Real-Time Sonography: Ventricular and Vascular Anatomy of the Fetal Brain in Utero

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Real-Time Sonography: Ventricular and Vascular Anatomy of the Fetal Brain in Utero

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Detailed fetal intracranial anatomy can be examined in utero using real-time sonography. The ability to demonstrate motion makes it possible to visualize important vascular landmarks which are helpful in identifying adjacent structures and in recognizing appropriate planes of section. The lateral ventricular system can be demonstrated and the lateral ventricular ratio can be determined in cases beyond 27 weeks gestation if the head is in an occiput transverse position. A lateral ventricular ratio greater than 0.45 (bodies) or greater than 0.65 (atrium) should raise the question of hydrocephalus and close follow-up measurements of the biparietal diameter, the head circumference/abdominal circumference ratio, and the lateral ventricular system should be made to evaluate this possibility. The fetal third ventricle is not routinely visualized before 34 weeks gestation in the absence of hydrocephalus; alternative anatomic explanations for the structure commonly referred to in the literature as the fetal third ventricle are discussed.

The improved resolution of current real-time instruments has made it possible to demonstrate anatomy previously identified using static image [1] (conventional B-scanner) instruments. This is particularly true in the evaluation of the fetus in utero [2-9]. In this report we (1) demonstrate the degree to which these instruments can define detailed fetal intracranial anatomy in the third trimester of pregnancy, including the lateral ventricular ratio [10]; (2) raise some questions regarding several previously accepted concepts of normal fetal intracranial anatomy as demonstrated by static image sonography [11-14], particularly with regard to the fetal third ventricle; and (3) encourage thorough evaluation of the fetal intracranial anatomy in all obstetrical examinations using real-time sonography.

Materials and Methods

The measurement of the lateral ventricular system was performed on 112 uncomplicated obstetrical patients at or beyond 27 weeks gestation (based on the menstrual history and/or measurement of the biparietal diameter) [4] in whom there has been no central nervous system pathology identified at delivery. All examinations were done by one of us (F. P. H.) using a linear phased-array real-time instrument (ADR, Tempe, AZ) with a 3.5 MHz single-focus transducer. The ventricle of the hemisphere farther from the transducer was consistently better visualized, and all measurements were made in this hemisphere using manual calipers. Appropriate images for measurement could only be obtained if the head was in an occiput transverse position; if the head was in an oblique position, it could often be turned into a transverse position by moderate pressure with the transducer. If the head position was occiput anterior or occiput posterior, appropriate images could not be obtained.

The routine examination included a series of transaxial scans beginning at the vertex progressing caudally to a level at which the bodies of the lateral ventricles were identified as echogenic linear densities paralleling the falx [12-14] (fig. 1). The lateral ventricular ratio (body) measured at this level related the distance from the middle of the falx echo to the *outer* margin of the echo of the ventricular body to one-half of the greatest transverse

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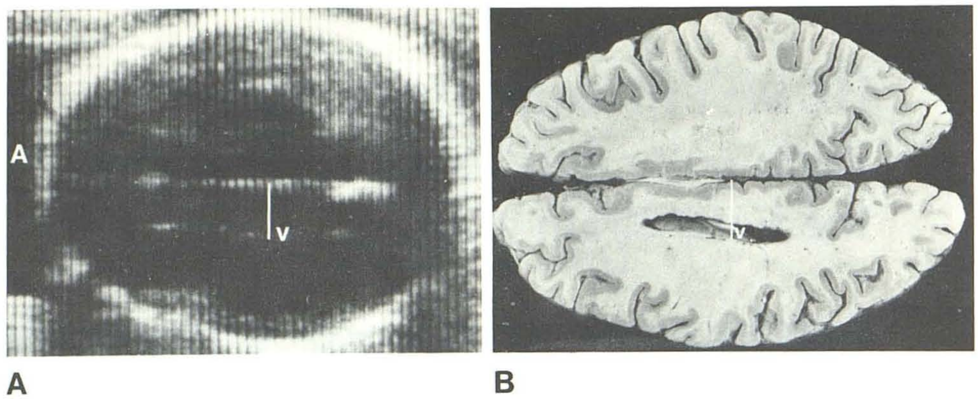

Fig. 1.—**A**, Real-time transaxial scan of fetal brain at level of body of lateral ventricle (V). A = anterior. **B**, Specimen at same axial level demonstrates body of ventricle. (Reprinted from [15].)

