Review Article

Ultrasound Assessment of the Fetal Optic Chiasm

CME Credits

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Abstract

This article reviews the literature on different methods of prenatal ultrasound visualization of the optic chiasm (OC) and its applications. Prenatal imaging of the OC is feasible from 19 to 37 weeks of gestation. Evaluation of the OC has been shown crucial in differentiating isolated agenesis of the septum pellucidum from septo-optic dysplasia. Multiple methods can be applied for imaging of the OC, including three-dimensional and two-dimensional ultrasounds in different views, as well as color Doppler. According to the literature, both transabdominal and transvaginal routes produce equally acceptable images. OC visualization might be challenging but can be achieved by developing a standard scanning protocol and raising awareness.

Keywords: Optic chiasm, prenatal ultrasonography, septo-optic dysplasia, septum pellucidum

Introduction

The optic chiasm (OC) is a critical anatomical structure that forms at the intersection of the optic nerves (ONs) and lies anterior to the cerebral peduncles. Even though recent advances in ultrasound technology allow to visualize the fetal ONs, chiasm, and tracts *in utero*,[1-7] it is still a challenge for clinicians and often delayed to the postnatal period. Accurate visualization of OC is crucial for the differential diagnosis of isolated agenesis of the septum pellucidum (ASP) and septo-optic dysplasia (SOD).[6,8] Prenatal differentiation can be helpful in parental counseling and management planning. As a result, the aim of the review was to summarize existing knowledge regarding the prenatal ultrasound assessment of the OC.

Anatomical Structure of the Optic Chiasm

The OC plays a vital role in the visual pathway, and it is situated in the suprasellar cistern, enveloped by the circle of Willis. This commissure is made up of converging ONs anteriorly and diverging optic tracts (OTs) posteriorly, as shown in Figure 1.

During embryonic development, the ON is formed by the optic vesicles, which come from the lateral protrusions of the forebrain. The optic vesicles transform into the optic cup, gradually developing into the retina. The ON consists of the axons and supporting cells of the retinal ganglion cells, surrounded by the meninges. As the ONs grow toward the brain, nerve fibers from each eye cross over at the OC. The fibers from the retina's inner portion cross to the opposite side, while the fibers from the outer portion continue on the same side. This arrangement integrates visual information from both eyes. The crossed and uncrossed ON fibers continue as OTs beyond the OC.

It is essential to note that the ONs and OC sections inside the skull are not positioned horizontally, as commonly assumed. They incline upward at a certain angle ranging from 15° to 45° from the optic canals.[9] This particular anatomical fact necessitates specialized imaging techniques and proper positioning to visualize these structures accurately. It is vital to be aware of this to avoid misinterpretations or inaccuracies in diagnosis or treatment.

Indications for the Optic Pathways' Evaluation

During routine mid-trimester fetal ultrasound scans, it is essential to consider the transventricular, transthalamic, and transcerebellar screening planes of the central nervous system.[10] One key landmark is the fluid-filled cavity known

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as the cavum septi pellucidi (CSP), located between the two thin membranes separating the anterior horns of the lateral ventricles. Typically, a gestational period when the CSP should be visible is around 17–37 weeks.[10,11] If the membranes of the septum pellucidum are not observable, combined with a fused frontal horn present, it may be indicative of either isolated or multiple congenital brain malformations like lobar holoprosencephaly or SOD.[12]

A comprehensive inspection, including OC, should be conducted to narrow down the differential diagnosis further. However, the distinction between isolated ASP and SOD in the prenatal period remains challenging.[13] SOD is a condition in which an individual may have a missing or underdeveloped septum pellucidum, underdeveloped ONs, anomalies in the pituitary gland, and endocrine problems. The severity of these symptoms can vary.[14] However, ASP results in partially or completely absent septum pellucidum when isolated. This condition is typically linked with a favorable prognosis.[8]

