

Columns of the Fornix, Not to Be Mistaken for the Cavum Septi Pellucidi on Prenatal Sonography

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Objective. Visualization of the cavum septi pellucidi (CSP) is considered an integral part of the prenatal second- and third-trimester sonographic evaluations of the fetal neural axis. We have noted that another anatomic structure, the columns of the fornix, can be mistaken for the CSP and result in the missed diagnosis of agenesis of the corpus callosum. **Methods.** We describe a case in which the columns of the fornix were misinterpreted as representing the CSP during a sonographic evaluation at 18 weeks' gestation. After a follow-up sonogram at 35 weeks, agenesis of the corpus callosum was detected. A retrospective evaluation of the prevalence of forniceal columns was then performed in 100 consecutive sonograms of pregnancies between 18 and 24 weeks' gestation. A prospective study was then performed in 20 patients to determine the prevalence of visualization of the columns of the fornix. **Results.** In 86 of 100 patients, the columns of the fornix were retrospectively identified as discrete and separate structures from the CSP. When additional views were obtained prospectively in the forebrain, the fornix could be identified in all 20 patients. **Conclusions.** The columns of the fornix may simulate the appearance of the CSP on second- and third-trimester sonograms. The distinction between these structures can be made because the columns of the fornix will show a linear reflection (3 lines) at their interface, whereas the CSP will appear as a fluid-filled triangular or rectangular fluid-filled space without a central line. **Key words:** cavum septi pellucidi; corpus callosum; fetal brain; fornix.

Abbreviations

CSP, cavum septi pellucidi

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For well over a decade, visualization of the cavum septi pellucidi (CSP) has been considered an integral part of the prenatal second- and third-trimester sonographic evaluation of the fetal neural axis. Virtually all professional guidelines and reviews recommend identification of the CSP as part of the fetal neurosonogram.¹⁻⁷ The embryologic development of the CSP is closely associated with other surrounding structures, especially the corpus callosum. Identification of the CSP virtually excludes complete agenesis of the corpus callosum. Abnormalities or non-visualization of the CSP may be associated with a variety of abnormalities, including agenesis of the corpus callosum, septo-optic dysplasia, holoprosencephaly, schizencephaly, porencephaly/hydranencephaly, basilar encephaloceles, and severe hydrocephalus.⁸

We have noted that sonographers infrequently image a structure that they misinterpret as representing the CSP, which, in fact, corresponds to the columns of the fornix, slightly more basal structures. These paired nerve columns are also interchangeably called the fornix. Because the embryologic development of the fornix is not directly associated with that of the corpus callosum, its identification will similarly not exclude the abnormalities stated above. A recent case of agenesis of the corpus callosum in which the columns of the fornix were misinterpreted as the CSP emphasizes this point.

In addition to describing a salient case of misinterpretation of the CSP, we attempted to identify the consistency of visualization of the columns of the fornix on normal second- and third-trimester prenatal neurosonograms and to describe their anatomy and embryologic development.

Materials and Methods

Case Report

A 36-year-old woman, gravida 2, para 1, was evaluated sonographically for advanced maternal age at an outside institution. A previous pregnancy was normal, and there was no family history of neurologic, genetic, or chromosomal abnormalities. Fetal biometric evaluation revealed a fetus at a gestational age of 18 weeks 4 days. Bilateral fetal pelviectasis (5 mm) was the only abnormality noted. Images of the fetal intracranial anatomy were reported as normal, specifically the lateral ventricles, cisterna magna, and CSP (Figure 1). The patient returned for a follow-up sonogram to assess the fetal pelviectasis, at which time intracranial abnormalities were noted, and the patient was referred to our center for evaluation. Sonographic evaluation revealed a fetus of 35 weeks 1 day with bilateral ventriculomegaly (18 mm) and a teardrop configuration of the ventricles (colpocephaly) and absence of both the CSP and corpus callosum (Figure 2). Irregularity of the wall of the lateral ventricle was seen, suggesting periventricular nodular heterotopia.⁹ Unilateral pelviectasis was also noted. A magnetic resonance imaging scan of the fetus confirmed the sonographic findings of ventriculomegaly, absence of the corpus callosum, and periventricular nodular heterotopia (Figure 3). The fetus died 10 days later without an autopsy.

