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E G Grant and D Schellinger

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Sonography of Neonatal Periventricular Leukomalacia: Recent Experience with a 7.5-MHz Scanner

Edward G. Grant[1]
Dieter Schellinger[1]

This study compared the relative efficacy of 5.0- and 7.5-MHz (high-resolution) transducers in the sonographic evaluation of cystic periventricular leukomalacia (PVL). Of 668 premature neonates evaluated by cranial sonography over a 4-year period, 34 were diagnosed as having PVL. Of these 34 neonates, 17 were examined with both 5.0- and 7.5-MHz transducers. Fifty-two neonates with no evidence of PVL also were evaluated by sonography with the two different-frequency transducers to determine the normal appearance of the neonatal brain. Among the neonates with PVL, features of the disease that have not been observed with routine 5.0-MHz transducers were apparent with use of the 7.5-MHz transducer: 7.5-MHz scanning clearly identified small areas of cystic PVL in three (17.6%) of 17 neonates that were not visible using the lower-resolution technique. The higher-resolution scanning also identified widening of the interhemispheric fissure by anechoic cerebrospinal fluid and demonstrated the falx as a distinct structure. The latter two superficial abnormalities were identified in combination with enlargement of the lateral and third ventricles, suggesting that diffuse cerebral atrophy accompanies PVL in most cases. The excellent near-field resolution of 7.5-MHz technology makes it the preferred method for the evaluation of PVL in the preterm neonate.

Burstein et al. [1] in 1979 clearly defined the magnitude of risk for intracranial pathology in the preterm infant. Since then, most researchers have concentrated their investigations on germinal matrix–related hemorrhage and posthemorrhagic complications [2–4]. Recently, attention has been drawn to another form of intracranial pathology that seems to have a predilection for the premature infant. This ischemic cerebral insult is periventricular leukomalacia (PVL).

Although PVL was described in the pathologic literature many years ago [5–6], radiologic descriptions of this entity have been few. The sonographic findings in a case of PVL were first described in 1982 [7]. Over a recent 4-year period, we diagnosed 34 neonates as having PVL at sonography. Our findings in this relatively large population have been published [8, 9] and corroborate those of other authors [7, 10, 11]. We describe two new features of PVL that were identified during scanning with a high-frequency (7.5-MHz) transducer.

Materials and Methods

Cranial sonography was performed on 668 premature neonates over a 4-year period. Of these, 34 were diagnosed as having PVL. These neonates were all of 32 weeks' or less gestational age and weighed less than 1750 g at birth. All "inborn" neonates (i.e., those delivered at our institution) underwent routine sonography once during the first week of life and again at about 2 weeks of age. If both examinations were negative, sonographic evaluation was discontinued. If either sonogram showed evidence of intracranial abnormality (other than congenital anomalies), scanning was continued at weekly intervals until resolution of the abnormality or discharge from the nursery. "Outborn" neonates usually underwent cranial sonography during the first week of admission and followed our "inborn" routine

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[1] Department of Radiology, Georgetown University Hospital, 3800 Reservoir Rd., N.W., Washington, DC 20007. Address reprint requests to E. G. Grant.

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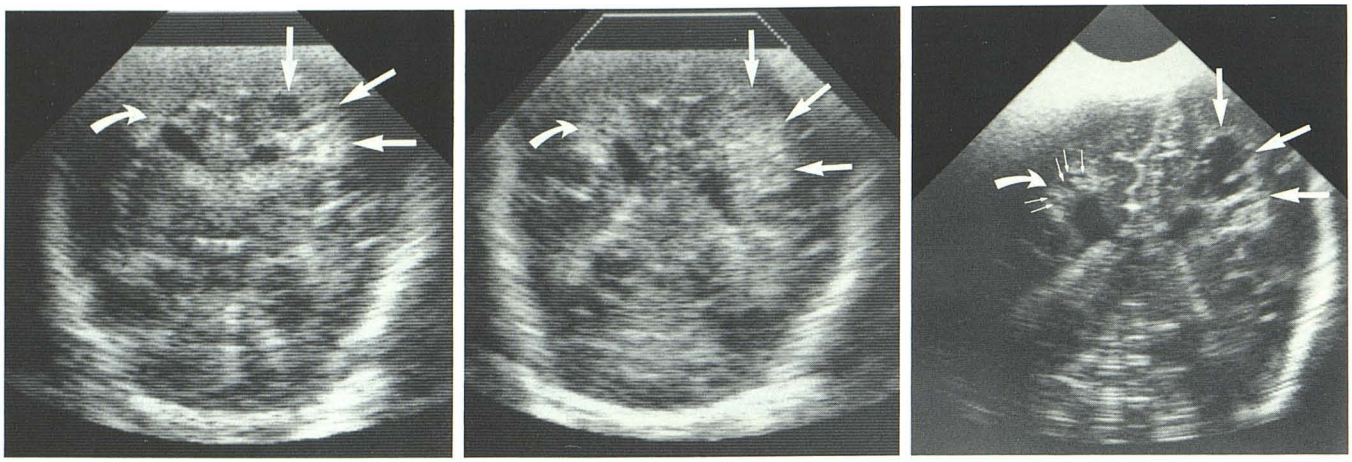

