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Real-Time Sonography of the Neonatal and Infant Head

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Fifty neonatal and infant heads were examined using a 5 MHz real-time sector scanner. Anatomic detail superior to that previously described was achieved by this method. Normal structures routinely imaged included the entire ventricular system and many parts of the subarachnoid spaces. The gray scale detail of parenchymal structures was usefully demonstrated. Routinely visualized vascular structures included the anterior cerebral artery system, the middle cerebral arteries, the choroid plexus, and the posterior cerebral arteries. Hydrocephalus, as well as intraventricular hemorrhage and its sequelae, were investigated. Computed tomography (CT) is considered diagnostic in hydrocephalus and intraventricular hemorrhage, but evaluation by sonography compares favorably. Among other advantages of sonography are the feasibility of bedside scans without removing the patient from the intensive care nursery and the elimination of ionizing radiation.

Echoencephalography has been used for many years for evaluation of midline shifts [1]. More recently investigators have taken advantage of the thin infant skull and used gray-scale sonography for evaluation of neonatal intracranial pathology. The methods have been quite varied. Pape et al. [2] used a linear array real-time scanner while Johnson and coworkers [3] primarily used static gray-scale imaging. Haber et al. [4] obtained high resolution scans of infant heads using the Octason, which employs a water delay technique. All of the preceding investigations were carried out through the infant skull.

We describe a different technique using a real-time sector scanner with the anterior fontanelle as a sonographic window. A similar technique was recently described by Ben-Ora et al. [5]. Their work primarily involved static scanning and was only performed in coronal and semicoronal planes. Babcock et al. [6] also used static scanning and the anterior fontanelle as a sonographic window. This report describes our experience with the first 50 infants evaluated for intracranial pathology and illustrates the anatomic details disclosed with this method.

Subjects and Methods

Fifty sonograms were obtained in 34 infants up to age 7 months. All examinations were performed with an ATL Mark III real-time sector scanner. Routinely, a 5 MHz transducer with a 90° field of vision was used, except in the largest children, where a 3.5 MHz transducer system was substituted. All examinations were recorded on videotape for viewing and preparation of static images at later times. No sedation was necessary and most examinations were performed in the nursery, without removing infants from their isolette.

After palpation of the anterior fontanelle the transducer was oriented in the coronal plane (fig. 1A). The circle of Willis area was used as a landmark and the transducer gradually angled forward directing the sonographic beam and the plane of vision toward the back of the head. Eventually good sonographic coupling was lost and the transducer was turned in the opposite direction, reoriented in the coronal plane at the level of the circle of Willis, and

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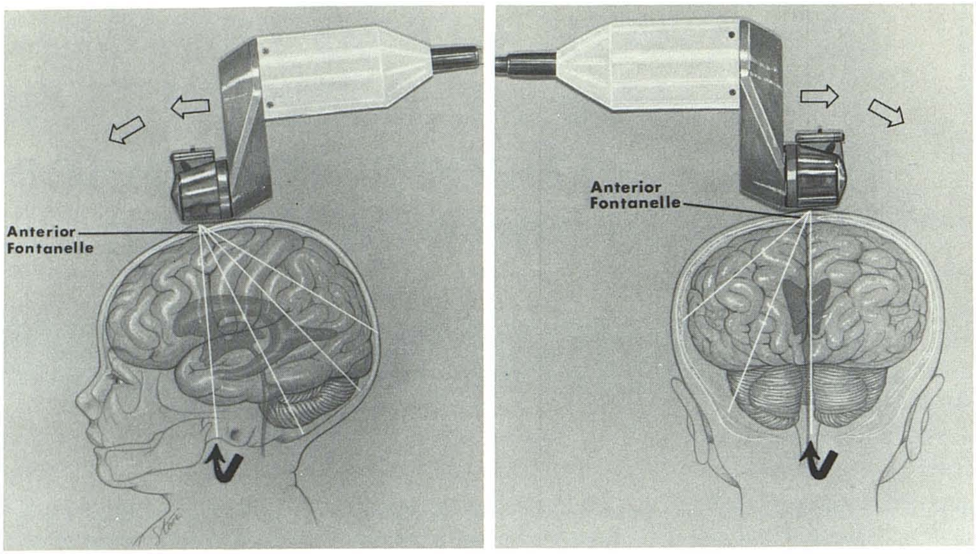


