Ultrasound of the Neonatal Craniocervical Junction

To determine the value of ultrasound scanning of the craniocervical junction in neonates via a posterior approach, we examined 50 infants with normal posterior fossae, 10 with congenital abnormalities, and eight with intracranial hemorrhage. Good evaluation of the cisterna magna, medulla, tonsils, vermis, cervical cord, and central canal was possible in most cases. In nine patients with spinal dysraphism, all displayed a Chiari II malformation; of these, a kink at the medullary cord junction was seen in six, and a cerebellar peg was noted in four. In one case, the Chiari malformation was confirmed by myelography, and all nine patients had some of the intracranial features of Chiari II malformation seen via the standard anterior fontanelle approach. The 10th patient in this group had a quadrigeminal plate cyst and gross hydrocephalus. In another four infants, diffuse subarachnoid blood in the cisterna magna was seen after recent intraventricular hemorrhage. A further two of four patients with posthemorrhagic hydrocephalus had localized clots. Direct scanning at the craniocervical junction was easily performed and allowed good evaluation of this area in normal infants and in patients with Chiari II malformation. This technique also allowed visualization of subarachnoid blood and clots obstructing the outlet of the fourth ventricle.

The craniocervical junction of the neonate has traditionally been assessed via the anterior fontanelle with ultrasound [1], by myelography [2], by computed tomography [3], and more recently by magnetic resonance [4]. Direct ultrasound scanning of the spinal canal in neonates and young infants has been widely reported [5–10], but detailed investigation of the craniocervical junction has not. In the neonate, and especially in the premature infant, the posterior arches of the spinal canal are minimally ossified, allowing an excellent acoustic window into this region [11]. To determine the appearance of the normal cervicomedullary junction, and particularly the central canal, 50 infants with normal craniocervical junctions were examined. These were compared with 10 babies with congenital abnormalities and eight with intracranial hemorrhage to assess the visualization of Chiari II malformation and to evaluate the blood in the cisterna magna.

Materials and Methods

All examinations were performed with a real-time sector scanner (ATL 1000A) using a 7.5 MHz transducer. Images were recorded on film via the built-in multifomat camera. The babies were scanned in the lateral decubitus position, preferably with the head flexed. If necessary, the examination was performed in the isocline. The transducer was placed at approximately C2 and angled upward and downward. Various angulations and positions were required for optimal visualization of all structures from the lower cervical cord to the fourth ventricle. Early in the study five examinations were unsuccessful because of patient movement; subsequently, the examinations were usually performed when the babies were sleeping or postprandial. One examination was undertaken after sedation.

The sonograms were performed on consecutive patients between September 1983 and May 1984. Ninety-four percent of the babies were in the neonatal unit at the Montreal Children's Hospital. Ultrasound examinations for both the normal and abnormal groups were...
Fig. 1.—Normal sagittal (A), parasagittal (B), and transverse sonograms (C) in a neonate viewed with the patient prone, showing the normal craniocervical junction. The arrowheads outline the cervical cord. (cm = cisterna magna, v = vermis, t = tonsil, m = medulla, f = fourth ventricle.)

Fig. 2.—Normal sagittal sonogram of the craniocervical junction in a neonate demonstrating the central canal as a distinct channel proximally (arrowheads) and as a single line distally (straight arrow). The vertebral bodies are seen anteriorly (curved arrows).

requested mainly to investigate apnea, seizures, or congenital abnormalities, or to study premature infants. Sagittal, parasagittal, and transverse images were obtained in 68 babies, 43 girls and 25 boys, ranging in age from 26 to 50 weeks (mean 39 ± 0.6 standard error of mean (S.E.)).

There were 50 infants with normal brain scans and normal craniocervical junctions whose ages ranged from 28 to 50 weeks (mean 39.5 ± 0.6 S.E.). Ten infants had congenital abnormalities and ranged in age from 37 to 41 weeks (mean 40 ± 0.04 S.E.). Nine of this group had spinal dysraphism. Another eight babies, ranging in age from 26 to 40 weeks (mean 32.3 ± 2.0 S.E.), had intracranial hemorrhage.

Results

Normal Patients

The cervical cord and subarachnoid space and the cisterna magna were identified in all normal infants and were seen well in most cases (78%). The cisterna magna provides an acoustic window. When it was clearly identified, the medulla was seen well (70% of examinations). The fourth ventricle was evident in 44% of the cases, but required steep angulation of
Fig. 3.—A, Sagittal sonogram at craniocervical junction in a patient with a meningomyelocele demonstrating the junction of the medulla and spinal cord with a spur (arrowhead). The scan is orientated vertically for comparison with the myelogram. The cervical cord with its central canal (straight arrow) is seen inferior to the larger sonoluent medulla. The cisterna magna (CM) is filled with cerebellar tissue. B, Myelogram on the same patient demonstrating the spur (arrowhead) and cerebellar tissue (straight arrow). C, Transverse sonogram of the cervical cord (arrowhead) viewed with the patient prone demonstrating the central canal (arrow). D, Transverse sonogram in region of the herniated medulla (arrowheads) viewed with the patient prone demonstrating the eccentric canal (arrow).
Congenital Abnormalities

Of the 10 infants with congenital abnormalities, nine had a Chiari II malformation and one had a quadrigeminal plate cyst. All nine with spinal dysraphism had cisterna magna obliteration. In seven of the nine (77%) the junction of the cord and medulla was seen in the cervical region. Three were at C2, two at C3, and two at C4 level. The cervical cord and its central canal were easily identified in the lower cervical canal. The medulla, with its eccentric canal, is wider and more uniformly sonolucent than the cervical cord. The posterior portion of its canal is formed by either the posterior wall of the elongated fourth ventricle or by a cerebellar peg (Fig. 3). The medullary canal was only clearly visible in three patients.

