posterior fossa in fetuses at 11 + 3 to 13 + 6 weeks of pregnancy and to determine whether it is possible sonographically to detect malformations of the posterior fossa and spine at this time.

SUBJECTS AND METHODS

This was a prospective study of 692 fetuses undergoing routine first-trimester ultrasound examination at the Fetal Medicine Clinic of the Department of Gynaecology and Obstetrics of Innsbruck Medical University Hospital. This center serves as a tertiary referral unit as well as providing screening services for a low-risk population. The study was approved by the local ethics committee, and informed consent was obtained from all patients.

In addition to the routine first-trimester scan, in all fetuses with a crown–rump length (CRL) between 45

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and 84 mm, we investigated the posterior fossa using a Voluson E8 or Voluson 730 Expert (GE Medical Systems Kretztechnik, Zipf, Austria) or an Aloka SSD 3500 (Aloka Inc., Tokyo, Japan) ultrasound machine. To achieve this, the fetal head was insonated through the anterior fontanelle in an axial plane, the plane used to measure the biparietal and fronto-occipital diameters (Figure 1). The transducer was then tilted caudally from this plane until the fourth ventricle (4V), the cisterna magna (CM) and the cerebellar nodules became visible (Figures 1 and 2).

Measurement followed strict criteria. The correct insonation plane showed anteriorly the falx cerebri and choroid plexus, and posteriorly the brainstem, 4V, cerebellum and CM. Further criteria included adequate magnification (head filling the entire image) and optimal setting of the gain. Calipers had to be placed on the echogenic parts of the structures being investigated ('on-to-on', Figure 2), similar to caliper placement for NT measurement. Image acquisition and measurements were performed three times in each case and, of the three images stored, the one that best met all the criteria for measurement was selected for analysis.

Fetal position prevented the posterior fossa from being insonated in 21 (3%) of the 692 fetuses. In 671 fetuses we measured the distance between the outer margins of the cerebellar nodules (transcerebellar diameter, TCD) and the distance between the posterior border of the 4V and the inner side of the occipital bone (anteroposterior diameter of the CM). Of these, 604 fetuses had a normal 20-week scan in our tertiary level institution or were born healthy, and their data were used to construct reference values for TCD and CM. In 502 fetuses, we additionally measured the distance between the brainstem and the posterior border (i.e. the anteroposterior diameter)