Fig. 1.—Position of transducer for visualizing coronal and saggital planes. **A**, Sonographic beam is first pointed toward circle of Willis area (*curved arrow*). Transducer is then angled forward (*open arrows*) allowing visualization of posterior parts of brain in coronal planes. **B**, Sonographic beam pointed toward midline structures (*curved arrow*). Transducer then angled to right (*open arrows*) to visualize left of brain.

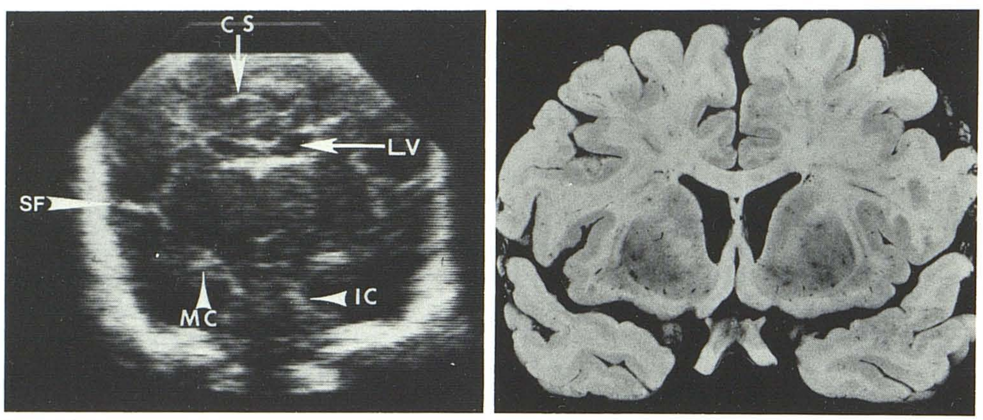


Fig. 2.—Coronal section (**A**) with corresponding normal anatomy (**B**) through circle of Willis area. Internal carotids (IC) with middle cerebral arteries branching laterally (MC). Superiorly specular reflections arise from apposing cortical surfaces surrounding sylvian fissure (SF). LV = lateral ventricles; CS = cingulate sulci. (Reprinted from [7].)

angled posteriorly, now directing the sonographic beam anteriorly, visualizing the frontal parts of the brain.

A similar method was used in the saggital planes and the anterior cerebral arteries were used to indicate midline. Each side of the brain was examined, again by angling the transducer in the direction desired (fig. 1B).

In selected children the scanner was angled through open sutures joining the anterior fontanelle. The posterior fontanelle was also occasionally used, although these positions were primarily used on hydrocephalics with widened sutures. The anterior fontanelle generally offered a wide enough sonographic window for our examinations and the images obtained through other sonographic portals did not compare in quality or generally add any additional information.

Computed tomography (CT) was performed on 28 occasions. Initially, all hydrocephalic patients in our series had both sonography and CT for the purpose of obtaining valid comparisons between the two methods. The accuracy of sonography for detection and follow-up of hydrocephalus was quickly realized. Therefore, as this study progressed, no further CT correlation was considered necessary and the hydrocephalic infants were monitored solely with sonography. However, all patients with suspicion of intraventricular hemorrhage had both sonography and CT during the entire length of study.

