Real-Time Sonographic Sector Scanning of the Neonatal Cranium: Technique and Normal Anatomy

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A commercially available wide field of view real-time mechanical sector scanner can be used to image the neonatal cranium. Because of the small transducer head size, the open anterior fontanelle can function as an acoustic window. By thus avoiding bone, higher frequency transducers may be used to improve image resolution. Infants may be scanned quickly without sedation in their isolettes in the neonatal intensive care unit. Sterility of the infant environment is maintained by placing the transducer in a surgical glove. Using this technique, detailed normal anatomy can be seen such as vascular structures, caudate nucleus, thalamus, third ventricle, cavum septum pellucidum, and the thalamo-caudate notch. Angled coronal and sagittal sonographic anatomy is correlated with neonatal cadaver brain sections sliced in similar planes centered on the anterior fontanelle.

The mechanical sector scanner has advantages over other real-time devices including improved image resolution, a wider field of view, and a smaller area of transducer skin contact. These unique assets are particularly applicable to the evaluation of the neonatal cranium. The small transducer of a sector scanner can easily be held in contact with the open anterior fontanelle using it as an acoustic window. This window avoids bone and makes possible the use of a higher frequency transducer resulting in improved resolution. We report our technique for neonatal cranial sonography using a mechanical sector scanner. Normal intracranial anatomy seen in angled coronal and sagittal planes is presented along with correlating neonatal cadaver specimens.

Materials and Methods

Seventy-two neonates who were clinically suspect for intracranial hemorrhage were examined in their incubators in the neonatal intensive care unit (NICU) using a mechanical sector scanner (ATL Mark III Imaging System). This has three internally focused 5 MHz transducers positioned on a rotating element. Each transducer is activated through the same 90° arc producing 18 to 45 images/sec. The transducer skin contact area is 1.5 x 1.5 cm. Images are generated in a circular sector format producing a pie-shaped field of view with the narrow, slightly truncated end representing the small area of skin contact (fig. 1). Images are processed through a real-time digital scan converter and projected on a video display system. A freeze frame mode is available so that video images may be recorded on 70 mm film.

In the NICU, the real-time sonographic unit is positioned beside the infant incubator. It is not necessary to move the incubator or adjacent support equipment or to disturb the oxygen and temperature controlled environment. A small amount of aqueous acoustic coupling gel is placed in the thumb of a sterile size 8 latex surgical glove. The transducer head is inserted into the thumb of the glove which then serves as a sterile barrier (fig. 2). A small amount of acoustic gel is applied to the anterior fontanelle. The glove-encased transducer is passed through the port of the incubator and placed on the anterior fontanelle in the coronal plane (figs. 3 and 4). By rocking the transducer back and forth, the ventricular system as well as periventricular structures can be examined (fig. 5). Freeze-frame images

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are recorded at the level of the anterior part of the frontal horns, the caudate nuclei in the plane of the middle cerebral arteries, the third ventricle, the midbody of the thalamus, and the atria of the lateral ventricles in the region of the choroid plexus. The transducer is then turned 90° into the sagittal plane and rocked in a similar fashion (figs. 4 and 6). Sagittal freeze-frame images are recorded at the midline as well as at the level of both caudate nuclei and the lateral parts of both lateral ventricles.

Anatomic-pathologic correlation with sonograms was obtained by cutting two neonatal brains in planes parallel to the planes of the sonographic images generated through the anterior fontanelle. The first brain specimen was from a term infant whose death 1 week after delivery was attributed to sudden infant death syndrome. At autopsy the location of the anterior fontanelle was marked on the superior surface of the brain. The brain was then removed from the skull and scanned in a water bath to insure that it was sonographically normal. Next, the brain was sliced five times in the coronal plane with the superior part of each slice beginning just below the anterior fontanelle. The slices extended inferiorly in five different angles relative to the canthomeatal line as diagrammed in figure 5. These cuts were designed to be parallel to the sonographic beam and show the same anatomy as the clinical sonograms in figures 7A, 8A, 9A, 10A, and 11A. A second brain from a similar infant was sliced in five sagittal planes centered on the anterior fontanelle, as seen in figure 6. The placement of these cuts was designed to be parallel to the sonographic beam and show the same anatomy as figures 12A, 13A, and 14A.