Ultrasonic Techniques for Visualization of the Optic Chiasm

Both two-dimensional (2D) and three-dimensional (3D) ultrasounds can be used for prenatal imaging of the optic pathways. Although several studies reported on the use of 3D fetal ultrasound for OTs visualization,[1,2] Bault *et al*. measured 98 morphologically normal fetuses between 21 and 36 weeks of gestation to present the reference range values for the OT diameter.[2] However, in daily clinical practice, the use of 3D techniques is confined to the specific equipment and probe and can be time-consuming, and also, it requires intricate processing. Furthermore, the quality of the images obtained is highly dependent on the experience of the operator. In the current article, we will describe transabdominal and transvaginal 2D ultrasound on different planes for the visualization of OC. The 2D acquisition can be conducted by transvaginal ultrasound[3,6] and transabdominal ultrasound.[4-7]

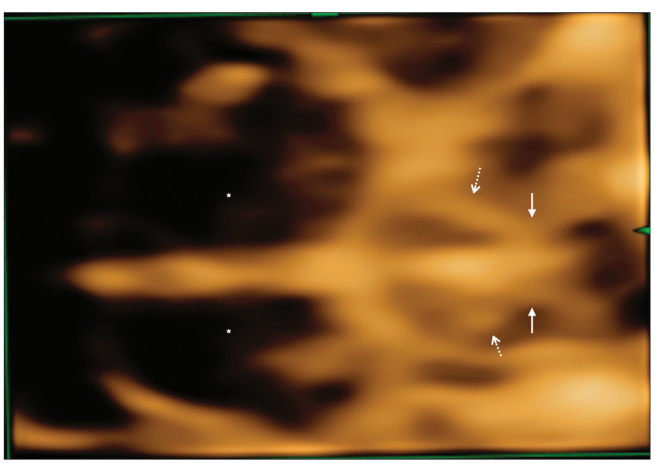

Figure 1: Three-dimensional ultrasound image in the axial plane of a 22-week fetus is showing the optic chiasm (OC) (arrow) as an X-shaped structure formed by the crossing of the optic nerves (ONs) located in front of the cerebral peduncles (*). The optic tracts (dotted arrow) are posterior to the OC, and the ONs are anterior to it

Transvaginal ultrasound, coronal view

Following the method described elsewhere by Timor-Tritsh and Monteagudo, the mid-coronal-2 section[15] across the fontanelle can be obtained, which allows for visualization of the CSP, the third ventricle, and a dumbbell-shaped structure located underneath the third ventricle that corresponds to the OC and appears moderately echogenic in a horizontal orientation. Then, color Doppler allows us to confirm the visualization of the OC, as a segment of the internal carotid artery and anterior cerebral artery bilaterally surrounds it.[3] While measuring, the ruler should be positioned at the margin of the OC, displaying moderate echogenicity. According to Viñals *et al*.,[3] although this method has good interobserver and intraobserver reproducibility, the reference data are limited within 21 and 29 gestational weeks. Besides, this approach can only be performed in the vertex fetal position and is limited by maternal preference and technical competence in routine screening.

Transabdominal ultrasound, coronal view

In the case of the breech fetal position, starting from the transventricular plane and rotating the probe 90° allow for the imaging of a coronal section of the fetal brain through the anterior fontanelle. Then, the transducer is moved back and forth using the color Doppler to identify the OC, as it appears as a dumbbell-shaped structure surrounded by the internal carotid artery and anterior cerebral artery on both sides. Finally, the calipers should be touching the inner walls of the chiasm [Figure 2]. The average reading of 2–3 measurements was noted.

In a study by Desai *et al*. using the 2D methods mentioned above,[6] the authors measured 97 morphologically normal fetuses. They established a reference chart for fetal OC width

