CASE REPORTS

Prenatal 2D/3D ultrasound in fetal dural sinus malformations: Case series and prognostic insights

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ABSTRACT

Objective: To assess the benefit of three-dimensional (3D) ultrasound over two-dimensional (2D) imaging in diagnosing fetal dural sinus malformations (DSM) and to explore the correlation between sonographic features, such as thrombosis and sinus involvement, with perinatal and postnatal outcomes, supported by a literature review.

Methods: This retrospective case series included 8 fetuses diagnosed with DSM at our center between 2020 and 2025. All cases underwent 2D and 3D ultrasound, with findings correlated to outcomes. The added diagnostic value of 3D ultrasound was specifically evaluated.

Results: Eight fetuses were diagnosed with DSM at a median gestational age of 27 weeks (range 20–35). Lesions primarily involved the torcular Herophili (4/8), torcular and superior sagittal sinus (2/8), superior sagittal sinus (1/8), and posterior fossa venous region (1/8). Associated anomalies included hydrocephalus, mild ventriculomegaly, fetal growth restriction (FGR), pleural and peritoneal effusions. 2D ultrasound identified cystic or anechoic extra-axial lesions (18 × 19 mm to 90 × 110 mm), with 62.5% showing echogenic intraluminal foci, suggesting thrombosis. 3D ultrasound improved lesion delineation, venous continuity, thrombus morphology, and confirmed the absence of arterialization. Genetic testing (cfDNA and/or CMA) was normal in all cases. Among the 8 pregnancies, two were terminated, one resulted in intrauterine fetal demise, and five infants were liveborn. Four (50%) had favorable neurodevelopmental outcomes at 29–60 months. Adverse outcomes were observed in cases with lesions >30 mm, multi-sinus involvement, and hemodynamic compromise.

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Conclusions: Combined 2D/3D ultrasound enhances prenatal DSM assessment by providing spatial and volumetric information. Key features, especially thrombosis, correlate with adverse outcomes. Our findings suggest that 3D ultrasound can be considered incorporated into routine DSM diagnostic protocols.

Key words: Fetal; Dural Sinus Malformation; Prenatal Diagnosis; 2D Ultrasound; 3D Ultrasound; Prognosis

Introduction

Dural sinus malformations (DSM) are rare congenital anomalies of the fetal cerebral venous system, most commonly affecting the torcular Herophili and adjacent venous sinuses (1, 2). These malformations are characterized by focal dilation of the dural venous sinus, often accompanied by altered venous drainage and intraluminal thrombosis (3, 4). Despite their rarity, DSM are clinically significant because they can result in hydrocephalus, mass effect, or adverse perinatal outcomes, depending on lesion size, location, and the presence of thrombosis (5-7). Accurate prenatal diagnosis is therefore crucial for parental counseling, pregnancy management, and postnatal planning.

Two-dimensional (2D) ultrasound remains the first-line modality for detecting abnormal venous dilation in utero (8). Prenatal ultrasound can often recognize a DSM as an atypical cystic space in the posterior fossa with turbulent flow on Doppler. In fact, most fetal DSM diagnoses to date have been made by mid-gestational ultrasound examinations (9). Magnetic resonance imaging (MRI) provides complementary information on lesion extent and parenchymal changes but is limited by cost, availability, and the requirement for advanced gestational age, restricting its routine use (8, 10). These limitations highlight the need for alternative or complementary imaging approaches.

Three-dimensional (3D) ultrasound has emerged as a valuable adjunct to 2D imaging. Volumetric reconstructions improve assessment of lesion extent, spatial relationships with adjacent venous structures, and thrombus morphology (11). However, systematic evaluations of the incremental diagnostic value of 3D ultrasound in DSM are scarce, with most reports limited to isolated cases or small series. Moreover, while MRI-based studies have linked thrombus formation and multi-sinus involvement to prognosis, these features have not been comprehensively analyzed in cohorts assessed with combined 2D/3D ultrasound (12).

To address these gaps, we present a retrospective case series of DSM evaluated with both 2D and 3D ultrasound, with correlations to perinatal and postnatal outcomes. We also conduct a literature review to contextualize our findings within the broader body of existing research. The primary aim of this study was to assess the additional diagnostic value of 3D ultrasound over 2D ultrasound in the prenatal evaluation of DSM, in order to improve prenatal counseling and guide clinical management.