Results

Normal Anatomy

In the coronal plane (fig. 2), the area of the circle of Willis is identified by prominent vascular pulsations. Pulsating linear echodensities representing the internal carotid arteries are also often identified in this plane. Laterally, the pulsating echoes of the middle cerebral arteries are visible and may often be followed to their bifurcations. More superiorly, nonpulsatile lines are seen that are believed to represent specular reflections from the apposing cortical surfaces surrounding the sylvian fissure. Normally, two slitlike anechoid areas are identified representing the bodies

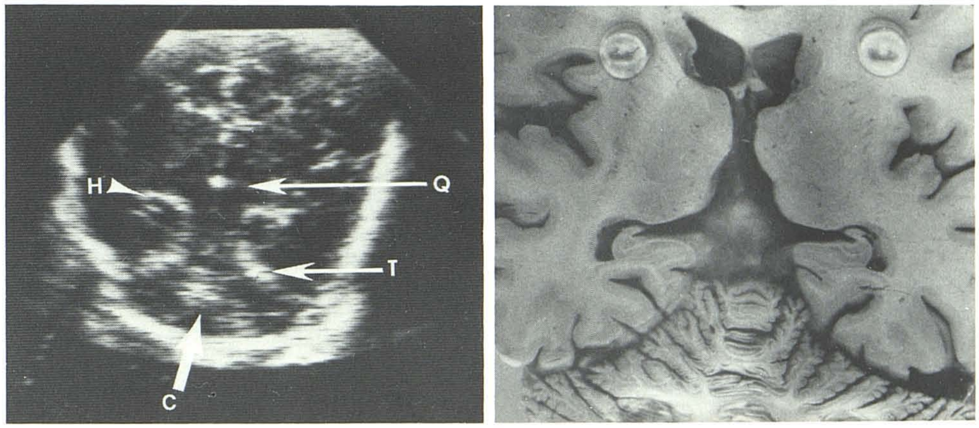


Fig. 3.—Sonogram (A) and corresponding normal anatomy (B). Specular echoes arise from tentorial leaves (T) and areas of hippocampal sulci (H). Beneath tentorium is cerebellum (C) and centrally the vermis. Pineal body is shown by strong echoes (Q) and is located centrally within quadrigeminal plate cistern.

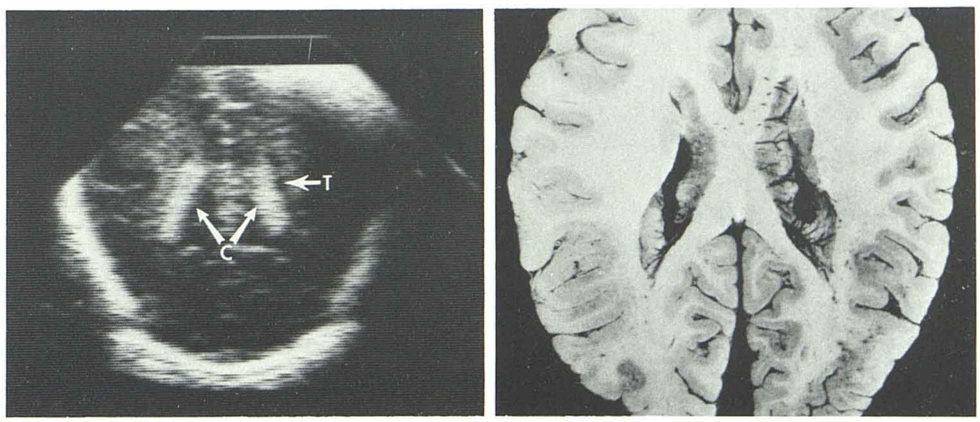


Fig. 4.—Sonogram (A) and corresponding normal anatomy (B). Choroid plexus (C) in trigone (T) region of lateral ventricle. (Reprinted from [7].)

of the lateral ventricles. A third midline anechoicity was occasionally identified representing the cavum septum pellucidum. Superiorly, a thin line of relative anechoicity is seen representing the corpus callosum, and above this the prominent specular reflections from the cingulate sulci are seen extending laterally from the interhemispheric fissure.

