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'Choroid bar': easy-to-seek marker of normal posterior fossa at 12–14 weeks' gestation

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CONTRIBUTION

What are the novel findings of this work?

This study describes a new sign, the choroid bar, which is easy to visualize at 12-14 gestational weeks. The advantage is that this sign can be easily visualized regardless of the line of insonation and is absent both in Chiari-II malformation and in cystic vermian malformations such as Dandy-Walker malformation or Blake's pouch cyst.

What are the clinical implications of this work?

The choroid bar may facilitate the assessment of the fetal posterior cranial fossa at 12-14 gestational weeks. This may lead to an increase in the detection rate of both open spina bifida and cystic vermian anomalies at this gestational age.

ABSTRACT

Objectives. Our objectives were: (1) to assess the visualization rate of the choroid bar in a consecutive series of 306 first trimester scans; (2) to verify – in this cohort of fetuses - the normalcy of the posterior fossa later in pregnancy; (3) to confirm the non-visualization of the choroid bar in a retrospective series of fetuses with posterior fossa malformations.

Methods. The study include a prospective and a retrospective series. The former includes 306 fetuses undergoing routine obstetric ultrasound at our Unit both in the first and the second trimester over the last 6 months, the latter includes 12 cases of posterior fossa malformations. In the prospective study, the choroid bar – defined as a visually continuous, homogeneously hyperechoic thick structure bridging the cisterna magna from side to side – was sought at the end of the 1st trimester nuchal translucency scan. In the retrospective study, previously acquired three-dimensional volume datasets were processed in order to assess whether the choroid bar could be visualized in case of open spinal dysraphisms and vermian cystic anomalies. In the prospective study patients, the confirmation of a normal posterior fossa was based on the sonographic aspect of this anatomic region at the time of the 2nd trimester anomaly scan at 19-21 gestational weeks, while in the retrospective study it was based on necropsy results, when available, or further direct imaging of the defect later in pregnancy.

Results. In the prospective study, the choroid bar could be visualized in all 306 fetuses: on transabdominal ultrasound in 287 (93.8%) cases, on transvaginal in 19 (6.2%). The choroid bar was displayed with a ventral/dorsal approach in 67 (21.9%) cases, with a lateral approach in 56 (18.3%) cases and with both in 183 (59.8%) cases. All 306 cases were confirmed to have a sonographically normal posterior fossa at 19-21 gestational weeks. On the contrary, in the retrospective study, it was never possible to reproduce the choroid bar.

Conclusions. We have described a new sign – the choroid bar – consistent with a normal posterior fossa at 12-14 gestational weeks. The choroid bar represents an option to screen for major abnormalities of the posterior fossa, since it allows to suspect both open spinal dysraphisms and posterior fossa cystic malformations being at the same time very easy to visualize, for it can be displayed with all lines of insonation.

INTRODUCTION

In the fetus, the posterior cranial fossa has always drawn the attention of the researchers. In particular, the cerebellum with its vermis, the 4th ventricle, the cisterna magna and the brainstem have been studied for decades from the 2nd trimester onwards[1-5]. More recently, the investigations have extended to the 1st trimester, thanks to the introduction of high frequency transducers – both transvaginal and transabdominal – which ensure a much higher resolution. This technological advance has led to the possibility to detect open dysraphisms at the end of the 1st trimester, owing to the identification of highly sensitive endocranial sonographic signs[6, 7], some of which related to the early recognition of the Chiari II malformation[6, 8]. Finally, over the last few years, the key role played by the position of the 4th ventricular choroid plexus (4VCP) in the differential diagnosis of cystic vermian abnormalities has emerged not only in the 2nd trimester[4, 5] but also at 12-13 gestational weeks[9, 10].

Hence, considering the above cited literature, it has become clear that the 4VCP is indeed the pivotal anatomical structure to assess in order to characterize and differentiate major posterior fossa anomalies, because its position and aspect varies according to the different pathological entities.