Retrospective and Prospective Studies

It was our impression that the fornical columns were commonly and readily visible on routine scans but usually not recognized or identified as a distinct structure. To test this impression, we initially performed a retrospective study and subsequently a prospective study to see how often they were visible on routine obstetric ultrasound examinations. After approval of this study from our Institutional Review Board, we interrogated our database for all cases in which “routine” obstetric sonography was performed between 18 and 24 weeks’ gestation from January 2005 through July 2007. Cases in which a fetal abnormality was detected were excluded from the study. One hundred consecutive cases in chronologic order were chosen for review, and fetal intracranial findings were retrospectively analyzed by a senior sonologist. Fetal imaging for both parts of the study was conducted with 2- to 4-MHz vector and 2- to 6-MHz curved array transducer formats with both selectable focus and frequency as appropriate for the size of the pregnancy. Images that included transverse axial, coronal, and sagittal planes of sections of the intracranial anatomy were analyzed and noted. An experienced sonologist reviewed the 100 cases, looking for the presence or absence of both the CSP and the columns of the

Figure 1. Transverse axial sonogram of the fetal brain performed at an outside institution at 18 weeks’ gestation. The structures between the arrows were interpreted as the normal CSP.



fornix (Figure 4). If a 3-second cinematic clip was needed to see any of the structures, this was noted as well.

For the second part of the study, 4 sonographers were educated with respect to the anatomy of the CSP and forniceal columns. They were instructed to obtain the standard images of the CSP as well as a transverse axial plane of section just inferior to the plane of section used to show the cavum septi pellucidi, which would depict the columns of the fornix. A prospective study was then performed on 20 patients referred for routine prenatal sonograms between 18 and 24 weeks' gestation. Still images were taken of fetal and intracranial anatomy by these sonographers and were reviewed by an experienced sonologist.

Results

In the retrospective evaluation, the columns of the fornix were visible in 86 of 100 cases. The CSP was seen in all 100 cases. Of the 86 cases in which the columns of the fornix were identified, 23 required a cinematic clip to identify the structures, whereas in the remaining 63 cases, an adequate display of the columns of the fornix was

seen on a still image. In the 14 cases in which the columns of the fornix were not seen, review of the images revealed that no specific effort had been made to obtain an appropriate plane of section in the fetal brain, specifically, a transverse axial plane of section just inferior to that obtained to depict the CSP.

In the prospective study of 20 patients, both the columns of the fornix and the CSP were displayed in all. Images of the columns of the fornix were seen in a transverse axial plane of section just inferior to that showing the CSP. This additional image was usually obtained in seconds, never required more than 1 to 2 minutes of additional scanning time, and was easily obtained by a standard transabdominal approach.

Discussion

During the past several years, we have noted that in transverse axial scans of the fetal calvarium, 2 adjacent hypoechoic structures of varying length in the forebrain are often seen (Figure 4B). We believe these represent the columns of the fornix. When the CSP is present, the columns of the fornix will be seen in a plane of section just

Figure 2. Transverse axial sonogram of the fetal brain at 34 weeks' gestation. The occipital horns of the lateral ventricles are dilated (colpocephaly), and the ventricles have a teardrop configuration characteristic of agenesis of the corpus callosum. Marked irregularity of the ventricular wall was seen, suggestive of heterotopia.