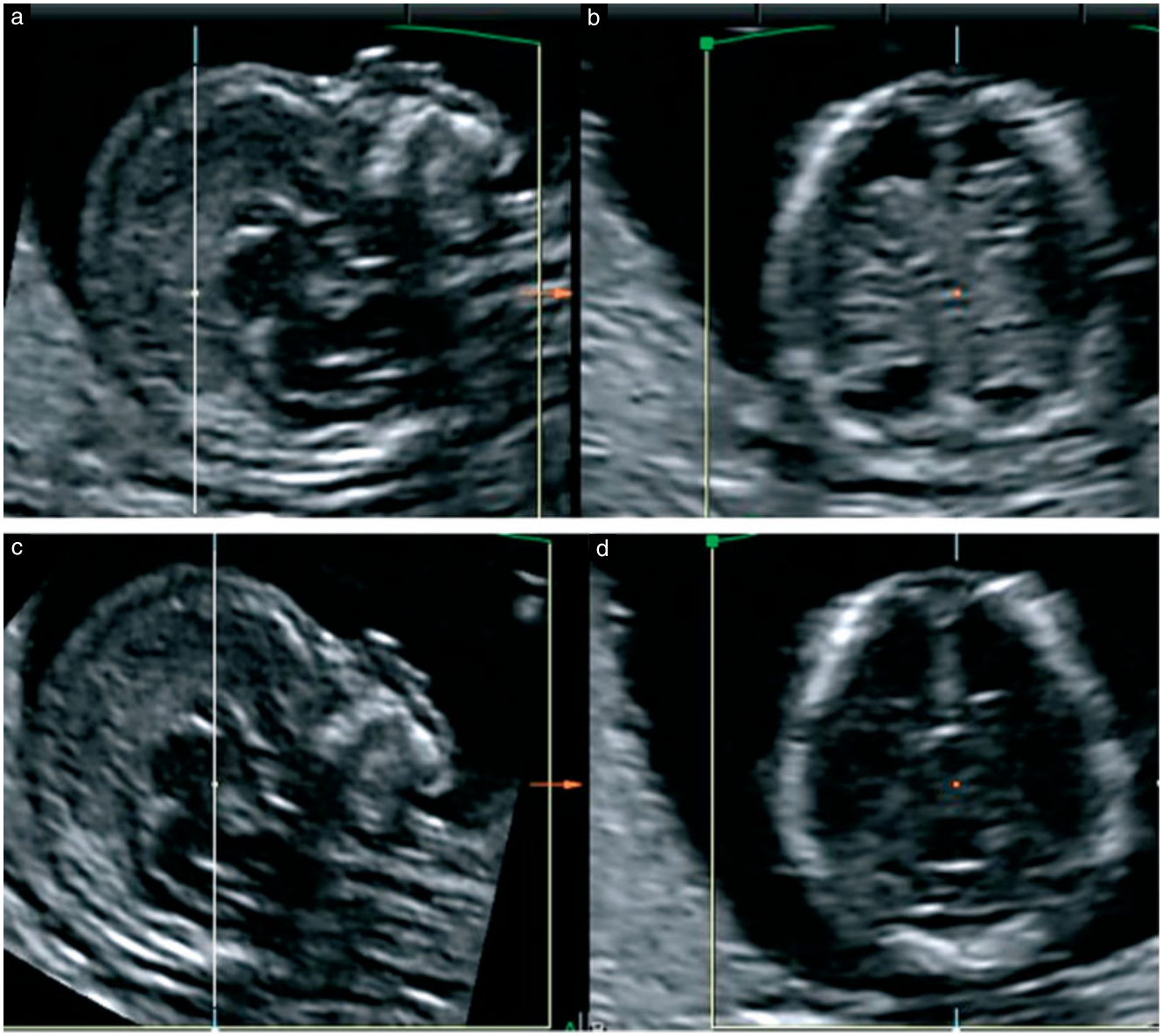

Figure 1 Transabdominal sonography of the fetal head at 13 + 2 weeks: three-dimensional reconstruction with sagittal (a,c) and axial (b,d) views demonstrating the different insonation planes (white lines) for measurement of the biparietal diameter (a,b) and for depiction of the posterior fossa (c,d).

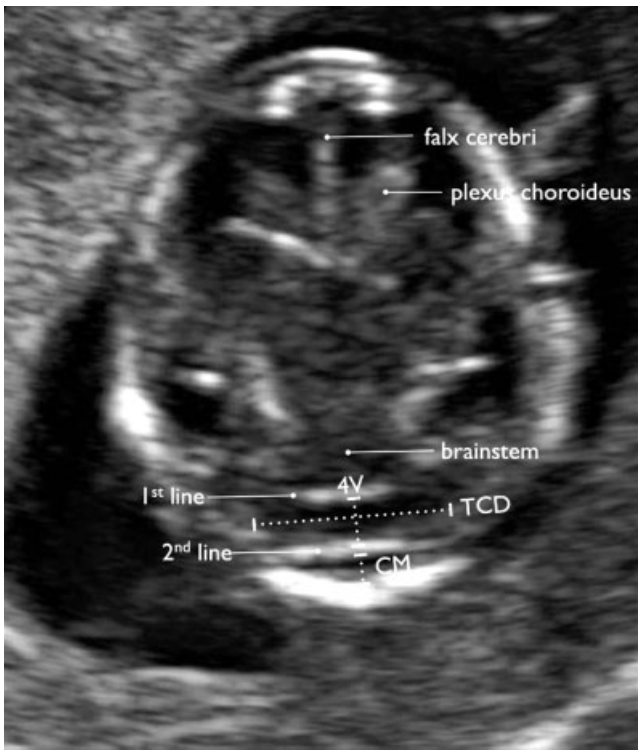

Figure 2 Transabdominal sonography of the head in a normal 12 + 4-week fetus, showing measurements of transcerebellar diameter (TCD), cisterna magna (CM) and fourth ventricle (4V). The indicated hyperechoic lines are the posterior border of the brainstem/anterior border of the 4V (1st line) and the posterior border of the 4V/anterior border of the CM (2nd line).

of the 4V. The anterior and posterior borders of the 4V were visible as two transverse echogenic lines, which were nearly identical in echogenicity to that of the skull. In 444 of these fetuses we could confirm normal development at the 20-week scan or at delivery and their data were used for construction of reference values for the 4V.

Intra- and interobserver repeatability were calculated in 25 fetuses using the method of Bland and Altman[5]. For this purpose both Sonographer 1 (M.S.) and Sonographer 2 (V.W.) scanned the fetuses and measured TCD, CM and 4V twice. Sonographers were not present at the same time during scanning and both were blinded to the results on the screen. The intraobserver repeatability was calculated using pairs of measurements made by Sonographer 1 and the interobserver repeatability was calculated using the first of each observer's pair of measurements. In all cases, measurements were performed during a single scanning session.