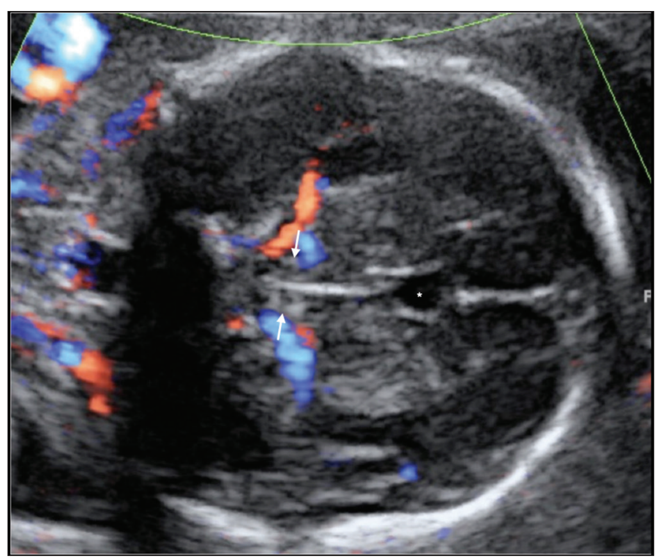

Figure 2: Transabdominal neurosonographic image in a normal 22-week fetus. Coronal view through the anterior fontanelle showing the optic chiasm (arrows) and cavum septi pellucidi (*) and measurement of the optic chiasm's width

from 19 to 34 gestational weeks. However, it is important to note that the reproducibility of this method was not evaluated in the study.

Transabdominal ultrasound, axial view

The OC can also be visualized in the axial plane with high echogenicity.[4] Alonso *et al*. proposed a step-wise evaluation of OC on routine transabdominal fetal ultrasound.[5]

Initially, a transducer with activated color Doppler function is moved caudally from the transventricular plane for identification of the circle of Willis [Figure 3], followed by a three-step procedure to visualize and measure the OC. The first step is to rotate the probe about 20°–40° in the front of the fetal head (this angle may vary with gestational age). To ensure the quality, the anterior orbit and cerebral peduncles should be visualized in this plane [Figure 4]. If the rotation is incorrect, the ON crossing can be observed only partially. The second step is identifying the cross-shaped hyperechoic structure representative of the OC. The middle cerebral arteries outline the OC borders [Figure 5]. The third step, the OC's width, is measured in the middle of the X with the color Doppler switched off. The measuring is done by positioning the calipers on-to-on [Figure 6]. In a subsequent study by Wu *et al*.,[7] this method was applied to also measure the width of the ONs [Figure 7] and OTs [Figure 8], and the results showed a high level of intraobserver repeatability and interobserver reproducibility for the OC evaluation, surpassing the reproducibility for measurements of the OTs and ONs. This study measured over 300 morphologically normal fetuses in a vertex position to establish the reference values for the OC, ON, and OT width at 19–40 weeks of gestation.

Comparison of Different Ultrasonic Approaches

Compared to other methods, the axial plane using 2D transabdominal ultrasound is easier to apply in routine practice,

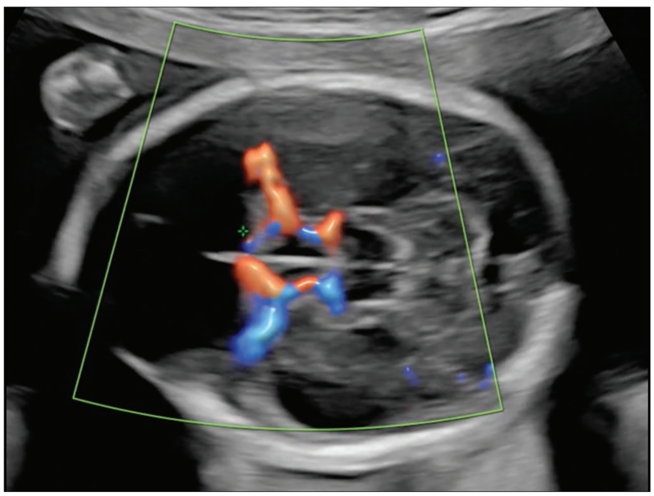

Figure 3: Two-dimensional transabdominal ultrasound image showing the circle of Willis in the axial plane of a 22-week fetus