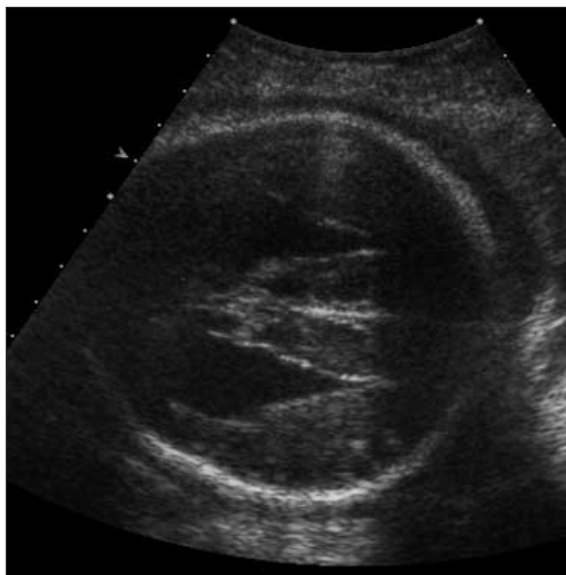
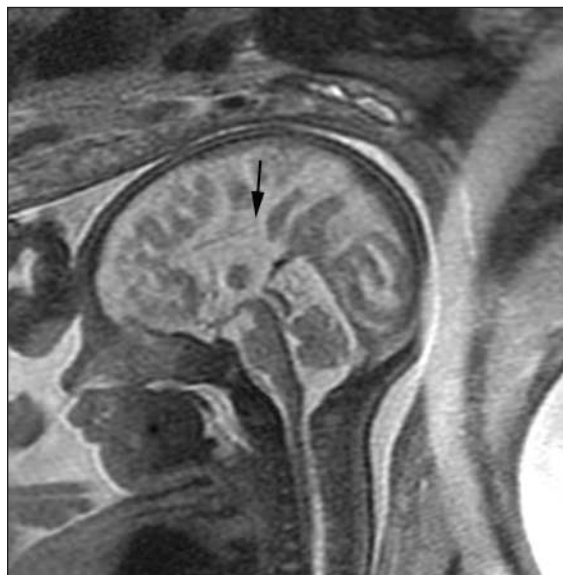


Figure 3. Magnetic resonance imaging of the same patient performed shortly after sonography. A midline sagittal single-shot fast spin echo T2-weighted image shows absence of the corpus callosum (arrow) with the characteristic appearance of the medial sulci radiating outward in a "sunburst" pattern typical of callosal agenesis.