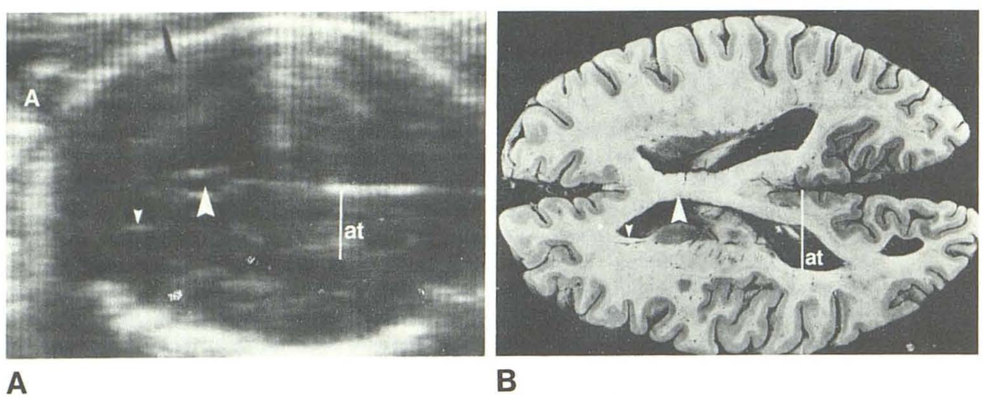

Fig. 2.—**A**, Scan 1-2 cm caudal to fig. 1A demonstrates atrium (at) and anterior horn (*small arrowhead*) of lateral ventricle and trunk of corpus callosum (*large arrowhead*). A = anterior. **B**, Specimen at same axial level also demonstrates atria (at) and anterior horns (*small arrowhead*) of ventricle and trunk of corpus callosum (*large arrowhead*). (Reprinted from [15].)

diameter of the brain at the same level measured from inner table to inner table. The transducer was then moved caudally 1.5-2 cm where an anechoic structure was imaged anteriorly in the midline (fig. 2). The atrium of the lateral ventricle was visualized well at this level because of the highly echogenic choroid plexus within it; the lateral ventricular ratio (atria) measured at this level related the distance from the middle of the falx echo to the *outer* margin of the atria to one-half of the greatest transverse diameter of the brain at the same level measured inner table to inner table.

Results

We were able to identify the lateral ventricular system routinely, and the values for the lateral ventricular ratio of the bodies and atria of the lateral ventricles are indicated in table 1. The range of the *mean* values during the period 27-40 weeks is narrow for both the bodies (0.36-0.38) and atria (0.51-0.58); the range of individual measurements, however, is relatively wide for both the bodies (0.26-0.45) and atria (0.47-0.63).

During the course of these examinations it was possible to demonstrate the normal anatomy of several other planes commonly seen in neonates and adults with computed tomography (CT); identification of major vessels was useful in confirming the location of these planes and in identifying adjacent structures. For example, if serial transaxial scans are done beginning at the level of the bodies of the lateral ventricles (fig. 1) progressing caudally, one encounters an anechoic rectangular area anteriorly in the midline (fig. 2A). Some authors consider this to be the fetal third ventricle [11, 13], but we think this represents the trunk of the corpus callosum at a point where its walls are perpendicular to the beam and are bordered on either side by the lateral ventricle (fig. 2B). About 1 cm caudal to this level, one can identify another rectangular anechoic area anteriorly in the midline (fig. 3); it is generally slightly narrower than the corpus callosum and has a central linear echo which we think represents the septum pellucidum.

Directly posterior to this area in the same axial plane is the true fetal third ventricle; it is generally 2-5 mm in widest diameter [16]. On either side of the third ventricle are the rather anechoic thalami. Also seen in this section is a highly echogenic linear area in the lateral aspect of the cerebral hemisphere; within this area one can see very striking pulsations of the middle cerebral artery branches, confirming its identity as the sylvian fissure [4, 13].

