ULTRASOUND FOR IDENTIFICATION OF BRAIN DAMAGE IN INFANTS AND YOUNG CHILDREN *

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Infant skulls do not provide the severe barrier to ultrasound diagnosis that the adult skull does. Improved ultrasound instrumentation has made it possible to visualize the brains of infants and small children in detail, through the intact skull, non-invasively and non-accumulatively. This has decreased the hesitancy of physicians to request diagnostic brain studies on seriously ill babies, particularly premature and neonatal ones. The ability to provide considerable diagnostic information in children through age $3\frac{1}{2}$ or 4 years, when diploe start to appear in the parietal bones, adds to the usefulness of two-dimensional ultrasound brain visualization.

METHOD

A prototype, portable, ultrasound scan instrument was used for this study. A 1.7 MHz transceiver, with a 5 cm. Lead Metaniobate element, ground spherically to focus the ultrasound beam at 20 cm., was passed in a linear path through a bath of warm degassed water. The bottom of a flexible plastic tank was applied to the child's parietal area with a coupling gel. The child was placed on a warming blanket which provided a soporific effect. Many of the children slept during the scan. The 3 - 4 cm. of water did not exert appreciable compression to even the loosely joined skull bones of severely hydrocephalic babies.

The ultrasound scans used to illustrate this paper are largely horizontal tomograms. Coronal tomograms were made to confirm abnormal findings in the horizontal scans, or to demonstrate additional aspects of pathology or structural anatomy. For maximally interpretable visualization, the patient's head was oriented precisely in relationship to the transceiver, so that the scan path was perpendicular to the midline plane of the brain and parallel to the canthomeatal plane. The break in the midline echo provided by the corpus callosum, impinging on it, was used to identify reference planes in horizontal and coronal scans. Using these reference planes, tomograms were made at either 5 mm. or 1 cm. intervals. These reference planes are often more difficult to identify in abnormal brains than in normal ones. The two-dimensional image was displayed on a 17-inch monitor. Selected tomograms were recorded permanently on polaroid film taken from a separate 9-inch monitor which recorded an identical image. It required 15 to 45 minutes to complete a study, depending on the detail needed.

RESULTS

A tomographic atlas was made very rapidly visualizing the entire brain (Fig. 1). The midline, lateral ventricles, including the temporal horns on the horizontal scans, the tentorial incisura and brain stem, (Fig. 2) were seen routinely in children younger than 1 year of age. A significant, but lesser amount of structural detail was seen in children up to 4 years. Fortunately, brain abnormalities could often be identified in older children even when anatomical structure could not be resolved. This is particularly true of hemorrhage, some margins of which reflect ultrasound more intensely than surrounding tissues with the exception of the bone (Fig. 3). Hemorrhage could usually be identified by using ultrasound sensitivity graded tomography as the reflections from its borders were visible at much lower gain settings than even strongly reflective midline structures.

Normal ventricles were often difficult to recognize because of their slit-like width. Dilated cerebral ventricles were more readily identified since both the superficial and deep ventricular walls produced linearly arranged echo patterns (Fig. 1). Tumors were reflective, particularly if they were surrounded by less dense ventricular fluid or cystic space (Fig. 4). Hemorrhage was more reflective than any of the tumors that were visualized. Cystic tumors were identified even through the thicker skulls of 3-4 year olds to aid in their differentiation from solid masses (Fig. 5).

The orientation of normal appearing anatomical structures provided a clue to dysfunction as in the case of a very slightly displaced and rotated brain stem (Fig. 2).