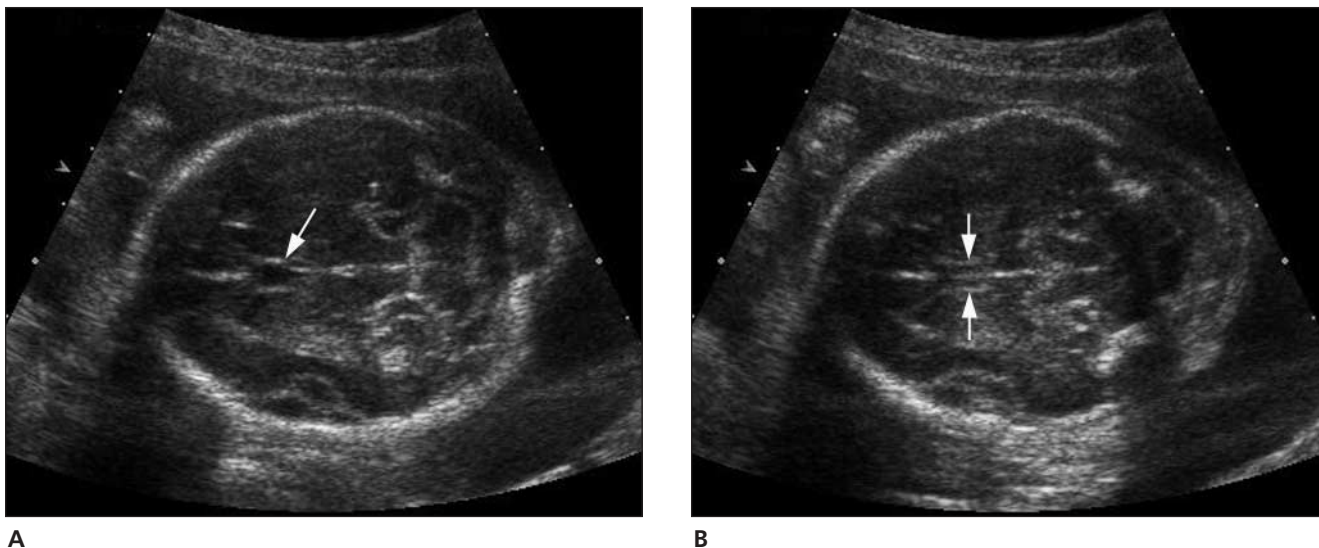


Figure 4. **A**, Transverse axial sonogram in a healthy fetus at 18 weeks' gestation. The CSP (arrow) appears as a fluid-filled box between its septi, which separate this space from the frontal horns of the lateral ventricles. **B**, Transverse axial sonogram in the same patient just slightly inferior to the plane of section in **A**. The columns of the fornix are seen as 2 hypoechoic structures (arrows) with a central interface reflection.

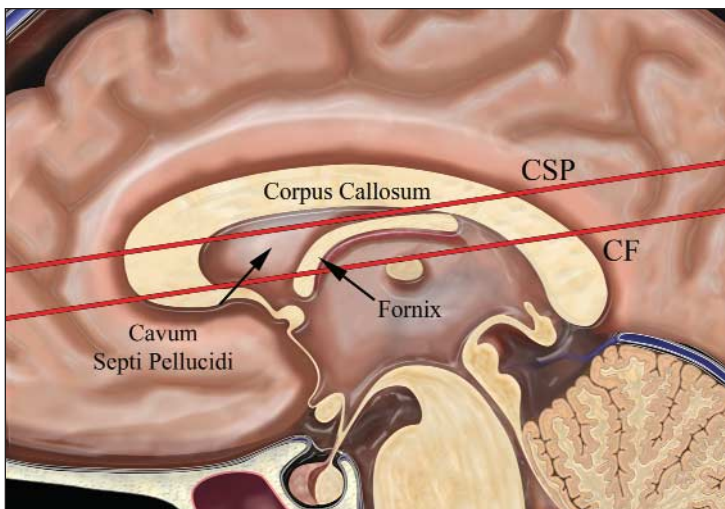
slightly inferior to the CSP (Figure 5). These structures can be seen more in their entirety and to elongate and diverge on slightly angulated coronal planes of section (Figure 6).

Anatomically, the fornix occupies a position close to the medial plane and follows part of the undersurface of the arch of the corpus callosum over the thalamus.¹⁰ It is composed of 2 thick

bands, separated at both ends but joined together at the middle. Although the fornix of the brain is often referred to generically as the “columns of the fornix,” it is divided anatomically into parts: the crus, the hippocampal commissure, the body, and the columns. The crus of the fornix begins posteriorly as a continuation of the fimbria of the hippocampus. It arches upward over the thalamus, closely applied to the inferior surface of the corpus callosum, and inclines toward the midline. The body of the fornix lies above the tela choroidea and ependymal roof of the third ventricle and is attached to the lower borders of the septum pellucidum and the under surface of the corpus callosum. Anteriorly, above the interventricular foramina, the body divides again into the columns or the anterior pillars of the fornix.¹⁰

Although the hypoechoic nature of the columns of the fornix may simulate the CSP to the uninitiated, the identification of a parallel “line” in the center of this hypoechoic structure helps make the distinction between the fornix and CSP. Thors and Hoogland¹¹ suggested that the echogenic lines along the lateral aspect of the fornices represent the medial walls of the lateral ventricles (Figure 7). They also suggested that the central line may represent the developing septum pellucidum. Although it is likely that the lateral lines

Figure 5. Midline sagittal illustration showing the relationship of the corpus callosum, CSP, and fornix. The planes of section showing the CSP and the columns of the fornix (CF) on corresponding transverse axial planes of section are depicted. (Illustration courtesy of James A. Cooper, MD, Imaging Healthcare Specialists, San Diego, CA.)



may be caused by reflections from the medial walls of the lateral ventricles, the central linear echo is more likely due to the interface between the columns of the fornix. The septum pellucidum is only likely to insinuate itself between the forniceal bands more posteriorly as the bands of the fornix diverge.