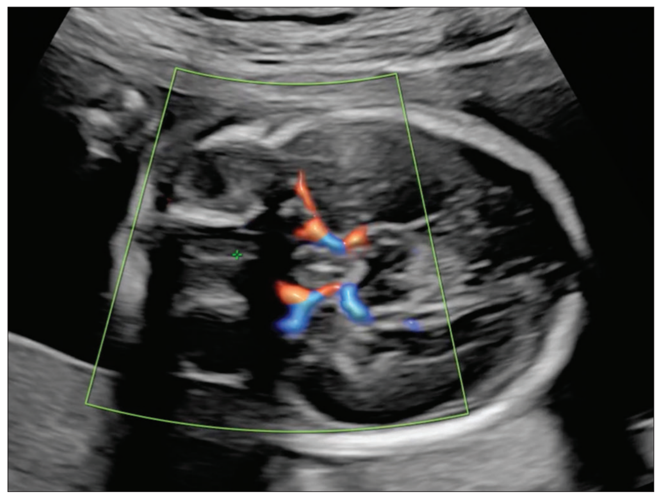

Figure 4: After rotating the probe about 20°–40° in the frontal part of the fetal head until at least one orbit and cerebral peduncles can be identified in this plane, two-dimensional transabdominal ultrasound image showing the optic chiasm as a hyperechoic structure, which is surrounded by the circle of Willis in the axial plane in a 22-week fetus

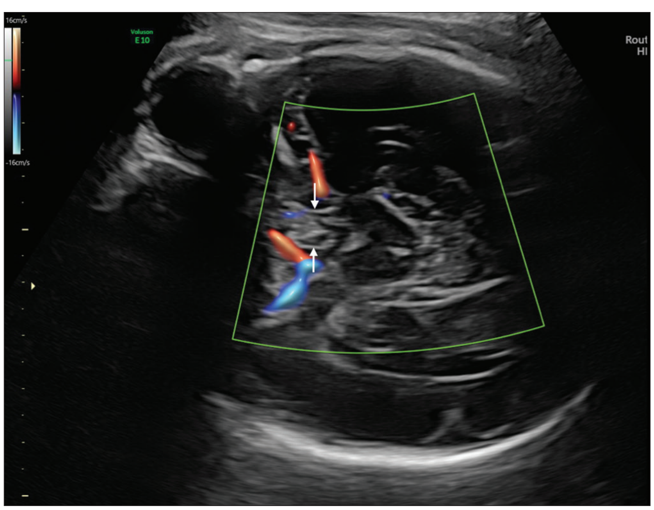

Figure 5: Two-dimensional transabdominal ultrasound image showing the width of the optic chiasm (arrows) in the axial plane in a 32-week fetus

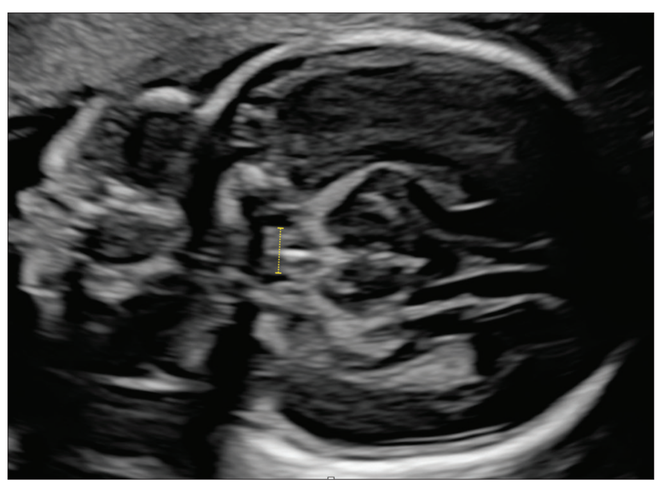

Figure 6: Two-dimensional transabdominal ultrasound image showing the width of the optic chiasm (yellow dotted line) in the axial plane in a 22-week fetus

allowing for the development of a standard protocol, and its quantitative assessment of OC is reproducible.[7] Besides, this method can be helpful to obtain the image of the ONs and OTs, but beyond 33 weeks, the shadows caused by the frontal, or the sphenoid bones obscure the imaging of the ONs.[7] However, each of the described methods can have advantages in certain contexts. In cases where the fetal head is positioned very low, it might be challenging to obtain an axial or coronal plane using 2D transabdominal ultrasound. In such situations, transvaginal ultrasound is a more suitable approach to evaluate the OC [Figure 9]. Obtaining the coronal image of the OC through abdominal ultrasound can serve as a dual-confirmation approach. The step-wise process for OC evaluation using the above-mentioned methods is summarized in Figure 10. 3D ultrasound is ideal for storage and postprocessing, as it allows the reconstruction of the plane for detailed analysis.