In this study, we test the hypothesis that the demonstration of a normal appearance of the two horizontal limbs of the 4VCP – which we refer to as the "choroid bar" – on a modified axial view of the posterior fossa might represent an easy marker to seek in order to confirm the normalcy of the posterior fossa anatomy at 12-13 gestational weeks, on screening ultrasound. Hence, our objectives are: 1) to assess the visualization rate of the choroid bar in a consecutive series of 306 first trimester scans; 2) to verify – in this cohort of fetuses - the normalcy of the posterior fossa later in pregnancy; 3) to confirm that the choroid bar cannot be recognized in a retrospective series of fetuses with posterior fossa malformations.

METHODS

Study design and population

The prospective study includes 306 consecutive fetuses undergoing routine obstetric ultrasound at our Unit both in the first and the second trimester over the last 6 months (November 2022 – May 2023) while the retrospective study includes 12 cases of posterior fossa malformations [Chiari II in open spina bifida: 3 cases; Dandy-Walker Malformation (DWM): 4 cases; Blake's pouch cyst (BPC): 5 cases]. Singleton pregnancies only were included in the study. Entry criterion for the retrospective study was the availability of one or more high-quality transvaginally acquired volume datasets of the posterior fossa, allowing multiplanar image correlation.

In the prospective study, the confirmation of a normal posterior fossa was based on the sonographic aspect of this anatomic region at the time of the 2nd trimester anomaly scan at 19-21 gestational weeks. Pregnancy and feto-neonatal outcome was normal in all, with absence of major cerebral and extra-cerebral malformations at birth (267/306 cases had delivered at our hospital, and in the remainder phone calls were made to the couple or local neonatologist).

In the retrospective study, confirmation of the diagnosis was warranted on ultrasound at 15 gestational weeks and, then, on necropsy, in 2 cases of open spina bifida and 1 case of DWM. In the other cases of open spina bifida (1) and DWM (3), termination of pregnancy was carried out at 14 gestational weeks, with no necropsy, and in 2/3 DWM cases there were concurrent anomalies [congenital heart disease + nuchal thickening + trisomy 13 in one and cystic hygroma [normal karyotype and cGH-array] in the other). All five cases of BPC underwent 2nd and 3rd trimester neurosononography: 3 regressed completely by 28 gestational weeks, 2 only partially and were confirmed on neonatal MRI.

Ultrasound technique

In the prospective study, all patients underwent the routine first trimester scan, performed according to Italian[11] and international[12] guidelines. **In** the prospective study, all examinations were carried out with General Electrics ultrasound systems (E10, Expert BT22; General Electrics, Zipf, Austria) equipped with 2-9MHz transabdominal convex and 6-12MHz transvaginal transducers. The sonographic assessment of the fetal head included the evaluation of the intra-cranial translucency[6]. All scans were performed by medical trainees (GB, FD) supervised by a senior expert in fetal medicine (DP). For the purpose of this study, once the anatomic evaluation had been completed, the choroid bar was sought by the operator on an axial plane of the fetal head, displayed either with a ventral and/or lateral approach. The "choroid bar" is constituted by the horizontal limbs of the 4VCP which visually join on

the midline and can be defined as a "visually continuous, homogeneously hyperechoic, thick structure bridging the cisterna magna from side to side" (Figures 1 and 2). To consider it as normal, cerebrospinal fluid should be present on both sides of the choroid bar, ie in the 4th ventricle anteriorly and the Blake's pouch posteriorly, the latter being a physiologic entity at this gestational age[4]. The presence of cerebrospinal fluid both ventrally and dorsally to the choroid bar excludes both an abnormal IT (Chiari II malformation) and cystic vermian anomalies (BPC and DWM), in which the 4VCP is displaced[9, 10]. The choroid bar can be visualized with a lateral (Figure 1a), dorsal (Figure 1b), and ventral (Figure 1c) approach to the fetal head.