Fig. 1.—Angled coronal sections in same neonate using 5.0- (**A** and **B**) and 7.5-MHz (**C**) transducers. Large area of PVL with cystic changes (*large straight arrows*) apparent about left lateral ventricle on all scans. Although increased echogenicity is seen around right lateral ventricle with 5.0-MHz transducer (**A** and **B**, *curved arrow*), only 7.5-MHz transducer demonstrates small cysts (**C**, *small arrows*) within abnormally increased periventricular echogenicity (**C**, *curved arrow*).

thereafter. During the last 24 months of this study, predischarge sonograms were also obtained on every infant because of the potential insensitivity of sonography in diagnosing the acute or echogenic phase of PVL. The last 19 of our 34 neonates with PVL underwent this final examination.

All scanning was performed on commercially available real-time sector scanners. Scans using a 5.0-MHz transducer were obtained in every patient. In the last 17 of the 34 neonates with periventricular leukomalacia, scans were obtained using both 5.0- and 7.5-MHz transducers, which were part of a multifrequency scanning apparatus (Mark 100 series, Advanced Technology Labs., Bellevue, WA). These 17 neonates form the basis of this report. The general sonographic findings in the first four of these 17 neonates were described previously [8].

An additional 52 neonates with no evidence of periventricular leukomalacia were also scanned with the multifrequency transducer system. These infants served as controls to establish the normal appearance of the neonatal brain with the higher-resolution scanner. For a more representative sample of the neonatal population, infants with germinal-matrix and small intraventricular hemorrhages were included in the control group. Neonates with large intraventricular hemorrhages or any suspicion of PVL or intraparenchymal hemorrhage were not included. The control group comprised both premature and term patients (gestational ages, 27–42 weeks), with ages at sonography ranging from 1 day to 7 months.

Results

Neonates with PVL

Identification of smaller cysts. Of the 17 neonates with PVL who were scanned with both 5.0- and 7.5-MHz transducers, findings using the routine and higher-resolution transducers were similar with respect to the diagnosis of cystic PVL in 14 infants. Discrepancies in diagnosis were noted in the other three. Among these three neonates, two appeared to have unilateral cystic PVL when examined with the routine 5.0-MHz scanner (figs. 1A and 1B), but both had unequivocal evidence of bilateral disease when examined with the 7.5-MHz transducer (fig. 1C). In the third child, a 5.0-MHz scan was interpreted as normal whereas the higher-resolution technique identified small, bilateral periventricular cysts. Therefore, in three (17.6%) of 17 infants, significant pathology was missed using the routine 5.0-MHz scanning technique.

Cerebral atrophy. Among the 17 neonates with PVL who were scanned using both techniques, high-resolution scanning revealed widening of the interhemispheric fissure in 10. Anechoic cerebrospinal fluid outlined the cerebral hemispheres and allowed clear visualization of the falx as an individual structure (fig. 2). The development of a widened interhemispheric fissure in these infants was considered to represent cerebral atrophy. No increase in head circumference such as might be seen in extraventricular obstructive (communicating) hydrocephalus was ever demonstrated in any of them. Widening of the interhemispheric fissure was only clearly defined in three of these 10 neonates with the 5.0-MHz transducer; however, 5.0-MHz scanning did identify mild ventriculomegaly involving the lateral and third ventricles in nine of these 10 children (fig. 3).

Of the remaining seven infants, three had hydrocephalus, which eventually required shunt. Preoperatively, the interhemispheric fissure was not widened in these three patients, nor was the falx visible (fig. 4A). In two of these three neonates, widening of the interhemispheric fissure suggesting atrophy was identified after operative decompression of the ventricles (fig. 4B). Two of the other four neonates developed moderately severe ventriculomegaly, but no surgical intervention was undertaken because their heads never increased in size and their fontanelles remained slack. In both cases the interhemispheric fissure was clearly widened, again suggesting atrophy (fig. 5). Only two of the 17 infants with PVL had neither widening of the interhemispheric fissure nor ventriculomegaly.

