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D. A. London, B. A. Carroll and D. R. Enzmann

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Sonography of Ventricular Size and Germinal Matrix Hemorrhage in Premature Infants

D. A. London[1]
B. A. Carroll
D. R. Enzmann

Using the anterior fontanelle as an acoustic window, high resolution gray scale sonography brain scans with mobile apparatus were obtained in 35 premature infants. The sonographic technique provided accurate assessment of ventricular size and detected the subependymal germinal matrix and intraventricular hemorrhages. Ventricular size measurements correlated closely with computed tomographic (CT) determinations ($r = 0.83–0.92$) in 29 infants. Sonography imaged the hemorrhages as areas of increased echogenicity with mass effect located characteristically in the region of the caudate nucleus. The size of the hemorrhages could be grossly estimated, but the full extent of hemorrhages was better delineated by CT. Sonography seemed superior in detecting small hemorrhages that were isodense with surrounding brain on CT. Despite its advantages of benignancy, accuracy, ease of examination, and cost, our sonography technique had limitations. False-negative sonograms occurred when the hemorrhage was located only in the posterior aspects of the ventricular system. Small hemorrhages in the caudate could be missed by either CT or sonography because of sampling error. Recognition of other disease processes was limited with sonography. The sonographic brain scan is a good initial test for high risk premature infants suspected of having subependymal germinal matrix and intraventricular hemorrhages. If the sonogram is negative or not typical for subependymal germinal matrix and intraventricular hemorrhages, CT is indicated.

Intracranial hemorrhage is recognized as a significant factor in mortality of premature infants. Although major advances in respiratory support and infection control have resulted in greater survival among these infants, improvements have also resulted in a significant shift in neonatal pathology. In 1972, only 25% of neonatal deaths were associated with intracranial hemorrhage; in 1978, this figure was 65% [1–3].

Computed tomographic (CT) brain scans permit accurate and noninvasive detection of subependymal germinal matrix and intraventricular hemorrhage in premature infants as well as assessment of possible sequelae such as hydrocephalus and porencephaly [4–6]. Because the accuracy of CT exceeds that of clinical examination in detecting such hemorrhages, the reported incidence of such hemorrhages has increased dramatically [5–8]. In premature infants weighing less than 1,500 g, the incidence by CT is 43%–70% [7, 8]. Unfortunately, the widespread and serial use of CT scanning for detection of hemorrhage and its sequelae is logistically limited in these fragile infants because of difficulties in transport, sedation, temperature maintenance, and respiratory support. The risk of repeated exposure to ionizing radiation must also be considered.

Sonography has been useful in determining ventricular size in both term infants and young children [9–13]. We report the use of a mobile sonography unit with a high resolution probe for measuring ventricular size and detecting subependymal germinal matrix and intraventricular hemorrhages in premature infants.

Subjects and Methods

An orbital sonography unit was adapted for use with premature infants. The linear array, high frequency (7.2 MHz) probe produces a real time, rectangular 3 × 6 cm image that can be frozen for photographing with a standard Polaroid camera. The axial resolution is 0.2–0.3 mm. The lateral resolution is 2 mm at less than 2 cm (near field) and 4–5 mm at 6

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[1] All authors: Department of Radiology, Diagnostic Radiology Division, Stanford University School of Medicine, Stanford, CA 94305. Address reprint requests to D. R. Enzmann.