As for the retrospective study, all examinations had also been performed with a General Electrics ultrasound system (E10) employing a volumetric 6-12MHz transvaginal transducer. The posterior fossa was assessed on three-dimensional multiplanar imaging of volume datasets stored in the Unit archive at the time of the diagnosis, which included in all cases a transvaginal early neurosonography[13]. The volume datasets were acquired from an axial plane, with a lateral sweep, as described elsewhere[13]. They were then processed and navigated on the three orthogonal planes in order to check whether the choroid bar could be reproduced or not.

Descriptive statistics only were performed on the study population.

RESULTS

Median maternal age was 34 years (SD: 5.59; range: 18 - 50) and median gestational age at ultrasound was 13 weeks (SD 3 days; range: 12+1 – 13+6) (CRL: 52.3 – 84.0). In the prospective study, the choroid bar could be visualized in all 306 fetuses: on transabdominal ultrasound in 287 (93.8%) cases, on transvaginal in 19 (6.2%). Of the latter, a direct transvaginal approach was chosen in 8 women with a BMI > 35 kg/m^2, whereas in 11 cases this approach was adopted because the anatomic evaluation, including the visualization of the choroid bar, could not be completed transabdominally, owing to acoustic shadowing from bowel gas with an empty bladder, extensive abdominal scars, or diffuse myomas/adenomyosis of the anterior uterine wall.

The choroid bar was displayed with a lateral approach (Figure 1a) in 56 (18.3%) cases, with a ventral/dorsal approach (Figure 1b,c) in 67 (21.9%) cases, and with both in 183 (59.8%) cases. All 306 cases were confirmed to have a sonographically normal posterior fossa at 19-21 gestational weeks, when the anomaly scan was performed (always in our Unit).

As for the retrospective study, the choroid bar could never be displayed, regardless of the sonographic approach to the posterior fossa. In Figure 3, the aspect of the choroid bar plane is shown in a normal fetus (Figure 3a), and three fetuses with open spina bifida (Figure 3b), Blake's pouch cyst (Figure 3c,d) and Dandy-Walker malformation (Figure 3e,f). The differential aspects of the posterior fossa and choroid plexus position and aspect according to the type of anomaly are summarized in Table 1.

DISCUSSION

The early assessment of the posterior fossa may become a key component of the nuchal translucency scan, due to the possibility to suspect and/or diagnose both Chiari II malformation[6], which is associated with open spinal dysraphisms, and cystic posterior fossa malformations, such as DWM and BPC[9, 10]. However, the visualization of the Intracranial Translucency may offer some difficulty and is not readily displayed in all cases. At the same time, there is no official criterion set for the assessment of the posterior fossa during the Nuchal Translucency scan other than the optional assessment of the Intracranial Translucency on the midsagittal plane of the fetal head[12], despite the fact that current technological capabilities have led to a significant increase in the image resolution. It should also be considered that several articles have been published over the last few years on the recognition of posterior fossa malformations at the end of the 1st trimester[9, 10]. Therefore, a significant discrepancy has arisen between the complete lack of recommendations for an early assessment of the posterior fossa on one side (other than the above mentioned IT) and the possibility to suspect/diagnose posterior fossa cystic malformations on the other. In this context, the Choroid bar represents an option that has two major advantages: 1) it allows to suspect on the same plane both open spinal dysraphisms and posterior fossa cystic malformations (Table 1, Figure 3); 2) it is very easy to visualize, regardless of the line of insonation (Figure 1). In fact, it could be obtained in all cases undergoing first trimester screening ultrasound examination performed by residents in training.

In addition, we were able to confirm that the Choroid bar can never be reproduced in abnormal cases (Figure 3). This is due to the fact that in DWM and BPC the 4VCP is displaced downwardly, acquiring a V-shape aspect in BPC; in DWM, it has been demonstrated by us and other researchers that the 4VCP lies outside the cyst associated with this anomaly, being displaced infero-laterally[9, 10]. In Chiari II malformation, which is always associated with open spinal dysraphisms, the whole cerebellum, including the 4VCP, is displaced downward, due to the continuous leakage of cerebro-spinal fluid through the spinal defect. This leads with time to prolapse or herniation of the cerebellar tonsils and/or the whole cerebellum across the foramen magnum; as a consequence, the 4VCP is dragged downward, too (Figure 3b).