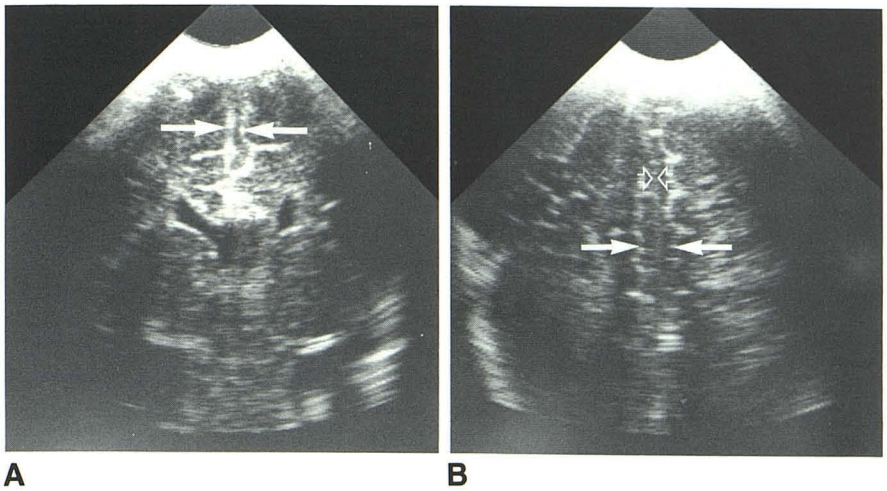

Fig. 2.—Angled coronal (**A**) and semiaxial (**B**) sections using 7.5-MHz transducer in infant with PVL and cerebral atrophy. Widening of interhemispheric fissure (*solid arrows*); visualization of falx as individual structure (**B**, *open arrows*).

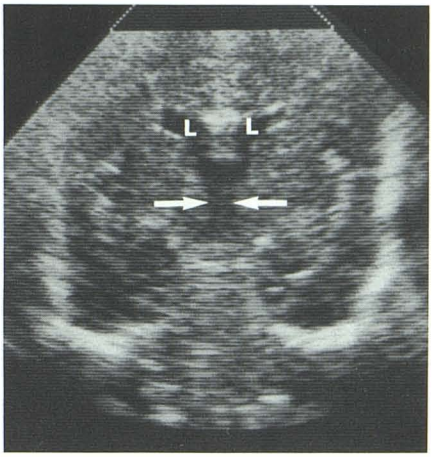

Fig. 3.—Coronal section using 5.0-MHz scanner in infant with PVL and cerebral atrophy reveals dilated lateral (L) and third ventricles (*arrows*). Because of poor near-field resolution, area of interhemispheric fissure is not optimally evaluated.

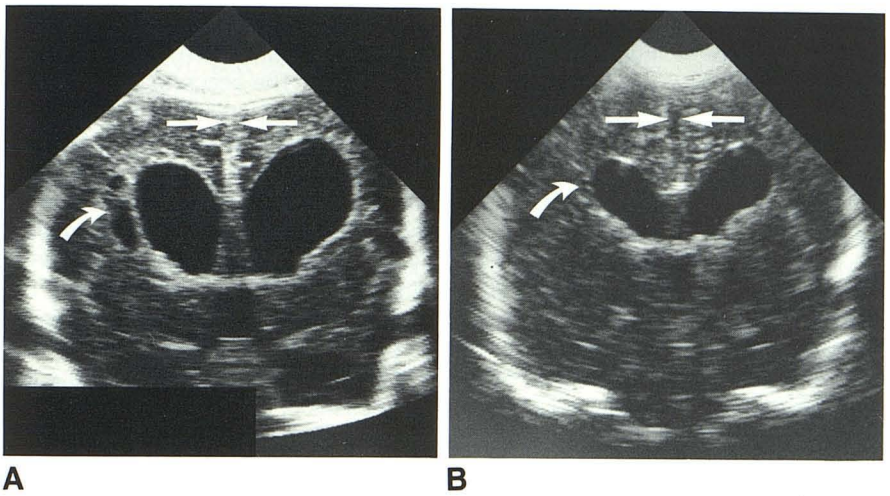

Fig. 4.—Coronal sections using 7.5-MHz scanner in infant with PVL and severe hydrocephalus, before surgery (**A**) and after placement of ventriculoperitoneal shunt (**B**). After operative decompression, ventricles and periventricular cysts (*curved arrow*) are decreased in size and interhemispheric fissure (*straight arrows*) is widened.