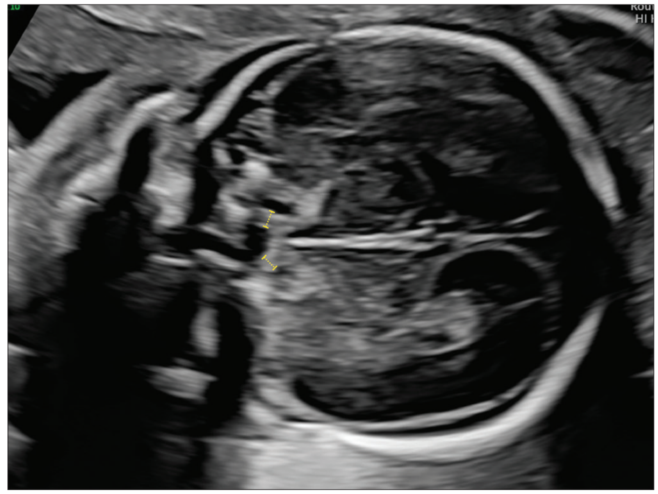

Figure 7: Two-dimensional transabdominal ultrasound image showing the optic nerve width (yellow dotted line) in the axial plane in a 22-week fetus

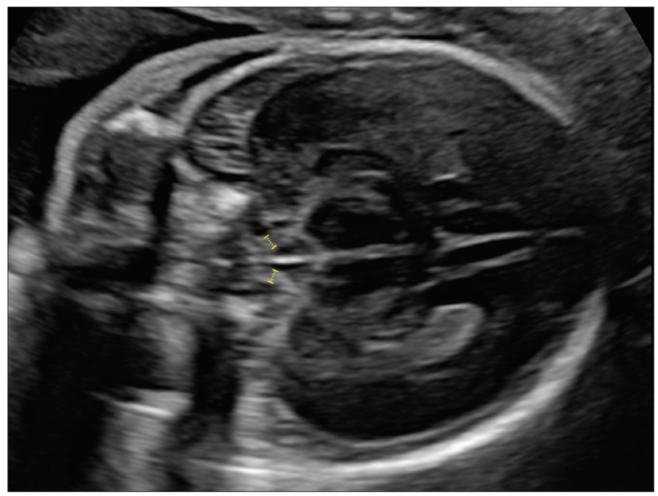

Figure 8: Two-dimensional transabdominal ultrasound image showing the optic tract width (yellow dotted line) in the axial plane at 23 weeks of gestation

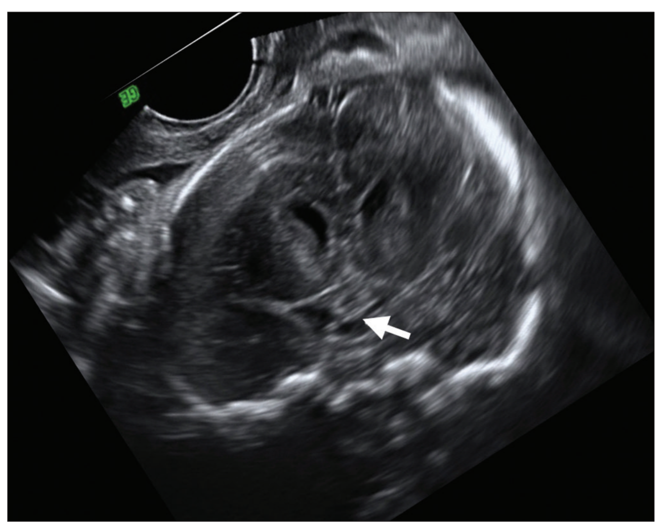

Figure 9: Transvaginal neurosonographic image in a 26-week fetus with partial agenesis of the septum pellucidum. Coronal view through the anterior fontanelle showing the optic chiasm (arrows)