Statistical analysis was performed with SPSS software, version 17.0 (SPSS Inc., Chicago, IL, USA), and MedCalc, version 5.00 (MedCalc Software, Mariakerke, Belgium).

RESULTS

We found a linear correlation between CRL and each of CM, TCD and 4V (Figures 3–5). Measurements taken by the same sonographer were not significantly different for different ultrasound devices.

Intraobserver repeatability for Sonographer 1, gave a mean (limits of agreement) value for TCD of −0.02 (−1.30, 1.25) mm, for 4V of −0.13 (−1.21, 0.96) mm and for CM of 0.03 (−0.63, 0.69) mm. Interobserver repeatability between Sonographer 1 and Sonographer 2 gave results for TCD of 0.17 (−1.76, 2.11) mm, for 4V of 0.02 (−0.48, 0.52) mm and for CM of 0.00 (−0.84, 0.84) mm.

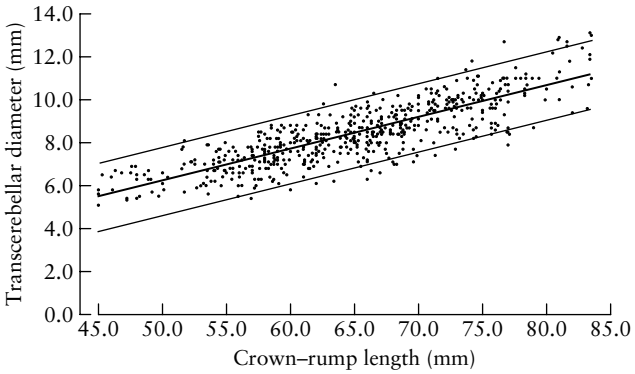

Figure 3 Reference range (mean and 5th and 95th percentiles) for transcerebellar diameter (TCD) according to crown–rump length (CRL) ($n = 604$). A linear correlation was observed (TCD = 0.1482 × CRL − 1.2083; $R^2 = 0.7011$).

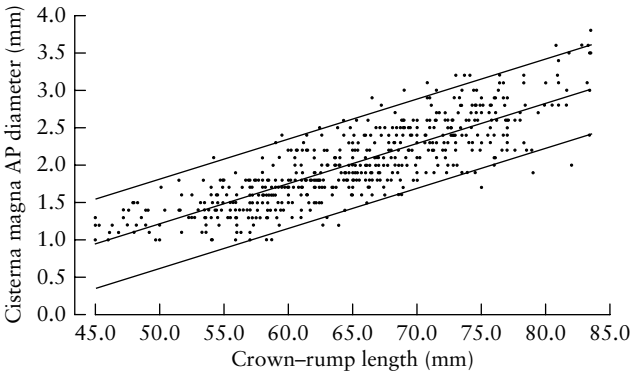

Figure 4 Reference range (mean and 5th and 95th percentiles) for cisterna magna (CM) anteroposterior (AP) diameter according to crown–rump length (CRL) ($n = 604$). A linear correlation was observed (CM = 0.0536 × CRL − 1.4701; $R^2 = 0.6882$).

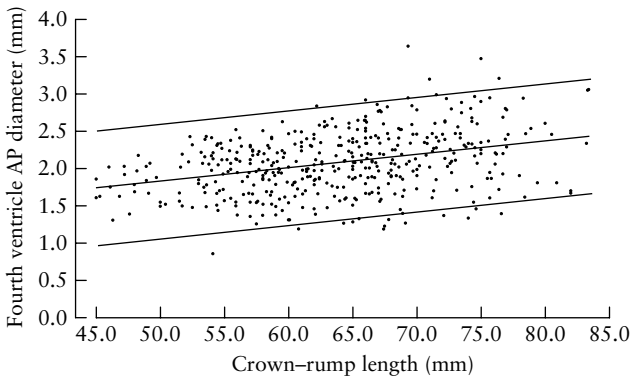

Figure 5 Reference range (mean and 5th and 95th percentiles) for fourth ventricle (4V) anteroposterior (AP) diameter according to crown–rump length (CRL) ($n = 444$). A linear correlation was observed (4V = 0.0181 × CRL + 0.9186; $R^2 = 0.1184$).