Results and Observations

Coronal Sections

Figure 7: coronal image with the transducer placed on the anterior fontanelle so that the sonographic beam is angled 80° relative to the canthomeatal line (fig. 5, plane 1). The plane of section includes the hypoechoic slitlike frontal horns of the lateral ventricles (5) and the fluid-filled cavum of the septum pellucidum (6), which lies between the frontal horns and is a normal structure in preterm infants. The relatively echoic heads of the caudate nuclei (7) lie inferior to the lateral parts of the frontal horns. Also well seen are the bony landmarks, which include the anterior clinoids (10) and the floor of the middle cranial fossa (12). The parenchyma of the temporal lobes (11) and frontal lobes (3) has a low echogenicity relative to the caudate nuclei. Specific gyri such as the gyrus rectus (8) and cingulate gyrus (1) can be identified by the echogenic subarachnoid cisterns that outline their boundaries. Vascular anatomy demonstrated includes the pericallosal artery (2) and the middle cerebral arteries (9) in the sylvian fissure (13). These arterial structures are identified by their pulsations as well as their location.

Figure 8: coronal section 70° to the canthomeatal line (fig. 5, plane 2) with the transducer on the anterior fontanelle angled 10° posterior to figure 7A. This section includes the lateral ventricles (5), the foramina of Monro (14), the third ventricle (15), and the parahippocampal gyrus (16). The bony landmarks of the greater wing of the sphenoid (17)
and the floor of the middle cranial fossa (12) are dense bands of linear echoes defining the inferior extent of the cranium. The homogenous low echogenic brain parenchyma of the temporal lobe (11) is again defined with the cingulate gyrus (1) and parahippocampal gyrus (16) bounded by the hyperechoic subarachnoid cisterns. The pericallosal artery (2) is seen in the midline pulsating superior to the hypoechoic corpus callosum (4). The corpus callosum is a homogenous hypoechoic bridge of tissue just superior to the medial parts of the lateral ventricles. The lateral ventricles (5) are arcuate and slitlike with the foramina of Monro (14) extending from their inferior medial margins. The fluid-filled hypoechoic cavum of the septum pellucidum (6) lies between the lateral ventricles and must be distinguished from the more inferiorly placed third ventricle (15). Adjacent to the inferolateral margins of the lateral ventricles are the bodies of the caudate nuclei (7).

**Figure 9:** coronal section 60° to the canthomeatal line (fig. 5, plane 3) with the transducer on the anterior fontanelle angled 10° posterior to figure 8A. This plane includes the lateral ventricles (5), the body of the caudate nucleus (7), the thalamus (22), the cerebral peduncles (19), and the upper extent of the pons (20). The ventricles continue to be arcuate and slitlike with the pericallosal artery (2) pulsating just superior to the hypoechoic corpus callosum (4). The body of the caudate nucleus (7) is again noted to be more echogenic than the surrounding white matter. The thalami (22) are large bilateral medium echo level structures inferior, medial, and posterior to the caudate nuclei. The cerebral peduncles (19) extend inferiorly in V-shaped hypoechoic bands that fuse at the pons (20), an equally hypoechoic structure. Bright specular echoes lateral to the pons represent the edges of the tentorium (21) and the choroidal fissure (34).

**Figure 10:** coronal section 50° to the canthomeatal line (fig. 5, plane 4) with the transducer centered on the anterior fontanelle and angled 10° posterior to figure 9A. The plane of this section includes the lateral ventricles (5), the thalamus (22), the quadrigeminal plate (23), and the cerebellar vermis (24). The lateral ventricles are again slitlike with the echoic caudate nuclei (7) in a similar inferolateral position relative to the ventricles. The large hypoechoic thalami (22) are inferior to the ventricles and are separated dorsally by the echoic quadrigeminal cistern (23). The parahippocampal gyrus (16) borders the inferolateral margins of the quadrigeminal cistern. The highly echogenic vermis of the cerebellum (24) is the most inferior structure. The sloping tentorial margins (21) outline the superior aspect of the cerebellum, with the parietal bone identified laterally (25).

**Figure 11:** coronal section 40° to the canthomeatal line (fig. 5, plane 5) with the transducer on the anterior fontanelle angled 10° posterior to figure 10A. This plane of section includes the atrium of the lateral ventricles (5), the splenium of the corpus callosum (27), and the vermis of the cerebellum (24). The pulsating pericallosal artery (2) continues in the midline between the superior margins of the ventricles. The pulsatile highly echogenic choroid plexus (26) can be seen lying along the inferomedial portion of the atrium of the lateral ventricles. The large hypoechoic structure separating the lateral ventricles is the splenium of the corpus callosum (27). The posterior part of the sylvian fissure (13) is seen as a horizontal band of linear echoes lateral to the ventricles.