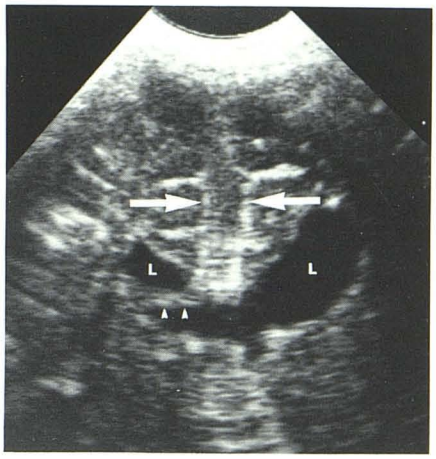

Fig. 5.—Semiaxial section using 7.5-MHz transducer in infant with PVL and moderately severe enlargement of lateral ventricles (L), who did not clinically require shunting. Interhemispheric fissure (*arrows*) is markedly widened. Linear echogenic band in right lateral ventricle (*arrowheads*) may represent scar or residual hematoma. Apparent disproportionate left ventricular enlargement may be porencephaly resulting from degeneration of infarcted periventricular tissue.

Neonates without PVL

Among the 52 control neonates, 41 were entirely normal by both 5.0- and 7.5-MHz scanning. In these infants no periventricular cysts were identified, the ventricles were of normal size, and the cerebral hemispheres were in direct apposition. The interhemispheric fissure was not defined as a fluid-filled structure; the falx and medial surfaces of the cerebral hemispheres formed a single specular reflection (fig. 6).

Eight of the 52 control infants had germinal-matrix or small to moderate intraventricular hemorrhages. Of these eight, one developed widening of the interhemispheric fissure. None of these eight children had significant posthemorrhagic hydrocephalus.

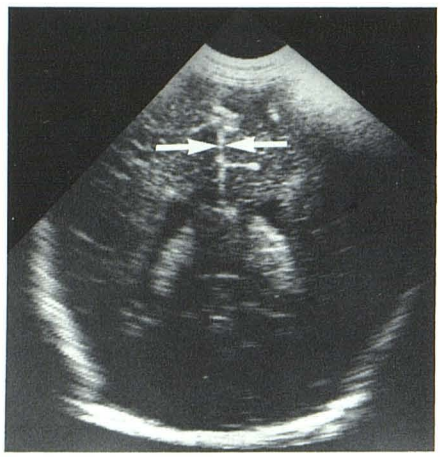

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Fig. 6.—Semiaxial section using 7.5-MHz transducer in normal control. Ventricles are of normal size; interhemispheric fissure and falx appear as single specular reflection (*arrows*). Note loss of information from deeper parts of brain owing to marked attenuation of high-frequency sonographic technique.

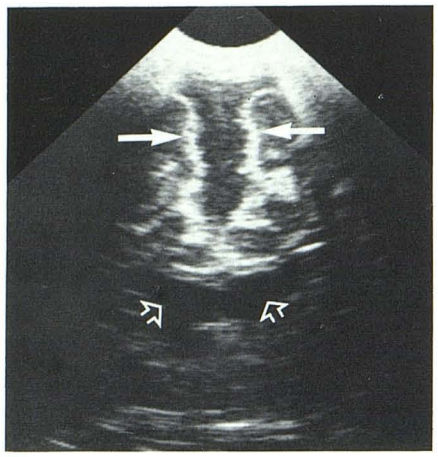

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Fig. 7.—Coronal section using 7.5-MHz transducer in term infant with cerebral atrophy. Widening of interhemispheric fissure (*solid arrows*) with mild ventriculomegaly (*open arrows*). Appearance of low-level echogenicity in fissure is probably a scanning artifact, commonly encountered in extreme near field; it results from using maximum overall system gain and maximum near-field gain to penetrate as deep as possible.

Three of our control neonates exhibited widening of the interhemispheric fissure and mild ventriculomegaly without other sonographic abnormality (fig. 7). The clinical histories of these three neonates were reviewed in an effort to identify reasons for atrophy. Two of the three were term infants who had multiple cardiac arrests. Both eventually died, and autopsies confirmed the sonographic findings of cerebral atrophy. The third infant, a preterm neonate, was the twin of a child with PVL. A computed tomographic (CT) scan showed abnormal white-matter density and suggested atrophy.