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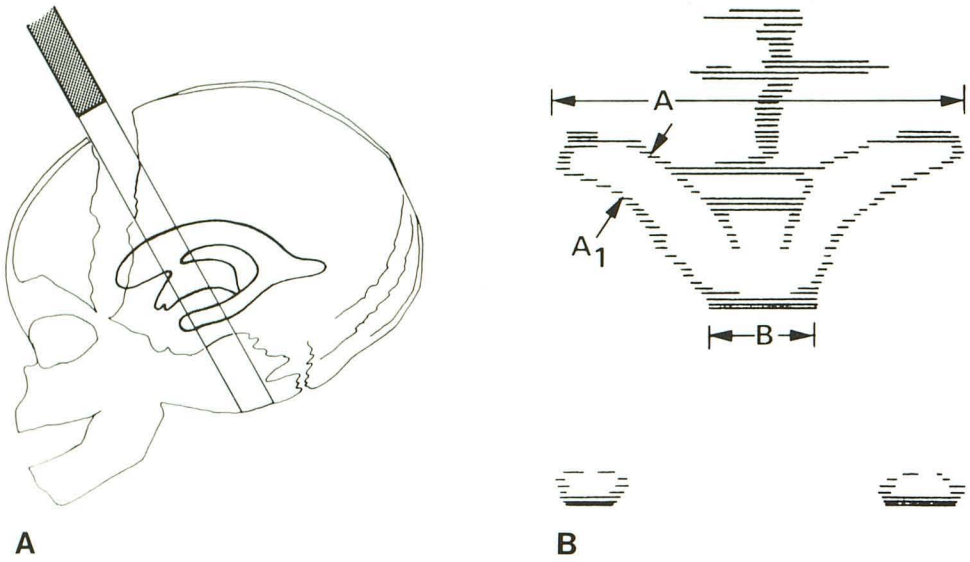

Fig. 1.—**A,** Sonographic scanning plane. Anterior fontanelle is acoustic window. **B,** Ventricular measurements in coronal plane at level of caudate nucleus. (More posterior ventricular span measurement at level of body is not diagrammed.)

cm from the probe. The small size of the probe permits examination of the infant through the portholes of the isolette in the newborn intensive care unit without sedation.

There were 82 sonographic examinations performed in 35 premature infants with birth weights of 690–3,600 g. Sonograms were prospectively compared with 37 axial CT scans in 29 of these premature infants. Six infants did not have CT correlation. Almost all sonograms were obtained immediately after CT. In a few patients, the sonogram was obtained a few hours before CT. In none of the patients was the interval between CT and sonography more than 12 hr.

The sonographic technique consisted of coronal and sagittal views of the lateral ventricles using the anterior fontanelle as an acoustic window. The standard sonographic examination consisted of near-coronal sections passing through the head of the caudate nuclei and the bodies of the lateral ventricles (fig. 1). These near coronal sections were positioned about 60°–70° to the Reid base line (fig. 1). Sagittal scans of the frontal horn and trigone were obtained of both lateral ventricles. Selected images were recorded on Polaroid film for analysis and comparison with CT scans (EMI model 1005, 160 × 160 matrix, 80 sec scan time). Although the plane of examination differed between CT (25° to the Reid base line) and sonography (60°–70° to the Reid base line), four similar measurements of ventricular size were obtained [14] (fig. 1): (A) maximum span of the frontal horns; (A_1) width of frontal horn at the level of the caudate nucleus; (B) intercaudate distance; and (C) span of the bodies of the lateral ventricles.

Measurements were made on Polaroid prints for both sonograms and CT scans. The correlation coefficient (r) was calculated for each of the four ventricular measurements [15].

Results

CT and Sonographic Correlation of Ventricular Size

There were 36 ventricular size determinations evaluated in 26 premature infants by both CT and sonography, regardless of the presence or absence of intracranial pathology. The correlation coefficient for each ventricular measurement was high (range, 0.83–0.92). (table 1).

TABLE 1: **Correlation of Ventricular Measurements by CT and Sonography**

Parameter	No. Patients	r
A	28	0.90
A_1	28	0.83
B	27	0.83
C	24	0.92

Note.—A = maximum span of the frontal horns; A_1 = width of frontal horn at level of caudate nucleus; B = intercaudate distance; C = span of bodies of lateral ventricles; and r = correlation coefficient.

Normal Ventricular Size by Sonography

Sonograms in 15 premature infants without clinical evidence suggestive of subependymal germinal matrix and intraventricular hemorrhages were used to determine the range of normal according to birth weight. In nine of these 15 infants, CT demonstrated no intracranial pathology; six infants had only sonograms but they were selected because of their lack of clinical problems. With increasing birth weight, each measurement of ventricular size increased incrementally (table 2). Because the width of the ventricles in these small infants often approached the limit of resolution on the CT image, accurate measurement of small ventricles was often difficult on CT, whereas sonography permitted measurements of the frontal horns, some only 1–2 mm wide. The frontal horns in very small infants were often difficult to identify, but the real-time capability and perserverance of the examiner allowed identification of difficult to detect slitlike ventricles (fig. 2). A cavum septum pellucidum appeared to be a relatively common, normal finding in premature infants on both CT and sonography (fig. 2).