Materials and Methods

Study design and population

This study was a retrospective case series conducted at our tertiary referral center from 2020 to 2025. We identified fetuses diagnosed with DSM during routine prenatal ultrasound screenings from our ultrasound database. Inclusion criteria were (1) a prenatal ultrasound diagnosis of DSM (defined as abnormal dilation of a dural venous sinus) and (2) availability of both 2D and 3D ultrasound imaging for the case. We excluded cases with incomplete imaging data or loss to follow-up. Clinical data were collected from medical records, including maternal age, gestational age at diagnosis, indication for the ultrasound, and any associated anomalies. All participants provided written informed consent. The study was conducted in accordance with the Declaration of Helsinki.

Ultrasound protocols

Prenatal ultrasound examinations were performed using a Voluson E8/E10 ultrasound system (GE Healthcare, Chicago, IL, USA), equipped with both 2D and 3D transducers. Standard 2D sonography was initially performed in the axial, coronal, and sagittal planes to evaluate the fetal intracranial venous system. Color Doppler and pulsed Doppler were used as needed to assess blood flow within the dilated sinus.

In the same session, 3D ultrasound was subsequently performed. Volumetric datasets were acquired with sweep angles of 60–120° and stored for offline analysis. Post-processing techniques, including multiplanar reformats and surface rendering, were utilized to delineate the full extent of the venous dilation, characterize any thrombus within the sinus, and examine the spatial relationship of the lesion to adjacent venous structures.

Diagnostic criteria

DSM was defined as a focal or diffuse dilation of a dural venous sinus (most often at the torcular Herophili), with or without evidence of intraluminal thrombosis. Thrombosis was suspected on 2D ultrasound if echogenic material was visualized inside the dilated sinus; when 3D Doppler data were available, the thrombus could be confirmed by demonstrating lack of flow within that echogenic area. We classified the lesion's extent as either isolated to the torcular region or involving multiple venous sinuses.

Outcome assessment

Pregnancy outcomes were recorded for each case, including live birth, intrauterine fetal demise, or pregnancy termination. Postnatal outcomes were obtained from hospital records and structured telephone follow-up interviews, focusing on survival, neurodevelopmental status, and any postnatal neuroimaging findings. The follow-up period ranged up to 5 years of age.

Statistical analysis

Data were analyzed using SPSS version 27.0 (IBM Corp., Armonk, NY). Continuous variables (e.g., maternal age, gestational age at diagnosis) were presented as means ± standard deviation (SD), depending on data distribution. Categorical variables (e.g., presence of thrombosis, type of sinus involvement, pregnancy outcomes) were expressed as counts and percentages. Given the small sample size, our analysis is descriptive and exploratory, aiming to identify patterns or trends rather than to perform inferential statistics.

Results

Baseline characteristics

Eight fetuses met the inclusion criteria for DSM during the study period. The mean maternal age at diagnosis was 28.38 ± 7.33 years (range 18–38 years), and the mean gestational age at diagnosis was 26.38 ± 5.83 weeks (range 20–35 weeks). Most cases (6/8, 75%) were identified during routine mid-trimester anomaly scans; the remaining cases were referred due to suspected central nervous system abnormalities or abnormal findings on prior imaging.

Of the eight fetuses, three were male (37.5%) and five were female (62.5%). Additional anomalies were noted in four cases (50%). These included central nervous system findings such as hydrocephalus, mild ventriculomegaly, a poorly visualized corpus callosum, subarachnoid hemorrhage, and delayed cortical sulcation/gyral maturation. Systemic findings in some cases included fetal growth restriction with absent end-diastolic umbilical artery flow, pleural effusions with ascites (hydrops), cardiomegaly with reduced right ventricular function, and the development of systemic–pulmonary collateral vessels. Genetic testing was performed in all cases; no chromosomal abnormalities were detected in any fetus. Table 1 summarizes the baseline clinical characteristics of the cohort.

Ultrasound findings

Prenatal 2D Imaging Findings

The dural sinus malformation involved the torcular Herophili in four cases, both the torcular Herophili and the superior sagittal sinus in two cases, the superior sagittal sinus alone in one case, and the posterior fossa dural venous region in one case. The median

Table 1. Baseline clinical characteristics.