A main limitation of this study is represented by the fact that the retrospective series only included cases of DWM, BPC and Chiari II malformation. However, it is highly likely that also vermian hypoplasia may be associated with failure to visualize the Choroid bar, considering that an abnormal position of the 4VCP is present also in this condition, at least in the 2nd trimester[9]. Another limitation is represented by the fact that no abnormality of the posterior fossa was diagnosed prospectively, being all the abnormal cases retrospectively evaluated on stored volume datasets. At this regard, an

important issue to consider is represented by the transducers employed in the scans. As already stated in the Methods section, all examinations of the prospective study were carried out with a high resolution transabdominal transducer (2–9 MHz), whereas all cases of the retrospective group (assessed over the last 3 years) had been assessed with a high resolution transvaginal volumetric transducer (6–12 MHz) and the axial planes were reconstructed from three-dimensional volume datasets. Hence, the sonographic approach was different (transvaginal three-dimensional vs transabdominal two-dimensional). However, the subjective, expert comparison of the images between the relatively few cases of the prospective study assessed transvaginally with the images of the abnormal ones allows to confirm that there is not a significant difference in resolution, the perceived, apparent difference being due more to the sonographic mode (two-dimensional vs three-dimensional) than to the emission frequency or time of release of the transducers (Figure 3). However, this represents a preliminary study addressing the feasibility and reproducibility of the technique. Assessment of the choroid bar is being used since the end of the enrolment in this study and the next step will be to demonstrate the role of this sonographic sign in the identification of posterior fossa abnormalities in a prospective study.

In conclusion, we have described a new sign – the choroid bar – consistent with a normal posterior fossa at the end of the 1st trimester. We have demonstrated that it can be achieved in all patients undergoing early anatomy assessment either transabdominally and/or transvaginally and with all insonation lines. Finally, we have demonstrated in a small retrospective series that the choroid bar can be visualized neither in Chiari-II malformation nor in cystic vermian anomalies (BPC, DWM).

Hence, the choroid bar can be effectively employed in the early anomaly scan in order to achieve a fast and consistent demonstration of a normal posterior fossa. As mentioned above, the second, ongoing part of this study will focus on the prospective assessment of the role of the choroid bar in the identification of posterior fossa malformations.

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FIGURE LEGENDS

Figure 1. The choroid bar is defined as a "visually continuous, homogeneously hyperechoic, thick structure bridging the cisterna magna from side to side (arrows)" and consists of the two horizontal limbs of the 4th ventricular choroid plexus (see text). To be considered normal, cerebrospinal fluid should be seen both ventrally and dorsally to the choroid bar (arrowhead), the two areas corresponding to the 4th ventricle and the physiologic Blake's pouch, respectively. In this figure, we demonstrate that it can be adequately visualized with all lines of insonation: A) lateral; B) dorsal; C) ventral. Gestational age of the three fetuses was 13+0, 13+1 and 13+0 weeks+days, respectively.