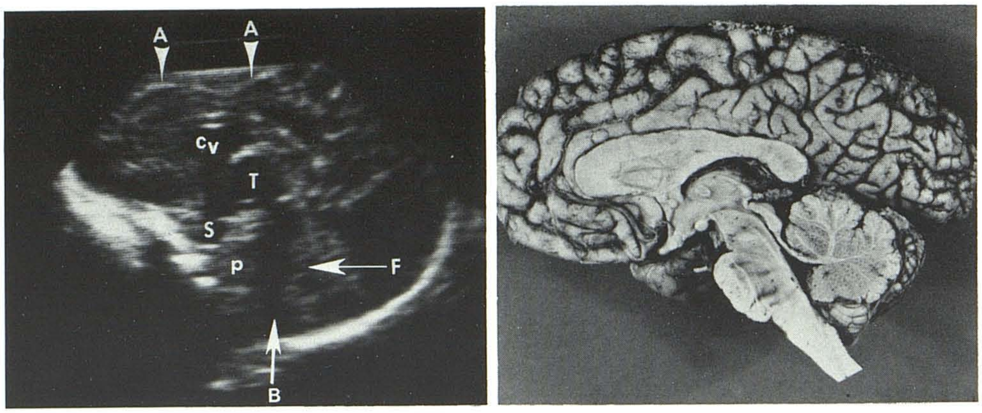
As the beam is angled posteriorly, prominent specular echoes arise from the tentorial leaves and the area of the hippocampal sulci (fig. 3). Beneath the tentorium the cerebellum may be seen as a highly reflective structure. Above the tentorium an anechoic area representing the quadrigeminal plate cistern is identified with the strong reflection from the pineal gland visible in its center. In this plane the lateral ventricles and cingulate gyri are visible again.

Further angulation brings the glomus of the choroid plexus and atria of the lateral ventricles into view (fig. 4). The choroid plexus is the most echogenic structure in the brain, possibly due to its irregular surface. At this point, this part of the examination may be terminated and by turning the transducer and angling the beam in the opposite direction, the frontal regions of the brain may be examined.

Changing orientation to the saggital plane, the midline is identified by the pulsations of the anterior cerebral artery and its major branches (fig. 5). A slight angulation to either side will reveal the minute lateral ventricles and thalamus. In many neonates a prominent anechoic area is found in midline, representing the cavum septum pellucidum. The clivus may be used as a readily visible landmark and the belly of the pons is seen as a highly echogenic area with the more rostral parts of the brain stem appearing very anechoic. Blending with the anechoicity of the white matter of the brain stem, the small triangular anechoicity of the fourth ventricle is seen pushing into the highly reflective cerebellum. More laterally the pulsations of the posterior cerebral arteries are seen and if the transducer is angled steeply enough the sylvian branches of the middle cerebral arteries come into view (fig. 6).

Clinical Findings

Fourteen examinations revealed ventricular enlargement in 12 babies (fig. 7). Eight of these examinations were performed on children suspected of having hydrocephalus in association with myelodysplasia. Five of these 14 positive examinations were performed to determine the presence of hydrocephalus arising as a complication of intraventricular



A B

Fig. 5.—Saggital section (**A**) with corresponding normal anatomy (**B**). Superiorly, anterior cerebral artery and major branches (A). More inferiorly, cavum septum pellucidum (CV) and thalamus (T). Sella turcica (S) and clivus; belly of pons (P) lies above. Very anechoic more rostral parts of brain stem (B) blend with anechoic triangle of fourth ventricle (F) as it indents highly echogenic cerebellum.