Case No.	Maternal Age (years)	Gravidity/ Parity	Gestational Age at Diagnosis (weeks)	Indication for Ultrasound	Fetal Sex	Associated Anomalies	Follow-up Duration
1	24	G3P2	34	Superior sagittal sinus	Male	Hydrocephalus; right-heart enlargement	Neonatal death
2	18	G1P0	20	Torcular Herophili	Female	Mild ventriculomegaly; corpus callosum poorly visualized	None
3	38	G1P0	26	Posterior fossa venous sinus region	Female	None	60 months
4	38	G2P0	20	Torcular Herophili	Male	Subarachnoid hemorrhage	None
5	23	G1P0	29	Torcular Herophili	Female	None	29 months
6	24	G1P0	24	Torcular Herophili	Male	None	36 months
7	30	G1P0	35	Superior sagittal sinus	Female	FGR;AEDF;Pleural effusions; ascites;Right heart enlargement; reduced RV function Delayed cortical lcation/gyral maturation Systemic-ulmonary collateral vessels	Neonatal death (day 3)
8	32	G2P2	23	Occipital region	Female	None	37 months

Abbreviation: FGR: Fetal growth restriction. AEDF: Umbilical artery absent end-diastolic flow.

gestational age at diagnosis was 27 weeks (range 20–35 weeks).

On 2D ultrasound consistently demonstrated anechoic or cystic extra-axial lesions adjacent to dural venous sinuses, with diameters ranging from 18 × 19 mm to 90 × 110 mm. In five fetuses (62.5%), internal echogenic foci or nodular high-echo regions were observed, suggestive of intraluminal thrombosis. One fetus exhibited arterial-venous communications and systemic–pulmonary collateral flow, indicating a more complex vascular malformation. Associated findings included hydrocephalus, mild ventriculomegaly, and delayed cortical sulcation in three cases, while five fetuses presented as isolated DSM.

Three-Dimensional Ultrasound Findings

In all cases, the addition of 3D ultrasound provided further diagnostic detail. The 3D volume reconstructions clarified the full extent of the venous lesion and its continuity with adjacent venous structures (such as the straight or sagittal sinuses). Surface rendering and multiplanar views helped differentiate the margins of the malformation from surrounding brain tissue and better demonstrated the spatial relationship at the torcular confluence. In cases with suspected thrombosis on 2D, the 3D power Doppler mode confirmed the presence of nonvascular material within the dilated sinus (i.e., a laminated thrombus) by showing absent flow in those regions, and it depicted the layered morphology of the thrombus when present. The 3D Doppler also proved useful in the fetus with arteriovenous channels by visualizing the continuity of the abnormal vessels and highlighting the underdeveloped cortical veins. Overall, 3D ultrasound increased our confidence in characterizing each lesion by confirming venous continuity, the absence of arterialization, and the presence or absence of thrombus within the malformation. The imaging findings and outcomes are presented in Table 2.

Table 2. Imaging findings and outcomes.