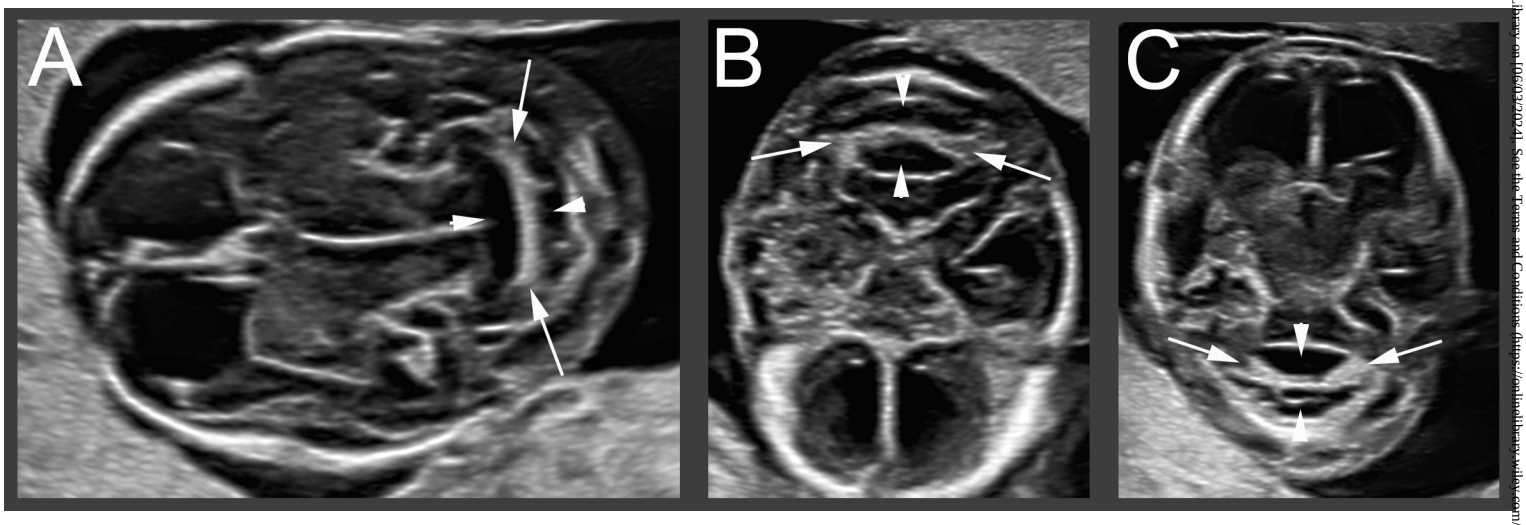
Figure 2. In this image, three-dimensional multiplanar imaging is used to demonstrate how significantly the aspect of the posterior fossa changes according to the acquisition plane [note the reference marker positioned on the choroid plexus in (A) and (B)]. A) lateral, axial acquisition, as per ISUOG early neurosonography guidelines[13]. The two orthogonal panels demonstrate the choroid bar on the axial acquisition plane (rotated 90; left panel) and the typical position of the choroid plexus on the reconstructed midsagittal plane (right panel); B) ventral, axial acquisition. In this case, the reconstructed plane is the midsagittal one (right panel), on which the aspect of the choroid plexus is similar to that of the classical IT plane; C) demonstration of the cranial posterior fossa on a 13 weeks specimen. Midsagittal plane (compare to the right panel of A). (Large arrowheads: choroid bar; small arrowhead: choroid plexus; arrow: physiological Blake's pouch; asterisk: 4th ventricle)

Figure 3. Comparison of the choroid bar plane in normal and abnormal fetuses. A) normal fetus, 13+0 weeks+days. Normal aspect of the Choroid bar, with cerebrospinal fluid ventrally and dorsally (arrowheads) to the actual choroid bar (arrows); B) Open spina bifida (13+6 weeks+days). The choroid bar plane cannot be demonstrated. Caudally, the two lateral ends of the horizontal choroid plexus limbs (arrowheads) are shown. Note the complete absence of cerebrospinal fluid, consistent with the Chiari II malformation; C) Blake's pouch cyst (13 weeks). Choroidal bar plane. Note the non-visualization of the choroid bar. The whole posterior fossa is cystic (asterisk); D) in the same case, just caudal to the former plane, the two horizontal limbs of the choroid plexus (arrowheads) can be seen displaced laterally; E) Dandy-Walker malformation (13 weeks). The aspect of the choroidal bar plane is almost identical to that of the Blake's pouch cyst shown in C, with a large fluid collection only (asterisk); F) however, in Dandy-Walker malformation, the choroid plexus (arrowheads) is outside the cyst and displaced inferolaterally, as evident in this plane, which is the lowermost level of the posterior fossa.

Table 1. Differential aspects of the posterior fossa and choroid plexus position and aspect by type of anomaly (see also Figure 3).