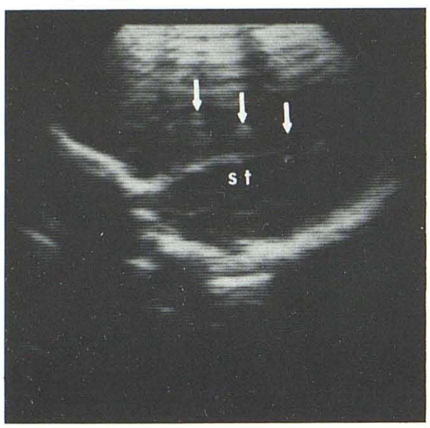


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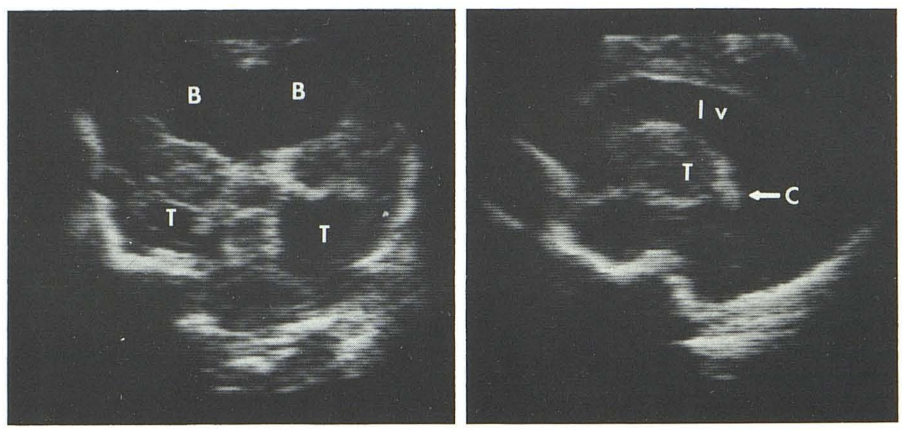
Fig. 6.—Sylvian branches of middle cerebral artery (*arrows*) pulsate with steep angulation of transducer. Beneath, superior temporal gyrus (st).



7A 7B

Fig. 7.—Hydrocephalus. **A**, Coronal section. Bodies (B) and temporal horns (T) of dilated lateral ventricles. **B**, Parasaggital section. Entire lateral ventricle (lv) surrounds thalamus (T). Choroid plexus (C).

hemorrhage. A 3-week-old infant with an intraventricular shunt was examined postoperatively to follow the response of the ventricles to that treatment and to determine the position of the shunt device. The shunt was well visualized within the lateral ventricle (fig. 8).

In 10 babies, intraventricular hemorrhage was diagnosed by sonography. CT was confirmatory in eight of these cases, failing to confirm two (20%) false-positive interpretations. No false-negatives were encountered. Two different sonographic patterns were found in association with intraventricular blood in the eight patients confirmed by CT. In four babies, diffuse low-level echoes were noted within the normally anechoic lateral ventricles (fig. 9). A second pattern was encountered in four neonates and consisted of discrete sonodense areas within otherwise anechoic ventricles (fig. 10). Actual blood/cerebrospinal fluid levels were seen in two. The densely echogenic material found in the latter four children occupied the most dependent parts of the ventricles. Naturally this varied depending on the position in which the child was examined since occasionally examinations were performed while the mother held the infant. Both sonographic patterns of intraventricular hemorrhage often showed remarkable similarity to those obtained with CT. It should be added that the highly echogenic choroid plexus will blend with equally echogenic intraventricular blood if the blood is located adjacent to the choroid.

Discussion

This preliminary investigation further confirms the usefulness of sonography in the evaluation of intracranial pathology in infants. Our material and that of others [2–4, 6] establishes its clinical usefulness in the evaluation of hydrocephalus. Sonography may be used as the primary method of evaluation in infants with abnormal head size. Due to the ease of the examination and lack of ionizing radiation, the scans may be frequently repeated for follow-up in infants already diagnosed as having hydrocephalus regardless of etiology. The reproducibility of the scans and use of centimeter markers allow rapid comparison of ventricular size with previous scans.