Case No.	2D Ultrasound Findings	3D Ultrasound Additional Findings	Presence of Thrombosis	Location/ Extent of DSM	Chromosomal testing	Pregnancy Outcome	Postnatal Outcome
1	Large left extra-axial cystic lesion between dura mater and calvarium, 90 × 110 mm.	3D US delineated lesion extent and venous continuity; demonstrated laminated intraluminal thrombus and slow phasic venous flow; no arterialization detected.	None	Superior sagittal sinus	cfDNA: low risk; no invasive testing.	Termination of pregnancy by cesarean delivery at 34 weeks' gestation.	Neonatal death.
2	Enlarged torcular and dural venous sinus, 34 × 28 mm; heterogeneous echogenicity with two hyperechoic nodules suggestive of intraluminal thrombi	3D US clarified sinus expansion and continuity; demonstrated nodular intraluminal thrombi with laminated morphology; improved visualization of venous connections.	Yes	Torcular Herophili	chromosomal microarray (CMA): normal; exome sequencing (ES): not performed.	Intrauterine fetal demise	-
3	Posterior fossa cystic lesion, 18 × 19 mm.	3D US clarified lesion boundaries and relation to torcular; confirmed extra-axial location; no definite thrombus visualized	None	Posterior fossa	CMA: normal;	Vaginal delivery at 39 weeks' gestation.	alive at 60 mo; no major NDI at last review.
4	Anechoic area within dural venous sinus, 31 × 22 mm.	3D US delineated cystic venous dilatation; confirmed continuity with dural sinus system; no definite thrombus detected.	Yes	Torcular Herophili	cfDNA: low risk; no invasive testing.	Termination of pregnancy at 20 weeks' gestation	
5	Enlarged torcular and superior sagittal sinus with a 23 × 19 mm cystic mass.	3D US confirmed sinus dilatation; clarified cystic mass continuity with venous lumen; improved delineation of lesion extent and adjacent structures	Yes	Torcular Herophili and superior sagittal sinus	cfDNA: low risk; invasive testing offered but declined.	Vaginal delivery at 38 weeks' gestation.	alive at 29 mo; no major NDI at last review.
6	nlarged torcular and superior sagittal sinus with a 26 × 25 mm cystic mass.	3D US delineated sinus dilatation and cystic mass; clarified venous continuity; no definite thrombus detected.	Yes	Torcular Herophili and superior sagittal sinus	cfDNA: low risk; no invasive testing.	Vaginal delivery at 40 weeks' gestation.	alive at 36 mo; no major NDI at last review.
7	Enlarged superior sagittal sinus (up to 9.2 mm) with several arterial communications (~2.3 mm); shallow sulci and delayed gyral maturation; abnormal flow tract between pulmonary artery and aorta.	3D US clarified venous dilatation and continuity of arterial–venous channels; improved visualization of cortical surface immaturity; confirmed systemic–pulmonary collateral flow.	NO	Superior sagittal sinus	Amniocentesis with karyotype 46,XX; CMA: normal; ES: not performed.	Cesarean delivery at 34 weeks' gestation.	Death 3 days postpartum
8	Enlarged torcular with a 24 × 21 mm hyperechoic intraluminal focus.	3D US confirmed torcular dilatation; demonstrated laminated intraluminal thrombus; improved spatial delineation of venous continuity.	Yes	Torcular Herophili	cfDNA: low risk; no invasive testing.	Cesarean delivery at 39 weeks' gestation.	alive at 37 mo; no major NDI at last review.

Presence of thrombosis and extent of involvement

Thrombosis was either suspected on ultrasound or confirmed by Doppler findings in five of the eight fetuses (62.5%). In most of these, the thrombus primarily involved the torcular Herophili and, in some cases, extended into the superior sagittal sinus. Two fetuses had multi-sinus involvement (beyond the torcular into other dural sinuses). We observed that lesions without any thrombus tended to remain stable in size or even regress slightly on follow-up scans, whereas those with extensive thrombus formation or with arteriovenous shunting components were more likely to show progression and to be associated with signs of hemodynamic compromise.

Genetic testing

All eight pregnancies underwent aneuploidy screening. cfDNA results were low-risk in seven cases, and one fetus (with a non-isolated presentation) underwent amniocentesis, which confirmed a normal karyotype (46,XX) and normal chromosomal microarray (CMA). No pathogenic variants were detected, consistent with previous literature indicating a low rate of chromosomal abnormalities in isolated DSM.

Pregnancy and postnatal outcomes

Among the eight cases, two pregnancies were electively terminated (at 20 and 34 weeks), and one resulted in intrauterine fetal demise. Five infants were liveborn: three by vaginal delivery (at 38–40 weeks) and two by cesarean section (at 34 and 39 weeks).

These four children (from cases 3, 5, 6, and 8) are currently 29 to 60 months old and show age-appropriate neurodevelopment with no major neurological deficits. Follow-up imaging in these cases has shown either stability or postnatal regression of the venous malformation. In contrast, two cases had poor outcomes: one neonate died at 3 days of age, and another infant died shortly after birth. Both of these fatal cases were characterized by very large lesions (>30 mm), involvement of multiple dural sinuses, extensive thrombosis, and resultant cardiac strain (including the presence of systemic–pulmonary collaterals causing high-output cardiac failure).

Representative case series

To illustrate the spectrum of findings, we describe two representative cases from our series:

Case 7

A 30-year-old primigravida was referred at 35 weeks of gestation after detecting fetal growth restriction and abnormal Doppler findings. 2D ultrasound revealed dilatation of the superior sagittal sinus (up to 9.2 mm) with multiple small arterial communications (~2.3 mm) between the sinus and adjacent cerebral arteries (Figure 1). Associated findings included pleural and peritoneal effusions, right heart enlargement with impaired right ventricular function, and absent end-diastolic flow in the umbilical artery, together with delayed cortical sulcation and gyral maturation. 3D Doppler imaging confirmed venous continuity and arterial–venous channels, as well as systemic-pulmonary collateral flow between the pulmonary artery and aorta. Amniocentesis demonstrated a normal female karyotype (46,XX) and normal CMA results. The infant was delivered by cesarean section at 34 weeks due to deteriorating fetal condition but died three days postpartum despite intensive neonatal care.