Abnormal Ventricular Size by Sonography

Six infants with abnormally enlarged ventricles were studied by both CT and sonography (fig. 3). Sonograms and CT

TABLE 2: **Sonographic Ventricular Measurements by Birth Weight in Normal Premature Infants**

Birth Weight (g)	No. Patients	Ventricular Measurements, mm (Mean ± SEM)			
		A	A_1	B	C
500–1,000	2	15 ± 0.6	1.7 ± 0.7	4.7 ± 0.7	16 ± 0.3
1,000–1,500	7	19 ± 0.6	2.5 ± 0.2	5.4 ± 0.3	19 ± 0.8
1,500+	6	22 ± 1.7	2.3 ± 0.5	7.5 ± 1.5	21 ± 1.2

Note.—A = maximum span of the frontal horns; A_1 = width of frontal horn at level of caudate nucleus; B = intercaudate distance; and C = span of bodies of lateral ventricles.

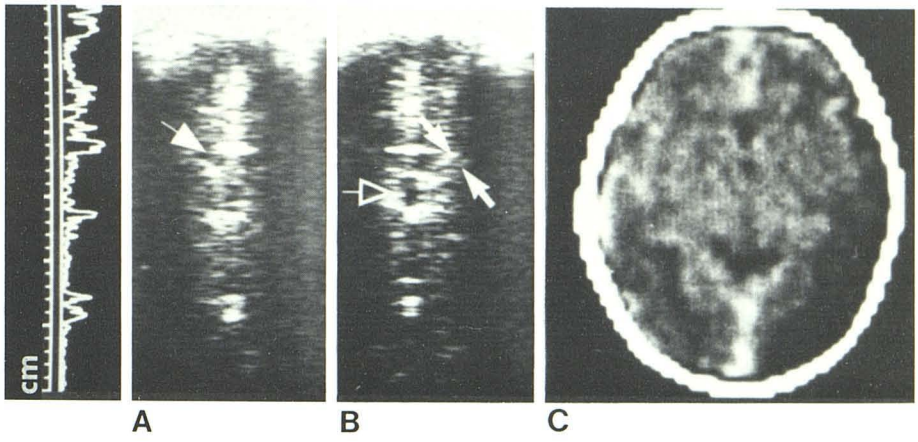

Fig. 2.—Normal ventricular size, about 31 weeks gestation, 1,240 g. **A** and **B**, Coronal sonograms through corpus callosus (*arrow*) and frontal horns (*arrows*). Rectangular, anechoic structure in midline represents cavum septum pellucidum (*open arrow*). Ventricles are sometimes small and difficult to image. Anechoic slit between parallel lines of echoes represents left frontal horn, about 1 mm wide (*arrows*). **C**, Axial CT scan. Normal ventricular size. Midline structure between front horns represents cavum septum pellucidum (normal in premature infants). Frontal horns not discerned on CT. Decreased density in left parietal occipital region is shading artifact. (Ventricular size on sonograms measured by scale at left.)

scans correlated closely. Actual measurement of ventricular size was often unnecessary because abnormal enlargement was readily apparent. In one patient, serial sonograms accurately monitored ventricular size changes while serial lumbar punctures were performed to reduce hydrocephalus.

Detection of Hemorrhage

The normal coronal and sagittal sonogram exhibited dense echoes above and below the corpus callosum and on the floor of the third and lateral ventricles (fig. 2). The ventricle itself is anechoic and the region of the germinal matrix and caudate nucleus is hypoechoic (fig. 4). Some echoes are produced by the choroid plexus as it traverses the foramen of Monro. The spatial resolution of the sonogram allows visualization of interhemispheric cortical sulci (figs. 1 and 4) and pulsating intracerebral vessels.

Recent hemorrhage, both parenchymal and intraventricular, is characterized by increased echogenicity. Subependymal hemorrhage characteristically produces intense echoes in the region of the head of the caudate nucleus with compression of the ipsilateral frontal horn (figs. 5 and 6). Sonography in 11 of the 13 infants with subependymal germinal matrix hemorrhages examined by both CT and sonography demonstrated bright echoes in the region of the caudate nucleus that correlated closely with the site of hemorrhage seen at CT (figs. 5 and 6). Compression of the frontal horn was associated with these echoes in eight infants. Intraventricular blood clot attached to the choroid plexus was detected in only one infant by both CT and sonography.