Nearly 4 decades ago, Rakic and Yakovlev¹² described their hypothesis of the embryogenesis of the forebrain with particular attention to the development of the corpus callosum and CSP. They hypothesized that the leaves (septi) of the septum pellucidum form as a result of cavitation of the medial inferior commissural plate during formation of the corpus callosum.¹² In the mid 1980s, several authors described the sonographic absence of the CSP as one of several features seen in agenesis of the corpus callosum.¹³⁻¹⁵ In 1989, in a postnatal and pediatric population, Barkovich and Norman⁸ described the importance of identification of the septum pellucidum during cross-sectional imaging of the brain and its association with a wide spectrum of brain malformations, including agenesis of the corpus callosum, septo-optic dysplasia, holoprosencephaly, schizencephaly, porencephaly/hydrencephaly, basilar encephaloceles, and chronic severe hydrocephalus (Chiari II malformation and aqueductal stenosis). Because the corpus callosum and septum pellucidum both derive from the commissural plate, and the corpus callosum forms first, absence of the septum pellucidum in patients with absence of the corpus callosum is consistent with the known embryologic development.⁸

Although the abnormalities of the corpus callosum stated above are important to recognize sonographically, the corpus callosum was, and still remains, often difficult to image on prenatal sonograms. With recognition of the close embryologic relationship of the corpus callosum and CSP, the fluid-filled CSP, which is far easier to recognize, became the focus of attention. In a report by Shaw and Alvord¹⁶ based on autopsy studies, the prevalence of the CSP was 100% in premature fetuses and premature neonates. In a sonographic study by Falco et al,¹⁷ the CSP was seen in 100% of cases between 18 and 37 weeks' gestation and in 79% between 38 and 41 weeks.

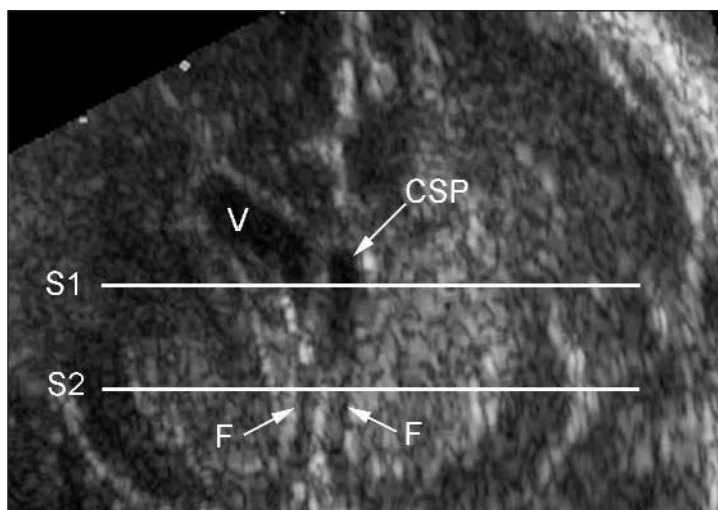
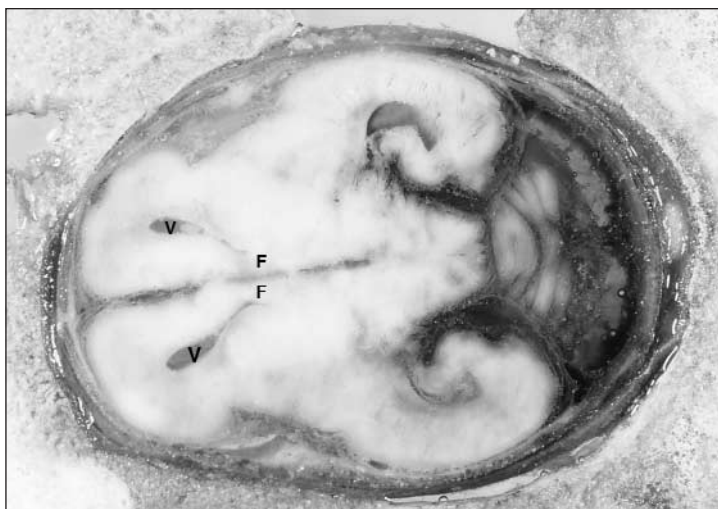


Figure 6. Angled coronal plane of section. The image has been rotated 90° counterclockwise. The fornix (F) is seen inferior to the CSP. In this case, the ventricles (V) were asymmetric but normal in size. S1 indicates the scan plane in which the CSP would be seen; and S2, the scan plane slightly more inferior in which the fornix would be visualized.