Case 8

A 32-year-old multigravida (G2P2) was referred at 23 weeks of gestation after an incidental finding of a cystic structure in the occipital region. 2D ultrasound demonstrated an enlarged torcular Herophili containing a 24 × 21 mm hyperechoic intraluminal focus, highly suggestive of thrombosis. 3D ultrasound confirmed torcular dilatation and revealed laminated thrombus morphology, with clear visualization of the venous confluence and surrounding structures (Figure 2). Noninvasive cfDNA screening indicated low risk for aneuploidy, and no other anomalies were identified. The pregnancy progressed uneventfully, and a female infant was delivered by cesarean section at 39 weeks with normal Apgar scores. Postnatal follow-up over 37 months demonstrated complete clinical stability and age-appropriate neurodevelopment, with gradual resolution of the venous dilation on imaging.

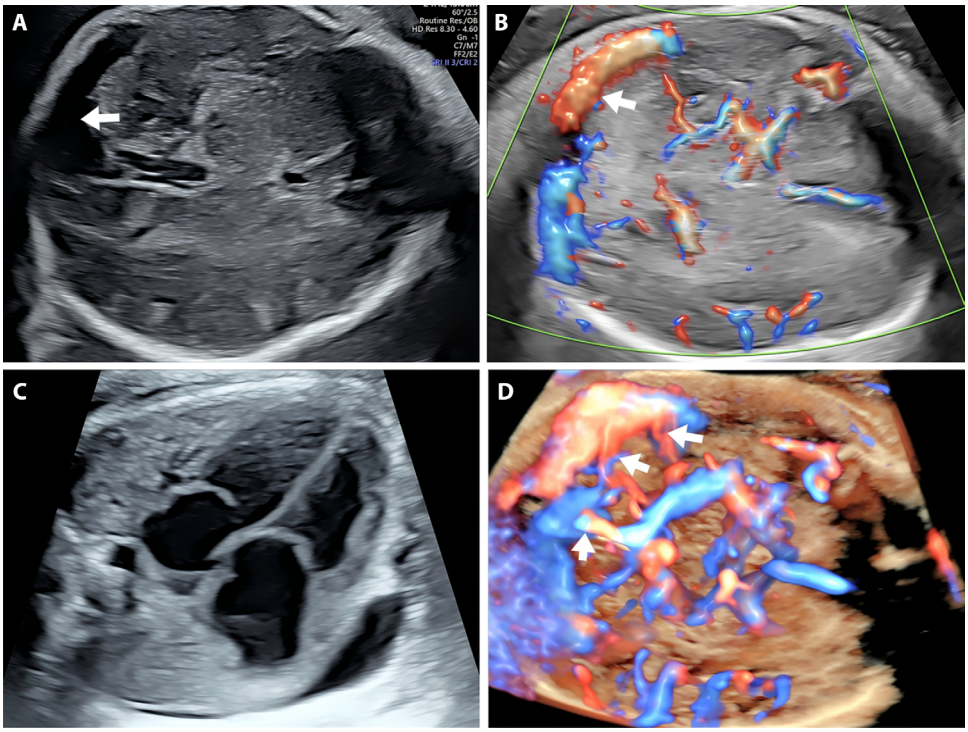

Figure 1. A) Two-dimensional ultrasound demonstrates increased intracranial echogenicity and widening of the dural sinuses (As indicated by the white arrow). Sulcal visualization is poor, and both the sulci and gyri appear shallow, with cortical development lagging behind the expected level for gestational age. B) Color Doppler imaging reveals dilatation of the fetal superior dural sinuses, with multiple communicating branches observed between the dural sinuses and cerebral parenchymal arteries (As indicated by the white arrow). C) The fetal cardiothoracic ratio is increased, accompanied by right heart enlargement. D) Spatiotemporal image correlation imaging demonstrates marked dilatation of the fetal superior dural sinus, with multiple communicating branches visible between the sinus and cerebral parenchymal arteries (As indicated by the white arrow).