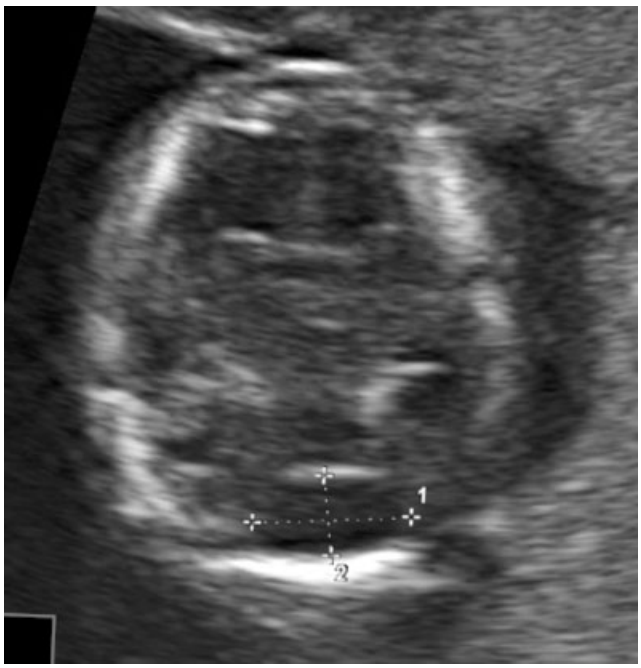

Figure 6 Transabdominal ultrasound image showing posterior fossa cyst (calipers) in a 13 + 0-week fetus.

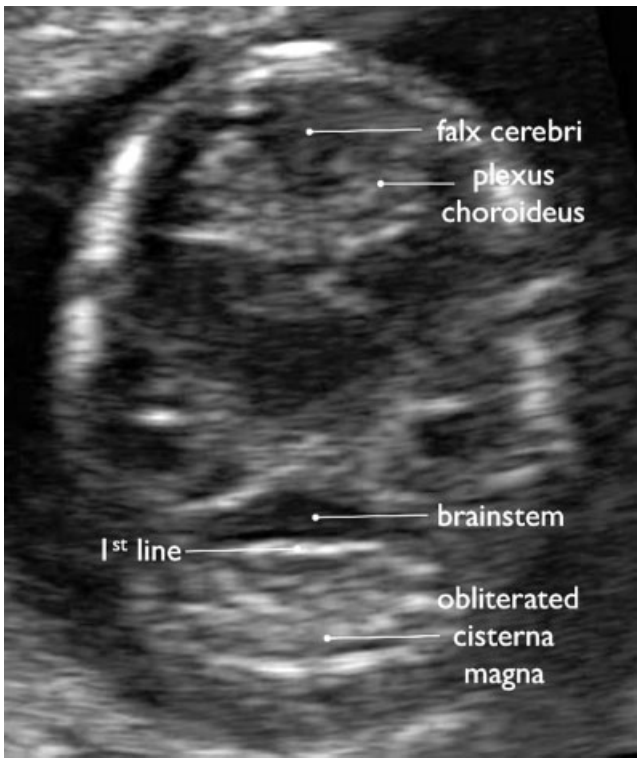

Figure 7 Transabdominal ultrasound image showing posterior fossa in a 13 + 4-week fetus with spina bifida. Only the first line (posterior border of the brainstem (1st line)) is visible.

Four fetuses with abnormalities in the posterior fossa were excluded from analysis for construction of reference values; of these, three had a posterior fossa cyst (Figure 6). One of them was apparently isolated at the first-trimester scan, and the karyotype was normal. The cyst gradually resolved during the course of pregnancy; at 23 weeks the fetal brain, and in particular the posterior fossa, appeared normal and no other abnormalities were noted. Postnatal outcome was good. In another fetus, an isolated tiny atrioventricular septal defect was diagnosed at 16 gestational weeks and confirmed postnatally. The karyotype was normal. The third fetus had a posterior fossa cyst in combination with increased NT and disproportion of the cardiac ventricles with tricuspid regurgitation. In this fetus the karyotype was trisomy 13. In all three patients, CM measurements were significantly above the normal range, being 4.9 mm, 4.7 mm and 5.0 mm, respectively.

Our series included one fetus with spina bifida at 13 + 4 gestational weeks (Figure 7). In this fetus, the 4V was displaced posteriorly and the CM obliterated. Because of this, the posterior echogenic line, produced by the posterior border of the 4V, disappeared and only the anterior line remained visible.

DISCUSSION

Improvements in ultrasound technology afford increasing spatial resolution and better visualization of fetal structures. This has permitted an increasing number of fetal defects to be diagnosed as early as the end of the first trimester of pregnancy, rather than at the anomaly scan at 20–23 gestational weeks. While depiction of the fetal heart[6–8] and its defects at this early gestational age has been the subject of considerable investigation, much less effort has been put into investigating the fetal central nervous system.