There were two false-positive and two false-negative sonograms in our series. One false-negative scan was produced by a germinal matrix hemorrhage that did not involve the head of the caudate nucleus (fig. 7). The hemorrhage was limited to the posterior body and occipital horn of the lateral ventricle, areas not imaged by our technique. The other false-negative sonogram was in a patient who had punctate densities in both caudate nuclei on the CT scan; the sonogram revealed no abnormal echoes. This examination probably represented a sampling error in the selection of image planes. One false-positive sonogram revealed echoes in both caudate nuclei but without a mass effect. Normal structures in this patient were also highly echogenic, a finding as yet unexplained. The second possible false-positive sonogram revealed a unilateral dense echogenic area of 4 × 4 mm in the caudate nucleus with an associated mass effect. The comparable CT scan did not reveal a dense lesion indicative of hemorrhage. The region in question was unfortunately poorly imaged on CT and may have fallen between adjacent scans [16, 17]. In this patient CT could well have been a false-negative examination.

Discussion

Although the overall neonatal mortality rates for premature infants has decreased markedly in the past 20 years, the relative importance of subependymal hemorrhage as a cause of death has increased dramatically. Furthermore, improving medical management of the premature infant can be expected to increase the number of survivors of subep-

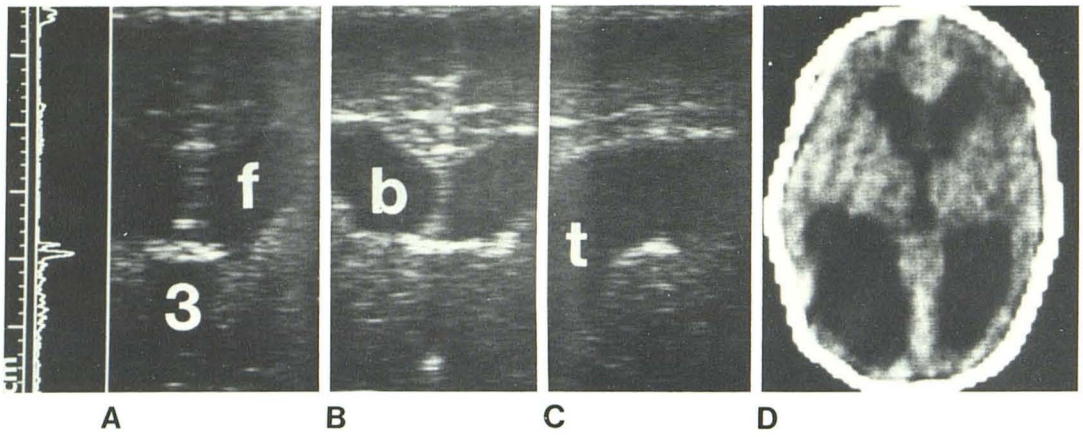

Fig. 3.—Abnormal ventricular size: enlarged ventricles and Arnold-Chiari II malformation. **A** and **B**, Coronal sonograms. Well delineated large frontal horns (f), third ventricle (3), and bodies of lateral ventricles (b). Midline echoes at foramen of Monro represent choroid plexus (**A**). **C**, Sagittal view. Trigone of lateral ventricle (t). **D**, Axial CT scan confirmed sonographic findings of marked ventricular enlargement. (Ventricular size on sonograms measured by scale at left.)