If the transducer is then moved about 1-2 cm caudally, one can visualize the upper brain stem as a relatively anechoic area in the midline [13, 14] (fig. 4). Anterior to the brainstem is the singular pulsation of the basilar artery, and on either side of it one can visualize pulsatile structures which are thought to represent the posterior cerebral arteries. About 1-1.5 cm anterior to the basilar artery one can image a group of pulsations representing the more anterior

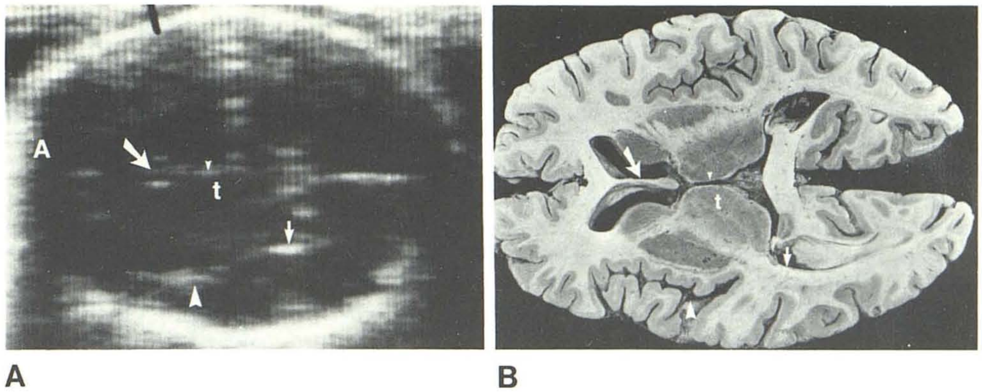

Fig. 3.—**A**, Scan 1 cm caudal to fig. 2A demonstrates septum pellucidum (*large arrow*), thalamus (T), third ventricle (*small arrowhead*), sylvian fissure (*large arrowhead*), and lateral wall of atrium (*small arrow*). A = anterior. **B**, Specimen at same axial level demonstrates septum pellucidum (*large arrow*), third ventricle (*small arrowhead*), sylvian fissure (*large arrowhead*), atrium (*small arrow*), and thalamus (t). (Reprinted from [15].)

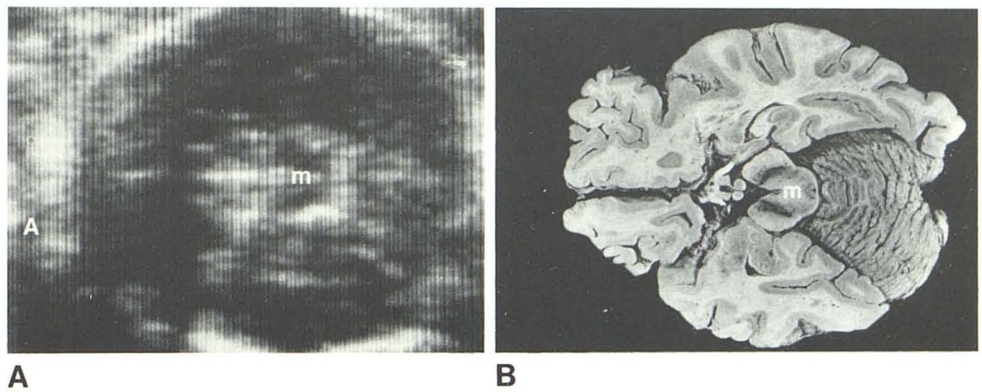

Fig. 4.—**A**, Scan at level of midbrain (m). A = anterior. **B**, Specimen at same level also demonstrates midbrain (m). (Reprinted from [15].)

TABLE 1: **Fetal Lateral Ventricular Ratio (LVR) as Function of Gestational Age**

Age (weeks)	No. Measurements	Mean LVR (Body)	Range LVR (Body)	Mean LVR (Atrium)	Range LVR (Atrium)
27–28	5	0.36	(0.30–0.43)	0.56	(0.53–0.60)
29–30	21	0.38	(0.31–0.45)	0.58	(0.50–0.63)
31–32	14	0.36	(0.27–0.43)	0.54	(0.51–0.60)
33–34	20	0.36	(0.26–0.45)	0.57	(0.46–0.63)
35–36	18	0.38	(0.30–0.45)	0.55	(0.49–0.63)
37–38	17	0.37	(0.29–0.45)	0.54	(0.47–0.63)
39–40	17	0.37	(0.30–0.44)	0.51	(0.47–0.55)

part of the circle of Willis [2, 13], but we have been unable to identify individual vessels in this area.