In addition, a cervicomedullary spur or kink was seen at this level in six of seven infants (86%) whose junctions were visible in the cervical region (Fig. 4). Posterior dilatation of the fourth ventricle was not seen in any case, but the kink overlapped the upper cord in four patients. In an additional four cases, a cerebellar peg was also seen at (in two patients) or below (in two patients), the foramen magnum. None of these features was seen with the standard anterior fontanelle approach. Four of these babies had repeat examinations, which confirmed the findings.

The cranial sonographic findings seen via the anterior fontanelle approach, in Chiari II malformation, include hydrocephalus with pointing of the frontal horns, asymmetry of the lateral ventricles, relative enlargement of the occipital horns compared with the frontal horns, partial absence of the septum pellucidum, abnormalities of the third ventricle with a prominent massa intermedia, and a V-shaped and low tentorium cerebellum [12]. In varying degrees, some of these features were present in all nine patients. In one case, the Chiari II malformation was confirmed by myelography.

One neonate had severe hydrocephalus due to quadrigeminal plate cyst, which was eventually diagnosed on CT ventriculography. There was little identifiable brain tissue on sonographs via the anterior fontanelle. Direct scanning at the craniovertebral junction showed the characteristic pattern of the cerebellum in this region with obliteration of the cisterna magna, indicating tonsillar herniation (Fig. 5).

Intrapaventricular Hemorrhage and Its Sequelae

In eight patients with intraventricular hemorrhage, four had the hemorrhage 1 to 3 days before the examination and four had it between 4 days and 3 weeks previously. Subarachnoid blood or clot was identified in four premature infants with recent intraventricular hemorrhage. In the acute phase, the blood was echogenic in the subarachnoid space and cisterna...
magna but it later became hypoechoic and formed localized clots, as seen with intraventricular hemorrhage (Fig. 6). The most severe of these cases eventually required shunting for posthemorrhagic hydrocephalus. All four patients with remote hemorrhage developed hydrocephalus. In one, clots were shown protruding into the distal end of the fourth ventricle, and, in another, they were within a dilated fourth ventricle and cisterna magna (Fig. 7). After the development of hydrocephalus, the cisterna magna was generally compressed or effaced.

The subarachnoid hemorrhage was not identified on routine anterior fontanelle scanning in any of these cases. In those cases with remote hemorrhage and hydrocephalus, the degree of dilatation of the fourth ventricle and the extent of communication with the cisterna magna, as well as the presence of blood clots, were better defined than via the anterior fontanelle approach.

**Discussion**

Sonography of the spine in both infants and adults is a well-recognized technique. In infants the procedure can dem-
onstrate a wide range of abnormalities [5–13]. Goodwin and Quisling [1] described the neonatal cisterna magna on sonography done via the anterior fontanelle. The cisterna magna area has also recently been described on CT examination [3]. However, there has been no detailed report of the cranio-cervical junction studied by sonography performed via the posterior approach.

The technique to assess the craniovertebral junction in neonates by sonography is easy to perform and is reproducible. Our study demonstrates that the normal cisterna magna, cervical cord, medulla, tonsils, and vermis can be seen in most cooperative infants. The diameter of the central canal can be measured and should be no greater than 1 mm. For babies with congenital abnormalities of the spine elsewhere, this examination can confirm or exclude the presence and extent of Chiari II malformation quickly and more accurately than can sonography done via the anterior fontanelle. It is particularly useful in those infants with lower cranial-nerve signs. The presence of a cerebellar peg and a cervicomедullary spur, which has been well described pathologically and on myelography [12], can also be visualized. The cerebellar peg is a downward herniation that may contain the nodulus, uvula, and pyramids in the midline. The cervicomедullary spur is caused by buckling of the medulla on the upper cervical cord due to the herniation.

This method of evaluating the craniovertebral junction may be helpful in determining the suitability of a cisternal or C1–C2 puncture for myelographic visualization of the spinal canal in certain spinal dysraphic states. It may also be an aid in determining the potential benefits of decompressing the hindbrain by upper cervical laminectomy and in evaluating the posterior fossa structures in infants with complex brain abnormalities.

Sonography via the posterior approach is also useful in infants with intracranial hemorrhage. Subarachnoid blood was clearly seen in four infants with recent intraventricular hemorrhage. The amount and age of the subarachnoid hemorrhage required for visualization of blood in the cisterna magna is unknown. To find out would require a detailed study with comparison to CT and lumbar puncture findings. It is possible that a small-convexity subarachnoid hemorrhage may be overlooked with the posterior approach. Anterior fontanelle sonography has been disappointing in diagnosing subarachnoid hemorrhage.

In patients with posthemorrhagic hydrocephalus, clots were observed in the fourth ventricle and cisterna magna. Serial sonograms showed the progression or resolution of these lesions. A method of treating posthemorrhagic hydrocephalus used occasionally is serial lumbar puncture rather than immediate ventriculoperitoneal shunting [14]. In those babies with obstruction of the fourth ventricle caused by clot, repeated lumbar puncture for control of hydrocephalus is un-
likely to succeed and may be dangerous. Visualization of these clots may help determine how the hydrocephalus should be controlled.

In conclusion, this study showed that ultrasound examination of the neonatal craniocervical junction via the posterior approach is easy to perform, yields good anatomical definition in the majority of infants, and is helpful in assessing infants with congenital malformations—particularly Chiari II malformations—and cases of intraventricular and subarachnoid hemorrhage.

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REFERENCES