**Sagittal Sections**

**Figure 12:** midline sagittal plane with the transducer centered on the anterior fontanelle (fig. 6, plane 1). This section includes the pulsatile callosal marginal (28) and pericallosal arteries (2) which are immediately superior to the large fluid-filled cavum septum pellucidum and cavum vergae (35). Inferior to the calva is the fluid-filled anechoic third ventricle (15). Extending from the posterior inferior margin of the third ventricle is the cerebral aqueduct (29) which traverses inferiorly over the hypoechoic midbrain (18). The pons (20)
Fig. 7.—Coronal section 80° to canthomeatal line is described in text under Results and Observations.

Fig. 8.—Coronal section 70° to canthomeatal line is described in text under Results and Observations.
Fig. 9.—Coronal section 60° to canthomeatal line is described in text under Results and Observations.

Fig. 10.—Coronal section 50° to canthomeatal line is described in text under Results and Observations.
and the medulla (30) are continuous with the midbrain and are of equally low echogenicity. Posterior to the pons is the very echogenic vermis of the cerebellum (24). The specular occipital bone (31) forms the inferior margin of the posterior fossa.

**Figure 13**: Sagittal plane with the transducer centered on the anterior fontanelle and angled 10° lateral to the midline (fig. 6, plane 2). The atrium of the lateral ventricle (5) is filled with the pulsatile, highly echogenic choroid plexus (26). The large hypoechoic thalamus (22) is inferior to the convexity of the lateral ventricle, with the more echoic caudate nucleus (7) lying just anterior to the thalamus. At the superior part of the junction line between them, the thalamocaudate notch (32) can be identified. The inferior bony margins are formed by the floor of the anterior fossa (33) and the occipital bone (31).

**Figure 14**: Sagittal plane with the transducer on the anterior fontanelle angled 20° lateral to the midline (fig. 6, plane 3). This plane of section includes the fluid-filled atrium, occipital horn, and temporal horn of the lateral ventricles (5, 36, 37, respectively). The highly echoic choroid plexus (26) can be seen running along the floor of the atrium into the temporal horn. Encased by the sweep of the ventricle is the lateral part of the thalamus (22).
Discussion

Sonography of the head was first performed in 1955 and involved the use of A-mode to detect midline structures and obtain a crude estimation of ventricular size [1]. Two dimensional bidirectional echoencephalography appeared in 1963 and was a significant technical advance since it provided better information about ventricular size as well as intracranial spatial relationships [2, 3]. However, only a relatively few highly specular structures could be demonstrated. The next technical improvement was the application of gray scale compound static scanners to echoencephalography, which markedly improved image information content [4–6]. Numerous cranial structures, including ventricles, brain stem, basal ganglia, and brain parenchyma, could be visualized. The accuracy of compound gray scale echoencephalographic measurements has been well established and compares with those obtained from computed tomography (CT) [7, 8]. Gray scale compound imaging offers several advantages over CT: less time required per study, lack of ionizing radiation, significantly lower cost, elimination of the need for sedation, and fewer artifacts [8]. However, for both CT and compound gray scale sonography, a newborn patient must be removed from the protective environment of the NICU and the infant incubator.
This problem is solved by using a compact high resolution real-time sonographic scanner that may be easily transported to the NICU. The infant can be scanned in the incubator without sedation and without disturbing support equipment. Rapid identification of intracranial anatomy is made possible by the freedom of movement of the hand-held transducer and the real-time display. Such a technique has been reported using linear array real-time equipment [9, 10]. However, several authors recognize problems with the use of linear array real-time related to the size to the transducer head, which is 8–16 cm long [7, 12]. Since only a small part of the large flat transducer face is in contact with the skin of the curved infant skull, only a narrow rectangular field of view is obtained. The mechanical sector scanner produces a 90° sector arc image using a small area of skin contact to generate a field of view that broadens as it extends away from the transducer. This is a significant improvement in field size compared to linear array real-time scanners.

Several authors have reported the use of the anterior fontanelle as an acoustic window into the neonatal cranial [10–11, 12, 15, 16]. The small area of skin contact required for a sector scanner makes it particularly suited to this technique. By imaging through the anterior fontanelle and thus avoiding bone, higher frequency transducers may be used which result in improved image resolution. Placing the transducer inside a new sterile surgical glove for each neonate helps control cross-contamination yet does not degrade the image or increase acoustic gain requirements.

The advent of improved neonatal care in high risk nurseries has meant the survival of more premature infants, increasing the clinical demand for safe, detailed intracranial imaging. Our experience demonstrates that a considerable amount of information about normal neonatal intracranial anatomy can be obtained using real-time sector scanning through the anterior fontanelle.

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