Discussion

Several authors have demonstrated normal fetal intracranial anatomy in utero using static image sonography [11–14] and there are a few reports demonstrating fetal hydrocephalus using this method [17–21]. These examinations require multiple scan sets and tedious attention to detail, and may be distorted at any moment by motion of the fetal head. Real-time examinations are not subject to these limitations [2]. The improved resolution of current real-time scanners has made it possible to demonstrate detailed fetal anatomy in utero including intracranial anatomy [2, 4, 12, 13, 16]. In addition, the ability to demonstrate motion makes possible the visualization of major vessels which are important anatomic landmarks useful in confirming the identity of adjacent structures [2, 4, 12, 13]; it also allows one to recognize immediately and correct for any change in position of the fetal head [2]. These characteristics make it possible to do a complete intracranial evaluation in a matter of minutes, and this is now done routinely in every obstetrical case in our institution.

Determination of normal measurements for the fetal lateral ventricular system is of obvious theoretical value in detecting hydrocephalus. Denkhaus and Winsberg [13] reported normal values for measurement of the frontal and temporal horns; they did not measure the body or atrium. Dunne and

Johnson [12] reported normal values (20–40 weeks) for the mid-body of the lateral ventricle; our values for fetuses of 27–40 weeks gestation are slightly higher than theirs, but these differences are a result of different methods of mensuration. For example, Dunne and Johnson [12] related the distance between the *outer* margin of the falx echo and the *inner* margin of the lateral ventricular echo to the distance between the outer margin of the falx echo and the inner table of the skull measured at the same axial level. Recalculation of our data using that technique produced a mean value (27–40 weeks) of 0.29, which is comparable to their mean value of 0.30 for the same period.

Our decision to make the ventricular body measurement from the middle of the falx echo to the *outer* margin of the echo from the body of the lateral ventricle was based on several observations. While in gross hydrocephalus the distance between the lateral ventricular wall and the midline echo represents the actual width of the dilated ventricle, this is not true in the normal fetus; there is considerable contribution medially from the cingulate gyrus and/or corpus callosum [15] (figs. 1 and 2). We believe that the highly echogenic linear structure seen by real-time sonography at the level of the superior lateral margin of the body of the ventricle (fig. 1) represents the entire width of the normal ventricle at this level. This concept is supported by the appearance of the body of the lateral ventricle on CT scans of the normal fetus at this level (fig. 5) and by correlative sonographic-pathologic studies in infants [22]. In the normal fetus, then, only a lateral ventricular ratio measured to the outer margin of the ventricular echo would include the true width of the slitlike fetal ventricular body (fig. 1A). We hope it will be possible with future instrumentation to visualize with certainty both the medial and lateral walls of the ventricle, so that one can monitor the actual width of this structure.

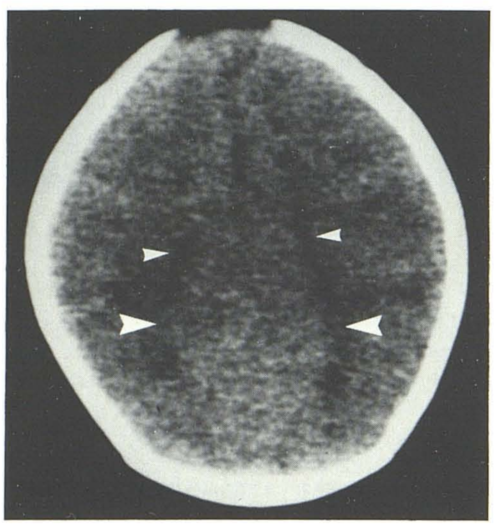

Fig. 5.—CT scan of normal neonatate demonstrates slitlike body (*small arrowheads*) and atria (*large arrowheads*) of lateral ventricles. A = anterior.