Discussion

DSM have been described primarily in case reports and small cohort studies, with diagnosis relying on a multimodality approach. 2D ultrasound serves as the first-line screening tool, detecting abnormal venous sinus dilatation or echogenic foci indicative of thrombosis. MRI complements this by defining lesion extent, parenchymal changes, and venous drainage, which are essential for prognostic counseling (1, 13). Previous literature establishes that intraluminal thrombosis, multi-sinus involvement, ventriculomegaly, and parenchymal injury are associated with adverse outcomes, whereas spontaneous regression generally predicts a favorable prognosis (9, 12, 14).

Recently, there has been increasing focus on 3D ultrasound, though systematic data remain limited. Case reports suggest that 3D imaging enhances the visualization of torcular enlargement, thrombus morphology, and spatial relationships compared to 2D imaging alone (5, 15). Qiu et al (16). demonstrated its utility in assessing complex vascular architectures, while volumetric fetal MRI assists in differentiating DSM from other posterior fossa cystic lesions (11). Collectively, these studies indicate that 3D imaging—whether ultrasound or MRI—adds incremental diagnostic confidence. However, current evidence is largely based on isolated cases (17, 18), lacking standardized protocols. This underscores the need for larger, prospective studies to validate 3D ultrasound's role and

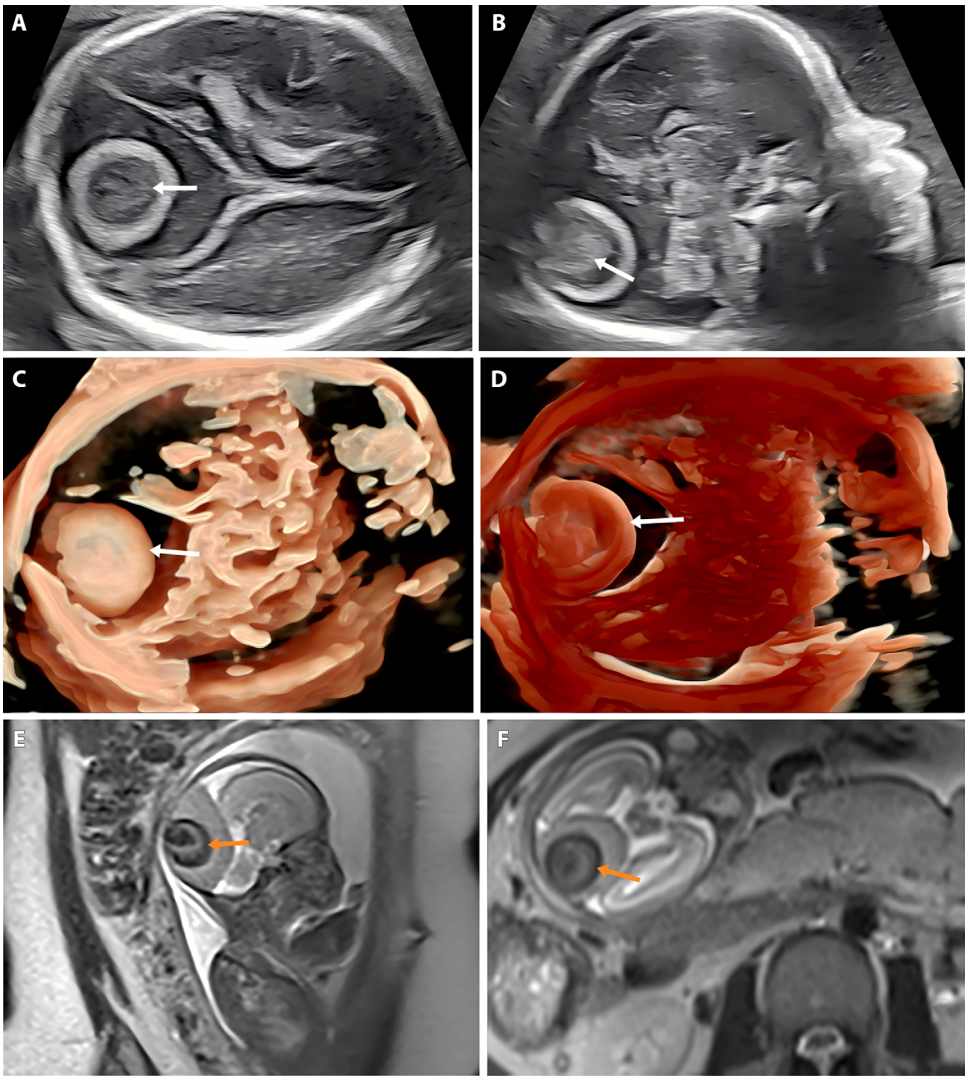

Figure 2. A) and B) Transverse and sagittal planes demonstrate a widened confluence of the dural sinuses with a triangular configuration, containing a hyperechoic intraluminal nodule (As indicated by the white arrow). C) 3D ultrasound demonstrates a widened confluence of the dural sinuses with well-defined borders, along with a hyperechoic intraluminal thrombus showing sharply demarcated margins. D) 3D ultrasound shows a hyperechoic intraluminal thrombus with internal hypoechoic areas, indicating the presence of liquid components (partial liquefaction) (As indicated by the white arrow). E) and F) The MRI sagittal and axial planes show the dilation of the dural sinus along with thrombus formation within it (As indicated by the yellow arrow).

integrate it with 2D ultrasound and MRI for optimal evaluation.

In this study, we assessed fetuses with DSM using both 2D and 3D ultrasound to correlate imaging features with outcomes. Our findings confirm that 3D ultrasound offers significant diagnostic value beyond 2D imaging. 3D reconstructions improved the delineation of venous dilatation and thrombus morphology while clarifying relationships with adjacent structures. These results align with recent reports highlighting the value of 3D rendering in evaluating anatomical boundaries. Notably, intraluminal thrombosis and multi-sinus involvement were associated with poorer outcomes, whereas isolated dilatations generally predicted

favorable prognoses. These findings reinforce the complementary roles of 2D and 3D ultrasound in diagnosis and prognostication.