Cyr *et al.*[9] described the sonographic appearance of the fetal rhombencephalon in 25 fetuses aged between 8 and 10 gestational weeks. Blaas *et al.*[10,11] were able to demonstrate development of the fetal brain from 7 to 12 weeks. However, these results were obtained only with purpose-built equipment, preventing implementation in daily clinical practice. Since these studies, improvements in ultrasound equipment with increasingly widespread availability have allowed investigation of the fetal brain in a much larger population, during routine first-trimester scanning.

In our experience, the best images of the posterior fossa are obtained by insonation through the anterior fontanelle in a posteriorly tilted axial plane. The axial plane is perpendicular to the long axis of the body and to the coronal and sagittal planes. Lateral and posteroanterior insonation did not allow sufficient imaging in our hands. The anterior fontanelle allows better penetration of the ultrasound beam than do other skull structures. Furthermore, the clinically most important measurements in the diagnosis of spina bifida are those of the CM and the 4V, for which axial resolution is better than is lateral resolution.

At 11–12 weeks the cerebellum is tiny and located above and dorsal to the 4V[12]. The 4V is delineated by a thin membrane, which we were able to demonstrate in a tilted axial fronto-occipital plane. Later, union of the cerebellar hemispheres takes place and the upper part of the vermis develops[13].

Our study showed CRL to correlate linearly with TCD, CM and 4V, although the correlation between CRL and

4V, while statistically significant, was poor. In their retrospective study of 544 normal fetuses, Guariglia *et al.*[14] found a linear correlation between gestational age and TCD measurements between 11 and 17 weeks of gestation. Von Kaisenberg *et al.*[15] measured transabominally in an axial lateral view, TCD in 120 fetuses and CM in 117 fetuses between 11 and 14 weeks of gestation, finding an exponential relationship between gestational age and both TCD and CM. In both studies, the mean values for TCD at 11 weeks were slightly larger than were those in our study, whereas at 13 weeks the mean values were nearly identical.

Von Kaisenberg *et al.* found the mean value for CM to increase from 1.5 mm at 11 weeks to 2.3 mm at 13 weeks[15]. This differs from our findings of a mean of 1.0 mm at 11 weeks and 3.0 mm at 13 weeks. This difference might be due to the fact that the CM is better depicted in an anteroposterior than in a transverse view and our measurements are therefore more accurate.

The reference ranges for the 4V determined in our study correspond well with measurements derived from sagittal sections[16] and axial lateral sections[17]. In the latter study, 11% of measurements had to be performed transvaginally.

Although the measurements obtained in our study were adequately reproducible, as demonstrated by the inter- and intraobserver repeatability, the fetuses with posterior fossa cyst and spina bifida could in fact be identified without any measurements, i.e. by visual assessment alone (Figures 6 and 7). In the fetus with spina bifida, the posterior of the two transverse echogenic lines, caused by the posterior margin of the 4V, disappeared. This might be a valuable sign in detecting spina bifida at 12–14 weeks.

The outcomes of the fetuses with posterior fossa cysts are in line with the findings of Nizard *et al.*[18], who described five cases of cystic malformation of the posterior fossa in the first trimester. Four of their cases had additional major malformations; one baby was diagnosed with isolated Dandy–Walker variant and was alive at 3 years, with normal development.

Our cases with posterior fossa cysts demonstrate how important it is to interpret carefully sonographic findings. It is also of utmost importance to have sound experience in evaluating the posterior fossa at 12–14 weeks before making clinical decisions that are based on apparent anomalies. Furthermore, it should be borne in mind that cerebral signs of spina bifida have no association with the location of the spinal lesion. Since disease prognosis is dependent mainly on the anatomic level of the lesion, the prognosis being better if the lesion is located at the lower sacral spine, cerebral signs do not allow assessment of prognosis.

In conclusion, we found that assessment of the fetal posterior cranial fossa is feasible from 11 + 3 to 13 + 6 gestational weeks during routine ultrasound examination. In our hands, a tilted anteroposterior axial insonation through the anterior fontanelle allowed good depiction of the structures of the posterior fossa. Furthermore, demonstration of two transverse echogenic lines allowed *prima facie* assessment of the 4V and CM. Measurements of the 4V, the CM and the transverse cerebellar diameter performed at this gestational age were reliable. The established reference values should assist in detecting fetal anomalies. However, findings must be interpreted carefully, as some supposed malformations might merely be delayed development of brain structures.

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