In 1989, Filly et al⁴ and subsequently others⁵⁻⁷ emphasized the importance of visualization of the CSP as an integral part of the prenatal second and third trimester sonographic evaluation of the fetal neural axis (intracranial anatomy). Presently, professional guidelines (American Institute of Ultrasound in Medicine/American College of Radiology, American College of Obstetricians and

Figure 7. Anatomic section of the fetal head from a fetus at 20 weeks' gestation. The medial walls of the frontal horns of the lateral ventricle (V) form the lateral margin of the fornix (F). (Image courtesy of Frans Thors, PhD, University of Limburg, Maastricht, the Netherlands.)



Gynecologists, and International Society of Ultrasound in Obstetrics and Gynecology)¹⁻³ recommend identification of the CSP as part of the fetal neurosonogram.

The CSP appears on prenatal sonograms as a rectangular or triangular fluid-filled structure anteriorly positioned between the frontal horns of the lateral ventricles on transverse axial planes of section. It is attached to the undersurface of the corpus callosum superiorly, to the anterior part of the fornix inferiorly, and posterior to the reflected portion of the corpus callosum anteriorly.¹⁸ The lateral surface of each lamina or septum of the CSP is directed toward the body and anterior horn of the lateral ventricle and is covered by the ependyma of that cavity.

Anatomically, the CSP is often regarded as part of the longitudinal cerebral fissure, which has become shut off by the union of the hemispheres in the formation of the corpus callosum above and the fornix below.¹⁸ On standard scanning planes, the CSP appears as a short box between the 2 septi. In the second trimester, this space can be seen to extend posteriorly and underlies the entire corpus callosum. The posterior part of this same space behind the foramina of Monroe is named the cavum vergae, and the entire space can be termed the CSP et vergae. With advancing gestational age, the center of the space becomes constricted, leaving an anterior part, the CSP, and a posterior part, the cavum vergae. In most individuals, these spaces also disappear, leaving a single central membrane, the septum pellucidum, which in fact is composed of the 2 fused septi pellucidi.

We chose to focus our study on fetuses between 18 and 24 weeks' gestation on the basis of data that the CSP should be visualized in all fetuses in this gestational age range.¹⁶ The width of the CSP increases gradually at a rate of 0.37 mm/wk between 19 and 27 weeks' gestation and plateaus between 28 weeks and term.¹⁹

Early sonographic studies in the fetus and neonate either misinterpreted the CSP as the third ventricle in normal cases²⁰ or a superiorly deviated third ventricle in cases of agenesis of the corpus callosum.²¹ In a more recent report, Pilu et al²² reported 2 cases in which absence of the CSP was not appreciated. This was due to the ultrasound beam crossing the walls of the frontal

horns, which are normally in close proximity; thus, in these 2 cases, parallel echoes simulated the CSP.²² This artifact was only present at mid gestation in their 2 patients, when the cavity of the fused frontal horns was small and was scanned along the axial plane. It did not occur when the frontal horns were scanned with different angles of insonation, particularly in the coronal plane, or later in gestation, when the frontal horns had a larger cavity. This emphasizes that when the 2 septi of the CSP are not seen with certainty, the operator should use other views (coronal) to search for them and also attempt to image the corpus callosum directly using a midsagittal view.

Recent improvements in ultrasound technology, namely 3-dimensional imaging, may make identification of the corpus callosum easier and more routine on prenatal sonograms.²³ However, the CSP is still likely to be seen more readily and should be specifically sought at the time of routine anatomic scans. Its identification is important in excluding other noncallosal abnormalities such as septo-optic dysplasia and schizencephaly. Familiarity with the sonographic appearance of the columns of the fornix will allow one to differentiate between the fornix and CSP and to prevent its misinterpretation.

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