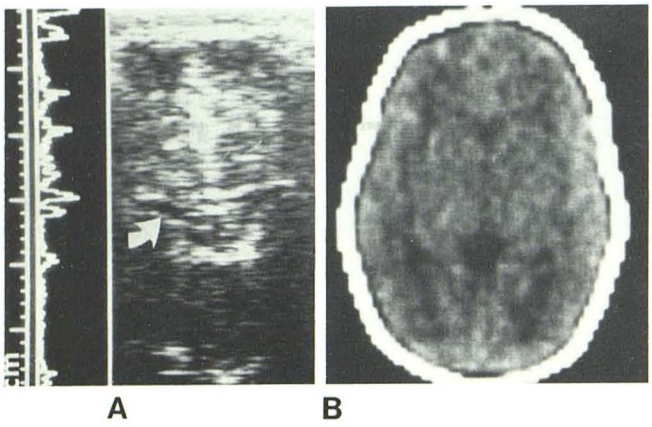

Fig. 4.—Normal ventricular size, 32 weeks gestation, 2,020 g. **A**, Coronal sonogram. Normal ventricular size (2 mm wide) at level of frontal horns (*arrow*). Dense midline echoes above ventricles represent interhemispheric fissure and cortical sulci. Echoes at bottom of image represent temporal horns and structures in basal cisterns. Vessels readily identified by pulsations with this real-time system. **B**, Axial CT scan. Normal ventricular size without apparent cavum septum pellucidum. Resolution of ventricular size better with sonography. (Ventricular size on sonogram measured by scale at left.)

endymal germinal matrix hemorrhages. Evaluation of the hemorrhage itself and its sequelae requires a reliable, accurate, and safe diagnostic method. At present, CT is the most accurate, but transport problems, sedation, and temperature maintenance, and the risk of ionizing radiation limit the use of CT in routine assessment of these fragile infants.

The use of sonography to examine the intracranial cavity is not new and, in fact, is preferable for infants who have a poorly mineralized calvarium. To penetrate the skull, lower frequency sound beams (3.5 MHz) have been used, but such beams limit spatial resolution. Our approach uses the anterior fontanelle as an acoustic window for a high frequency probe (7.2 MHz) that provides excellent spatial resolution. The interpretation of anatomic landmarks and pathologic changes was not difficult and was aided by pulsation of vessels displayed in the real-time mode.

The coronal plane through the caudate nuclei was the single most important image permitting both reproducible ventricular size determination and optimal visualization of subependymal germinal matrix hemorrhages. Ventricular size was accurately depicted, correlating closely with the concurrent CT scan and previous measurements in the literature [16]. Ventricular size in premature infants increased incrementally with increasing gestational age.

Recent hemorrhages were highly echogenic and characteristically located in the caudate nucleus and lateral ventricular wall. A mass effect on the adjacent frontal horn or cavum septum pellucidum was characteristically present and it provided confirmatory evidence in very small hemorrhages. Normal echoes emanating from the floor of the lateral ventricle were readily distinguishable from hemorrhage by their location, intensity, and configuration.

Although sonography accurately identified subependymal hemorrhages involving the caudate nucleus, it did have limitations. Large hemorrhages were easily detected, but small lesions were susceptible to sampling errors, i.e. the selection of scanning planes that miss the lesion. There were two false-negative sonograms. In one patient this was due to the very small size of the lesion and in the other because of the far posterior location of the hemorrhage. Hemorrhages located posteriorly in the trigone region infrequently occur in premature infants of less than 28 weeks gestation; however, these would be difficult to detect with our sonographic technique [6]. Although the CT scan is considered standard for diagnosis of subependymal germinal matrix hemorrhage, it also may suffer from sampling errors with small hemorrhages. In our series, one false-positive sonogram may actually represent a false-negative CT scan. In this infant, abnormal echoes in the caudate nucleus were small but quite typical on the sonogram for a small hemorrhage with a mass effect. A sampling error may have occurred on CT because the hemorrhage fell in an area between adjacent scans, an area where small lesions can be missed [16, 17]. In one infant the hemorrhage was easier to detect by sonography because it was small and nearly isodense on the CT scan. The incidence of germinal matrix hemorrhages may actually be much higher than previously suspected in view of the number of small and subtle hemorrhages in our patients that were difficult to detect even on the CT scan.

Our sonographic technique is well suited for the diagnosis of germinal matrix hemorrhage in premature infants, but its other diagnostic potential is somewhat more restricted. Besides posterior germinal matrix hemorrhages, the various