Our results are consistent with earlier prenatal DSM ultrasound studies (19, 20), but extend prior knowledge by systematically evaluating the added benefit of 3D imaging. Earlier studies focused on 2D ultrasound features—such as venous sinus dilatation or echogenic foci suggestive of thrombosis—often with MRI for additional information. While MRI is the gold standard for intracranial venous anomalies, its use is limited by cost, availability, and the need for more advanced gestational ages. Previous accounts of 3D ultrasound were largely anecdotal and did not correlate findings with outcomes. By demonstrating the added diagnostic value of 3D ultrasound and linking specific imaging features (e.g., thrombosis, multi-sinus involvement) to prognosis, our study provides stronger evidence to suggest integrating 3D techniques into routine DSM evaluation.

Clinically, the combined 2D/3D approach facilitates early, accurate detection and tailored counseling. In our cohort, 3D imaging increased diagnostic confidence, aiding in the risk stratification of lesions likely to regress versus those progressing to hydrocephalus or neurodevelopmental impairment. This information guides perinatal management, including surveillance intensity and delivery planning. Furthermore, in settings where MRI is unavailable, 3D ultrasound represents a cost-effective, accessible alternative for comprehensive evaluation

Regarding prognostic markers, all children with favorable long-term outcomes in our cohort presented with lesion diameters <30 mm at diagnosis. In contrast, adverse outcomes clustered in cases with massive lesions or high-risk features such as extensive thrombosis and hemodynamic compromise. While a lesion size <30 mm may serve as a pragmatic early marker for favorable prognosis, size alone is neither necessary nor sufficient. Confounders such as termination bias, measurement errors, and systemic hemodynamics must be considered. Therefore, we propose the <30 mm observation as a hypothesis-generating counseling prompt to be integrated with Doppler and MRI findings, rather than a standalone criterion. Future prospective validation should standardize measurement protocols and evaluate 3D volumetry as a potentially superior predictor.

This study has several limitations, including its retrospective design, small sample size, and limited follow-up duration, which restrict definitive conclusions regarding long-term neurodevelopment. Additionally, we did not assess inter-operator reproducibility. Future research should aim to validate these findings in multicenter cohorts with standardized protocols and explore advanced techniques like spatiotemporal image correlation (STIC). Establishing consensus guidelines for incorporating 3D ultrasound alongside 2D ultrasound and MRI would greatly benefit clinical practice.

Conclusion

In conclusion, 3D ultrasound provides significant diagnostic value over 2D ultrasound in the prenatal evaluation of fetal DSM. By enhancing the visualization of venous dilatation, thrombus morphology, and anatomical relationships, 3D ultrasound improves diagnostic confidence and offers valuable prognostic insights. Despite study limitations, our findings suggest the integration of 3D ultrasound into routine DSM diagnostic protocols. Larger, multicenter studies with long-term follow-up are needed to confirm these observations and establish evidence-based clinical guidelines.

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Consent for Publication: Informed consent was obtained from all subjects involved in this study.

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