Application of Magnetic Resonance Imaging

The spatial resolution of magnetic resonance imaging (MRI) images of the optic pathways has traditionally been limited, making it difficult to obtain reliable measurements. However, recent advances in imaging equipment and technology supported the development of normal reference charts in the adult population,[16] pediatric reference values,[17] and postmortem fetal MRI.[18] Nevertheless, the quantitative assessment of the ONs and chiasm remains challenging in fetal MRI due to spatial resolution issues.[12] Despite this limitation, the fetal MRI is still useful for the qualitative assessment of optic pathways and the pituitary gland [Figure 11].[19]

The Value of Prenatal Assessment of Fetal Optic Chiasm

Ultrasound is the first-line tool for detecting ASP in the second-trimester anatomical screening. To differentiate between abnormalities such as holoprosencephaly and schizencephaly and to exclude SOD or nonisolated ASP, a thorough fetal neurosonography, including the optic pathways, should be performed. A measurement method proposed by Alonso *et al*.[5] can be used with the normal data range provided by Wu *et al*.,[7] for assessing optic pathways development between 19 and 40 weeks gestation. The real-time nature and accessibility of ultrasound allow us to track OC development as pregnancy progresses. Recent guidelines recommend arranging MRI when the septum pellucidum is not visualized during the ultrasound.[12] MRI can provide valuable data that may supplement the ultrasound findings and influence further clinical management.[19] In addition, although the specific gene or group of genes involved is not yet fully understood, previous research has described gene mutation patterns related to SOD, in which the transcription factors encoded by these genes are crucial for the normal development of the forebrain and pituitary gland, including HESX1, SOX2, OTX2, and TCF7 L1.[14,20-22] Whole-exome sequencing can also be arranged in addition to karyotype and chromosomal