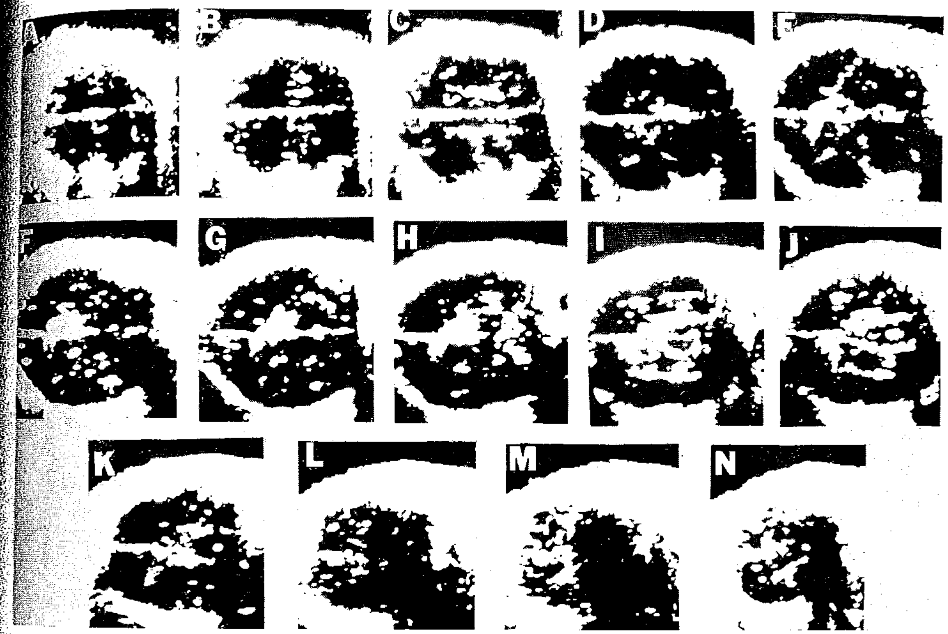

Figure 1.

Horizontal scans of 3 week old infant with convulsions and difficulty breathing and swallowing. The scans were made at 5 millimeter intervals from the superior plane where the lateral ventricle echoes (A) first appear to the cerebellum at the base (L, M and N). The child's head is oriented with the left side up face toward the right. Medial and lateral walls of the lateral ventricles are shown on either side of the midline in scan B. An abnormal echo appears to straddle the midline in scan E, and persists in the same location through scan H or possibly scan I. The brain stem is clearly outlined in scans I and J. The aqueduct of Sylvius, cerebral peduncles and quadrigeminate plate can be identified in scan J, and probably the basilar artery just anterior to the brain stem and bracketed by the tentorial incisura.

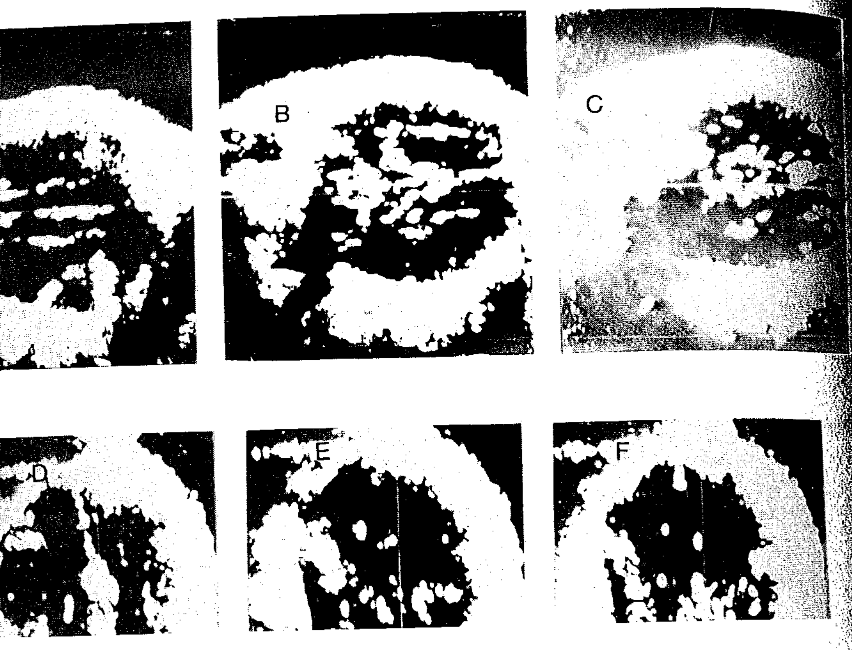

Figure 2.

orizontal, (upper row) and coronal scans (lower row) of a
h old infant with right-sided convulsions. The right side
head is at the top of the horizontal scans, face toward the
The left side of the head is on the left of the coronal scans.
cular echoes are seen both horizontally and coronally, more
identified in horizontal scans. The temporal horns bracket
ntorial incisura and brain stem in scan B, with more than the
echo intensity in the chiasmatic and inter-peduncular cysterns
nterior to the brain stem. The brain stem appears slightly
ed in relationship to other structures in scan C. This twist-
s confirmed by a slight shift of the brain stem toward the
in scan E. This shifting can be explained by abnormal echoes
e Sylvian fissure region, presumably a hemorrhage on the left
e other two coronal scans, D and F, in the superior left
tal area in scan A.