Anomaly	Choroid bar plane	4VCP position	4VCP shape
DWM	Only CSF collection	Displaced inferolaterally	Two AP bars
BPC	Only CSF collection	Displaced downward*	V-shaped
OSD	No CSF	Displaced downward	Only lateral ends visible

4VCP: choroid plexus of the 4th ventricle; AP: antero-posterior; BPC: Blake's Pouch Cyst; CSF: cerebrospinal fluid; DWM: Dandy-Walker Malformation; OSD: open spinal dysraphism. *Superolaterally to the cyst inlet.



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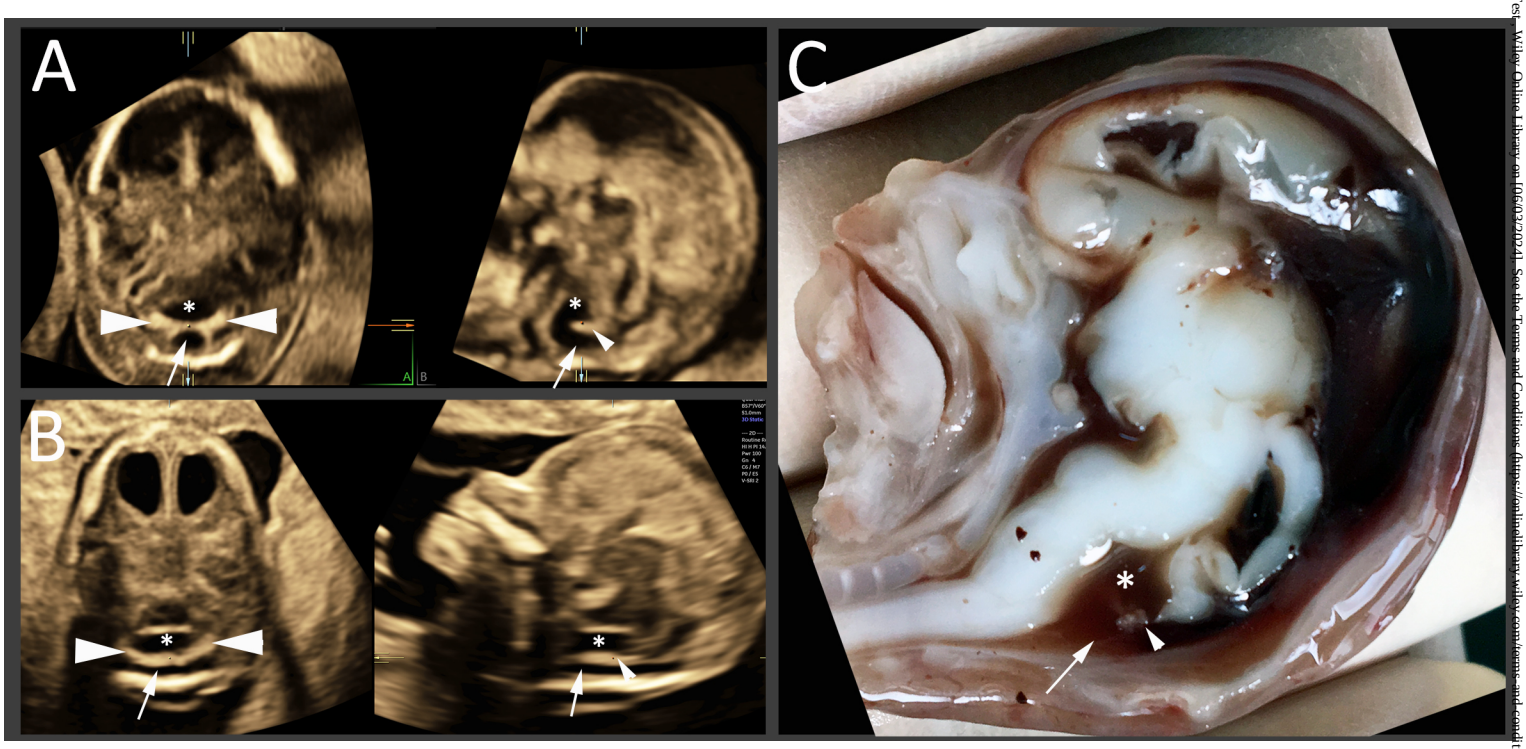
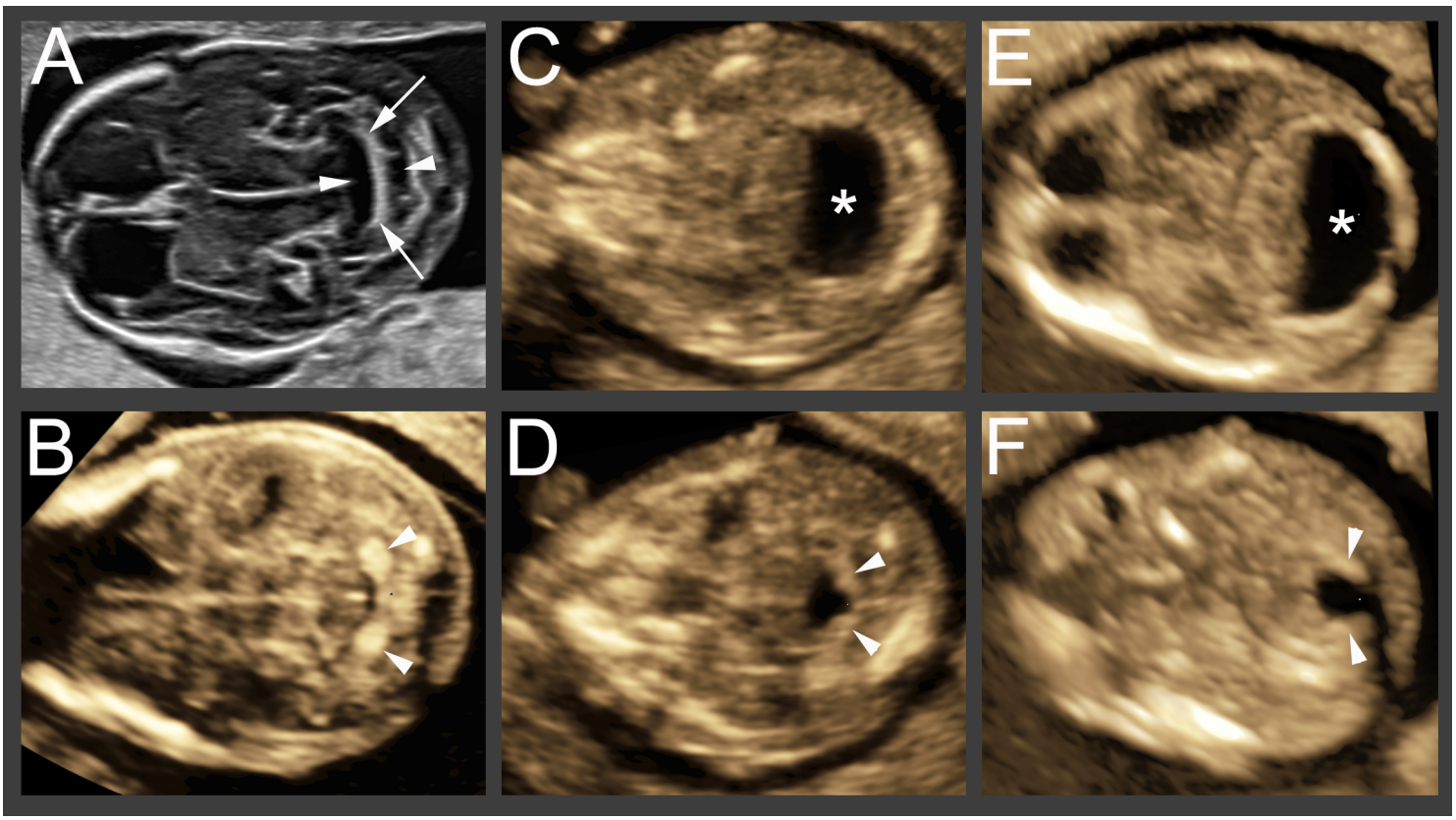


Fig_2.jpg



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