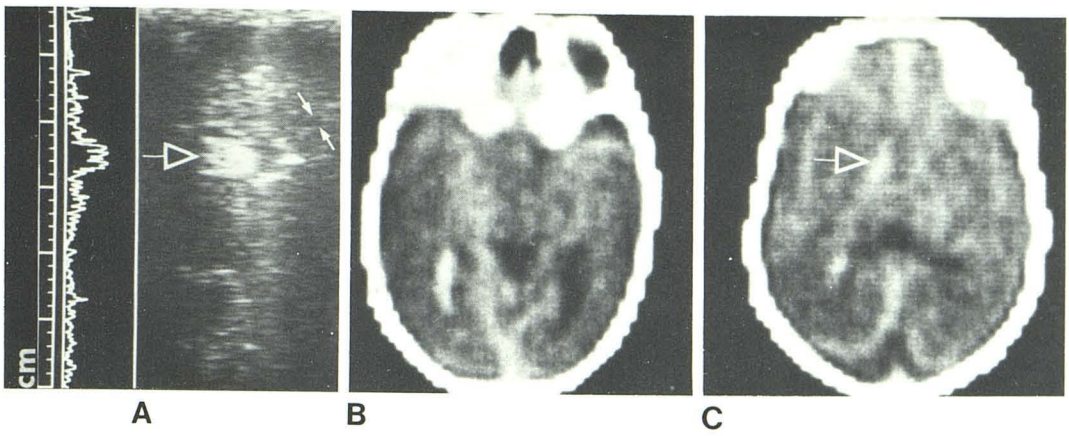

Fig. 5.—Subependymal hemorrhage, 26 weeks gestation, 980 g. **A**, Coronal sonogram. Highly echogenic lesion (*open arrow*) in right caudate nucleus compresses right frontal horn and cavum septum pellucidum. Right frontal horn was 2 mm wide where not compressed. Left frontal horn more difficult to visualize (*closed arrows*). Axial CT scans verified presence of small subependymal germinal matrix hemorrhage on right (**C**, *arrow*) extending into occipital horn (**B**). (Ventricular size on sonogram measured by scale at left.)

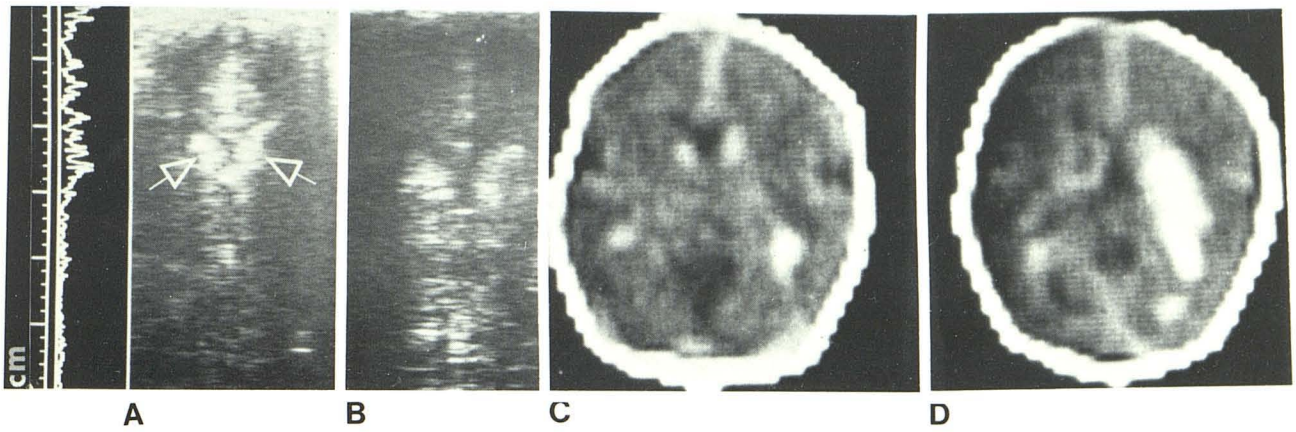

Fig. 6.—Subependymal hemorrhage, 26 weeks gestation, 790 g (twin of infant in fig. 5). **A** and **B**, Highly echogenic mass lesions (*open arrows*) in both caudate nuclei (**A** slightly anterior to **B**). **C** and **D**, Axial CT scans. Bilateral subependymal germinal matrix hemorrhages in caudate nuclei. Extent of hemorrhage best characterized by CT. (Ventricular size on sonogram measured by scale at left.)

other types of intracranial pathology seen in infants could not be diagnosed using sonography alone, although a mass effect on the ventricular system would be evident. Ventricular enlargement is easily detected by sonography, but the status of the posterior fossa and fourth ventricle cannot be determined and, thus, other causes of hydrocephalus would be difficult to diagnose.