Intraventricular hemorrhage is a common complication in

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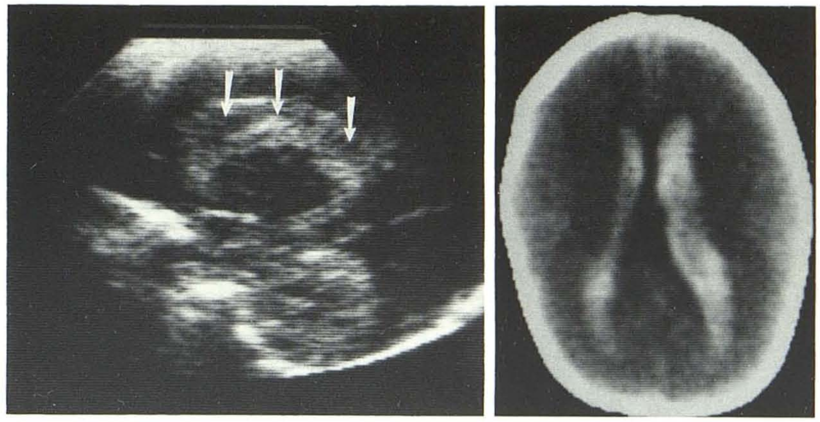
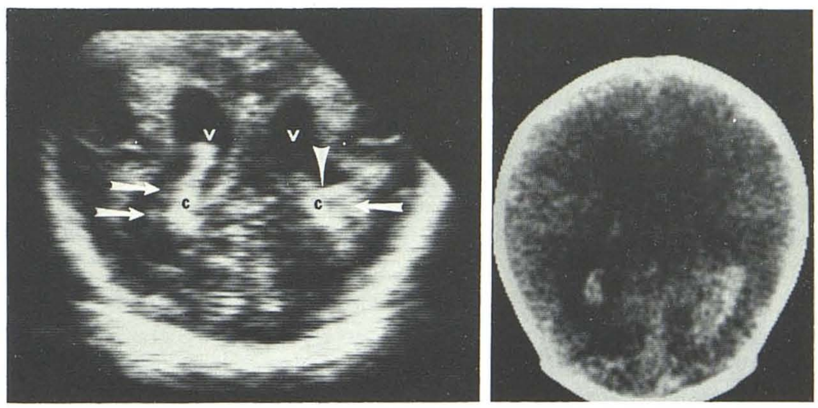
Fig. 8.—Parasaggital section. Intraventricular shunt (*arrow*) in lateral ventricle.



9A 9B

Fig. 9.—Intraventricular hemmorhage. **A**, Parasaggital section. Castlike pattern; ventricles appear filled with echogenic material (*arrows*). **B**, Ventricles filled with blood.



A B

Fig. 10.—Intraventricular hemorrhage. **A**, Angled coronal view. Mildly dilated ventricles (V) with particulate material (*arrows*) in both. Choroid plexus in each (C) and cerebrospinal fluid/blood level on right (*arrowhead*). **B**, Similar to sonogram.

low birth weight babies. According to Burstein et al. [7], it occurs in as many as 44% of infants under 1,500 g. Our experience with intraventricular hemorrhage indicates that sonography can be a suitable method of diagnosing this condition. At this time, we believe sonography can be used confidently as a simple screening procedure in the nursery, reserving CT for confirmation of the findings when sonography is positive. Further investigation is needed in this area since other authors have met with limited success in diagnosing intraventricular hemorrhage with sonography.

The low-level echoes leading to two false-positive diagnoses may be inherent in the type of sonographic unit used. Artifactual low-level echoes are frequently found in purely cystic lesions imaged elsewhere in the body and must be taken into account when diagnosing intraventricular hemorrhage. In comparing sonography with CT, one must consider that clots may become isodense on CT yet be seen by sonography; the two methods image totally different physical properties. This was also mentioned by Johnson et al. [3].

Moreover, the choroid plexus must not be confused with intraventricular blood. Its shape is fairly constant surrounding the thalamus, but it may occupy much of the trigonal area of the lateral ventricles in some babies. Intraventricular blood should occupy areas beyond this, and it is usually dependent in location. It should be emphasized that the two will form one echo-producing complex if the hemorrhage occupies adjacent areas or fills the entire ventricle.

In summary, we suggest that sonography is of use in evaluating many types of intracerebral pathology in the infant. Our experience indicates that sonography is as accurate as CT in the evaluation of hydrocephalus. Our findings in intraventricular hemorrhage are encouraging, although a large scale prospective study must be completed before firm conclusions are drawn.

Foremost among the advantages of this method over CT and some other sonographic systems is the ability to perform the study in the nursery. Other advantages include lack of ionizing radiation, low cost, ease, and speed of the examination. One short transducer maneuver can result in a full sweep through the brain versus individual tomographic sections. Vascular pulsations are clearly seen. A sonographic unit may be available in institutions where there is no CT installation, thus providing these hospitals with diagnostic capabilities usually reserved for larger hospitals.

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