We consider a lateral ventricular ratio (bodies) of 0.45 the upper limit of normal in fetuses of 27–40 weeks, using the technique we employed. Reported cases of fetal hydrocephalus affecting the bodies of the ventricles detected by sonography in utero [4, 12, 17–21] have had lateral ventricular ratios (bodies) greater than 0.45 using this technique, and this figure would have resulted in no false-negative and no false-positive cases in the series of Sjogren et al. [23] of 42 infants (under age 1 year) studied with both sonography and pneumoencephalography. Similarly, we consider a lateral ventricular ratio (atria) greater than 0.65 abnormal. Garrett [10] suggested that a measurement of the actual width of the atrium of the ventricle (greater than 10 mm is considered abnormal) may be a better method of evaluating the atria. In either case, visualization of this part of the ventricular system is considered critical, since it and the adjacent posterior horns may be the first area affected in fetal hydrocephalus [12].

We have detected six cases of fetal hydrocephalus in utero using real-time sonography (proven by CT or autopsy after delivery), and in each the lateral ventricular ratio of the body has exceeded 0.45, and the lateral ventricular ratio of the atria has exceeded 0.65 (fig. 6). Further, we were able to successfully exclude the diagnosis in a fetus suspected of having hydrocephalus on the basis of a biparietal diameter of 10 cm at 34 menstrual weeks; the fetus died shortly after delivery by cesarean delivery 6 weeks later, and the autopsy

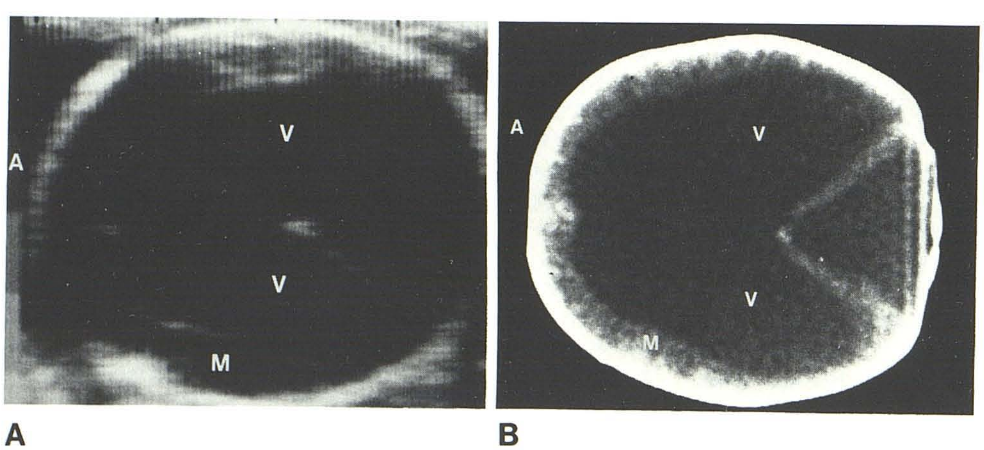

Fig. 6.—**A**, Real-time transaxial scan of fetal head (34 weeks) demonstrating gross dilatation of lateral ventricles (V) with thinned mantle (m) of cerebral cortex remaining. A = anterior. **B**, CT scan of same fetus after delivery also demonstrates grossly dilated ventricles (V) with thin mantle (m) of cortex remaining.

revealed megalocephaly (fetal brain weight 640 g) but no ventricular dilatation. It should be emphasized that our normal measurements apply only to fetuses of 27–40 weeks, and are definitely not applicable below 20 weeks when the fetal ventricular system is normally disproportionately large in relation to the size of the cranium. [12, 18].

Just as the imaging capabilities of current real-time instruments have made it possible to go far beyond simple biparietal diameter and circumference measurements in evaluating the fetal head, future instrumentation will undoubtedly expand current capabilities. It is therefore incumbent on those performing obstetrical sonography to become familiar with basic neuroanatomy, particularly the ventricular and vascular anatomy, so that proper planes for important measurements may be chosen intelligently, and so the abnormal can be recognized when it is encountered. We have found helpful a basic atlas of CT anatomy [15], and a specialized article on CT demonstration of the cerebral vasculature using a rapid high-dose technique [24].

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