A brain sonogram with mobile apparatus is indicated as the first diagnostic imaging test in any premature infant whose clinical deterioration is either typical of subependymal germinal matrix and intraventricular hemorrhages or remains unexplained. Using our technique, if the sonogram is negative, a CT scan should be performed because something other than subependymal germinal matrix and intraventricular hemorrhages may be responsible. If the sonogram is abnormal but not typical of subependymal germinal matrix and intraventricular hemorrhages, CT must be performed. This can occur when blood refluxes into the ventricular system from a subarachnoid hemorrhage or cerebellar hemorrhage; however, the latter occurs primarily in term infants. Cerebral mass lesions (including hematomas) can cause deformity and displacement of the ventricular system, but the findings will be atypical for subependymal germinal matrix and intraventricular hemorrhages. If sonography demonstrates typical findings of subependymal germinal matrix and intraventricular hemorrhages, one can be confident of the diagnosis, but CT could still be indicated if it is important to determine the entire extent of hemorrhage. The sonogram provides enough information to roughly estimate the hemorrhage size and, thus, the need of CT for further delineation. If hydrocephalus is detected by sonography, the diagnosis is a confident one. The occipital horns in infants usually enlarge to a greater extent than the rest of the ventricular system. Nevertheless, the lesser degree of enlargement of the frontal horns is coincident with occipital horn enlargement and our technique is very sensitive to changes in frontal horn size.

It would not be unreasonable to perform this bedside examination on high-risk infants (less than 1,500 g), despite the lack of obvious clinical findings. Diagnosis of subependymal germinal matrix and intraventricular hemorrhages on clinical criteria alone can be quite unreliable [5]. As a screening test, sonography could identify infants at higher risk for developing complications of subependymal germinal

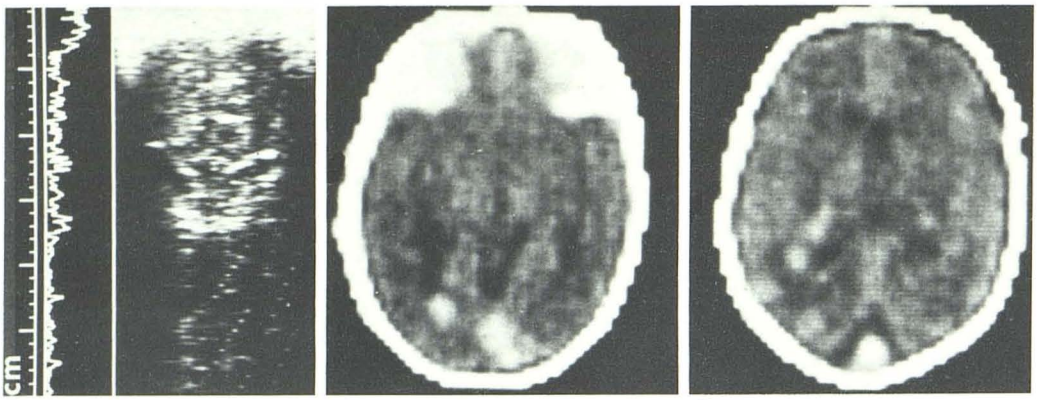

Fig. 7.—False-negative sonogram, 31 weeks gestation, 1,410 g. **A**, Coronal sonogram. No evidence of hemorrhage at level of caudate nuclei. Ventricular size within normal limits. **B** and **C**, Axial CT scans. Small posterior subependymal intraventricular hemorrhage on right. (Ventricular size on sonogram measured by scale at left.)

matrix and intraventricular hemorrhages than would otherwise be possible. Treatment for hydrocephalus could be instituted more efficiently, since it would be detected at an earlier stage. Treatment such as repeated lumbar punctures could be monitored closely and tailored to ventricular size.

The brain sonogram in premature infants provides valuable and accurate information and represents a valuable adjunct to CT. The noninvasive and benign nature of sonography results in an excellent test for detecting subependymal germinal matrix and intraventricular hemorrhages and hydrocephalus. The mobility of the device permits examination without the difficulties of transfer, sedation, temperature maintenance, or respiratory support. Finally, the technique is of relatively low cost. We believe sonography will become a standard examination in the care of the premature infant.

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