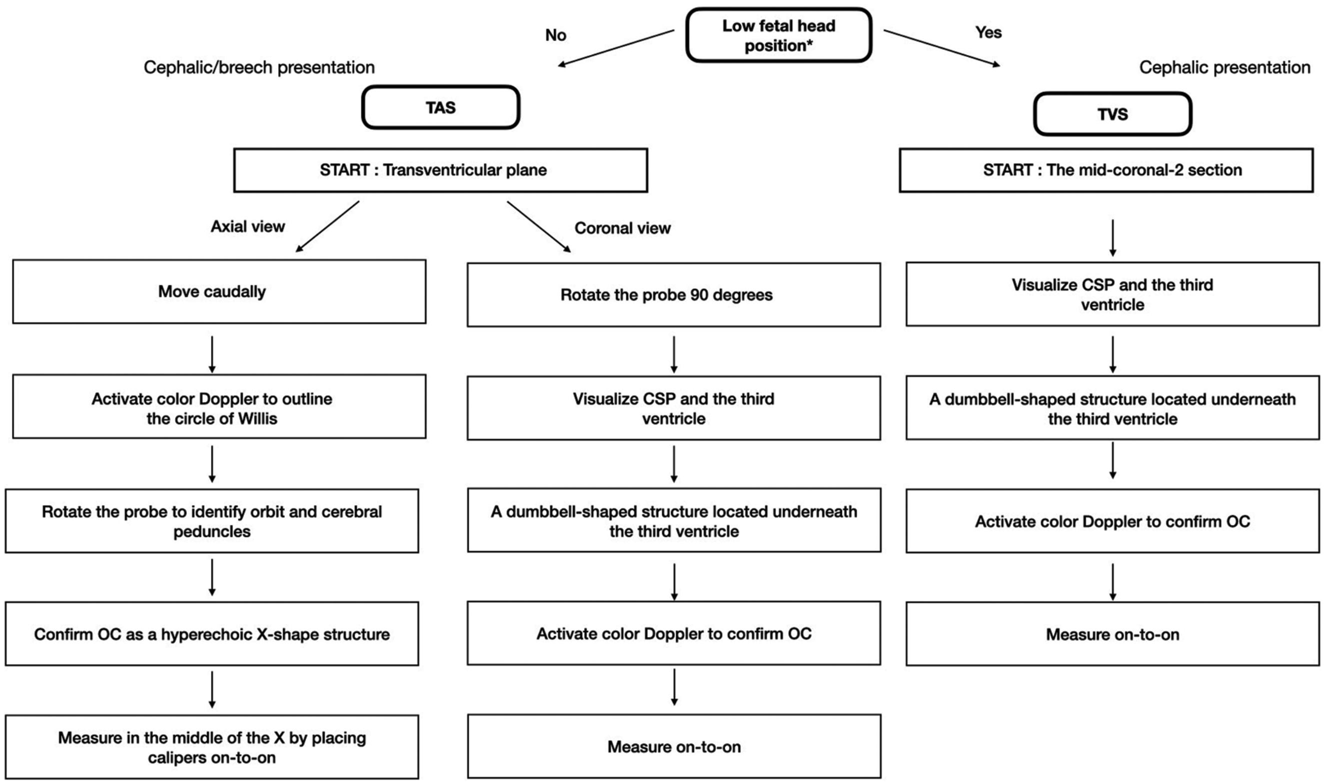

Figure 10: Flowchart summarizing methods for 2D ultrasound assessment of the fetal optic chiasm. Depending on the fetal head position, a suitable method should be applied. The fetal head position is considered too low when due to bone shadowing, it is impossible to obtain optimal transventricular plane (asterisk). 2D: Two-dimensional, OC: Optic chiasm, CSP: Cavum septi pellucidi

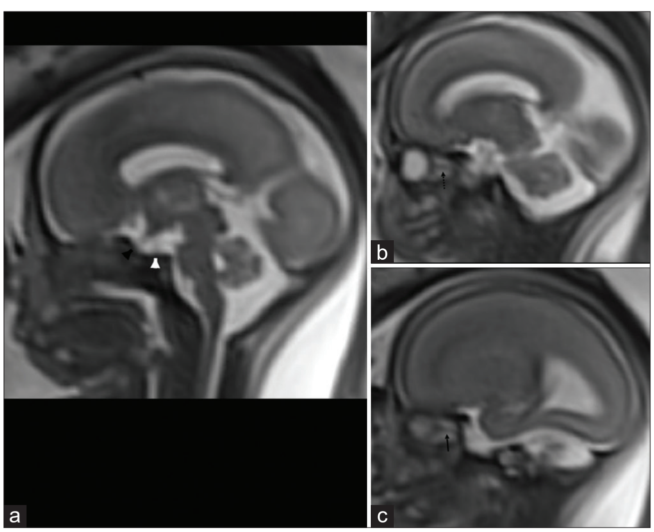

Figure 11: Sagittal T2-weighted magnetic resonance images of a 24-week fetus with absent septum pellucidum. The midsagittal plane (a) shows the unremarkable corpus callosum, pituitary stalk (white arrowhead) and optic chiasm (black arrowhead). The parasagittal planes (b and c) demonstrate bilateral optic nerves (black arrows)

microarray analysis to provide supplementary information for a prenatal consultation.

In a retrospective study,[8] the outcomes in patients with the prenatal appearance of isolated ASP were evaluated. Additional anomalies negatively impacting clinical outcomes were detected postnatally in around 14% of cases. However, in most cases, the outcomes were favorable. In addition, the study revealed that fetuses with isolated ASP on prenatal ultrasound had a risk of approximately 19% for developing SOD and around 7% for significant neurological impairment.[8] For fetuses with observable OTs/OC/ONs on fetal ultrasound, the remaining risk of SOD was reduced by half and was primarily associated with endocrine spectrum disorders.[8]

Conclusion

The results of the thorough literature review revealed that prenatal evaluation of the OC is feasible and has good reproducibility with training.

Therefore, when prenatal septal defects are detected, a detailed prenatal evaluation of the brain and optic pathways is needed to exclude associated abnormalities. On ultrasound, the OC can be evaluated in either axial or coronal views depending on the fetal position. It is crucial to be familiar with the different approaches, associated landmarks, and corresponding normal range data to provide more detailed information for the prenatal consultation.

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Conflicts of interest

Dr. Tung-Yao Chang, an Editor at *Journal of Medical Ultrasound*, had no role in the peer review process of or decision to publish this article. The other authors declared no conflicts of interest in writing this paper.

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