Discussion

References to PVL can be found as early as 1843, when Little [12] drew attention to the high association of spasmodic contractures and mental retardation in patients with a history of prematurity. During the 1870s, both Virchow [5] and Parrot [6] described the pathologic features of PVL in considerable detail, but until the publication by Banker and Larroche [13] in 1962, only occasional references to PVL had appeared in the literature. Their classic investigation reiterated the clinical and pathologic features of PVL and strongly emphasized the role of anoxia as an etiologic factor. Since the study of Banker and Larroche [13], few authors have contributed significantly to our understanding of this relatively common disease [14–17]. The radiologic findings in PVL have been even less extensively investigated and the CT diagnosis has been rather controversial. In 1978, DiChiro et al. [18] described the CT findings of PVL; however, differentiation between ischemic disease and the normal premature brain may be quite difficult by this method [19–22]. Recently, authors have described the findings of PVL at sonography [7–11]. Broad bands of increased periventricular echogenicity represent the immediate insult and are followed by areas of cystic degeneration 2–6 weeks later. In a significant number of cases, the more acute or echogenic phase may be difficult or impossible to identify prospectively [7, 10]. For this reason we advocate obtaining pre-discharge sonograms in all premature neonates even if earlier studies were negative.

Two new sonographic features of PVL were identified during our investigation of 17 patients using a 7.5-MHz transducer. The first is the definitive identification of smaller regions of cystic periventricular leukomalacia than was possible with routine 5.0-MHz scanning. The improved resolution of higher-frequency transducers should logically enable one to identify smaller areas of cystic pathology. The accurate identification of very small periventricular cysts is particularly important in PVL because the only gross pathologic abnormalities present in some clinically devastating cases may be areas of periventricular cystic degeneration no larger than 2–3 mm in diameter [13–15]. Therefore, sonographic evaluations limited to routine 5.0-MHz scanning may fail to identify a number of patients with cystic PVL. Furthermore, CT scanning may also be incapable of detecting small, cystic periventricular lesions in a significant number of patients [8, 10]. High-resolution sonography is, therefore, the only truly adequate technique for identifying the more subtle cases of PVL.

The second constellation of sonographic abnormalities identified in neonates with PVL using the high-resolution scanner indicates that many have suffered a diffuse anoxic insult leading to cerebral atrophy in addition to focal infarction of the periventricular white matter. This diffuse insult is evidenced by findings of global atrophy, the sonographic manifestations of which include widening of the interhemispheric fissure, visibility of the falx as a distinct structure, and, often, *ex vacuo* enlargement of the lateral and third ventricles [23]. The autopsy study of Banker and Larroche [13] and that of DeReuck et al. [14] also found generalized atrophy, including widening of the cerebral sulci and *ex vacuo* ventricular enlargement, to be common in patients with PVL.

Although even minimal ventricular enlargement may be adequately evaluated by 5.0-MHz scanning, abnormalities indicative of atrophy near the surface of the brain, such as widening of the interhemispheric fissure, are very difficult to detect with most 5.0-MHz scanners. This is readily apparent in figure 1. The most superficial portion of the interhemispheric fissure is merely a blur with the 5.0-MHz scanner, whereas the 7.5-MHz system clearly shows the apposing cerebral

surfaces as separate structures almost to the surface of the brain. Therefore, the high-resolution short-focal-length technology is essential when evaluating patients for cerebral atrophy, whether or not there is a history of PVL.

In summary, we have examined a group of infants with PVL using both a routine 5.0-MHz transducer and a higher-resolution 7.5-MHz system. The higher-frequency system can identify small periventricular cysts better than the 5.0-MHz scanner; thus, high-frequency transducers are preferred for diagnosing more subtle cases of PVL. It should be obvious from our illustrations, however, that although the 7.5-MHz scanner has exceptional resolution in the near field, it cannot penetrate beyond a few centimeters even in the watery neonatal brain. We therefore recommend the use of both 5.0- and 7.5-MHz transducers for optimal examination of the cranial contents.

The second abnormality identified with the higher-resolution scanner in this infant population was widening of the interhemispheric fissure. When coupled with mild ventriculomegaly and absence of increase in head circumference or bulging of the fontanelle, it implies generalized atrophy of the brain; this was present in most of our patients with PVL. From these early sonographic findings we may eventually be capable of making more specific predictions about which children will have neurologic deficits attributable only to deep white-matter infarction or PVL and which children will have deficits of a more global nature.

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