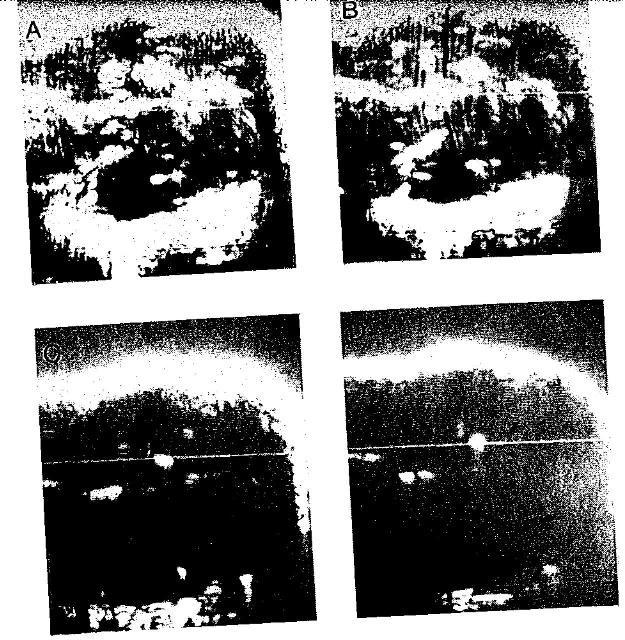

Figure 3.

Horizontal ultrasound scans were made on this 4 week old infant because of almost constant generalized seizure activity. The head is oriented left side up, face toward the right of the photographs. Small reflections from the medial and lateral walls of the right lateral ventricle can be seen below the midline, scan A. These are visible but not as distinctly in scan B and absent in scans C and D. Progressive decrease in instrument gain from an attenuation of 20 decibels in scan A, 25 db scan B, 40 db scan C and 50 db scan D was used. A linear reflection close to the inner table of the left (upper) parietal skull probably represents the lateral wall of the left lateral ventricle in scans A and B. The medial wall area of this ventricle is occupied by a dense reflection in the thalamic region. This dense reflection appears to be a continuation of an echo crossing the anterior portion of midline structures. The midline crossing echo disappeared with a slight gain decrease. Persistence of the left thalamus echo at progressively lower gains in B, C and D shows that it is different from the artifactual shadows which disappear. It undoubtedly represents contused or hemorrhaged brain tissue with an unusually highly reflective lateral (ventricular) edge.

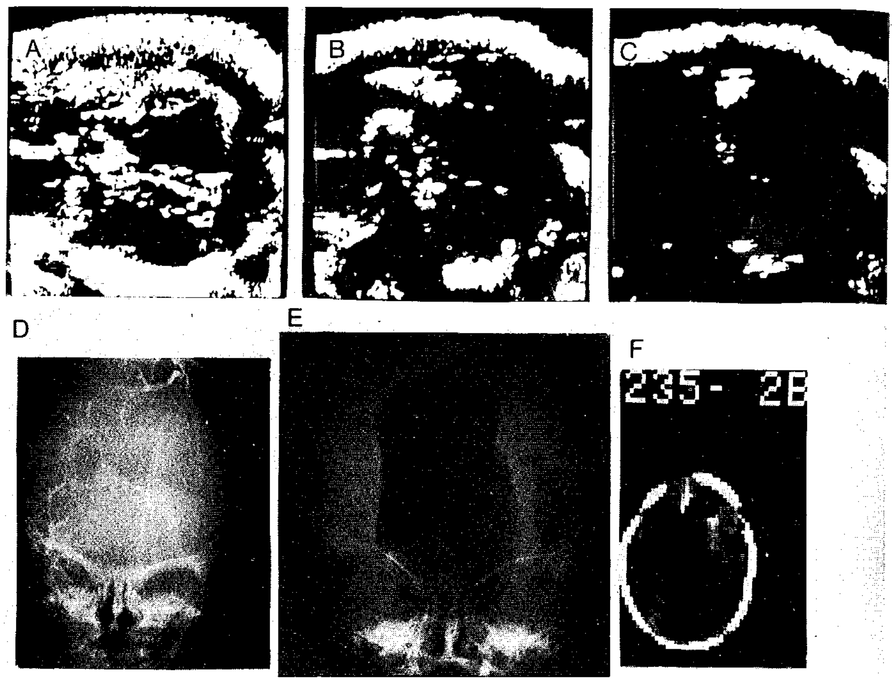

Figure 4.

A one year old unresponsive child with enlarging head had equivocal angiography D, air ventriculography E and computerized axial tomography F in two separate test "series". Because of the gross distortion of brain structure only a marked midline shift, left to right, is well demonstrated in scan A. The horizontal tomograms, left side up, face toward the right, show the medial and lateral walls of the left lateral ventricle, above the shifted midline structures. The linear echoes of the ventricular walls persist but less distinctly in scans B and C which show decreasing gain, attenuation 40 decibels A, 50 db B and 55 db C. The persistent heavy reflection hanging onto the lateral portion of the left (upper) lateral ventricle suggested a choroid plexus papilloma pre-operatively. A choroid plexus vascular malformation was removed at surgery. Many scans confirming the illustrated ultrasound displays were needed to make this diagnosis, with the added information from the three x-ray studies, without which the ultrasound scans above would have been even more difficult to interpret.

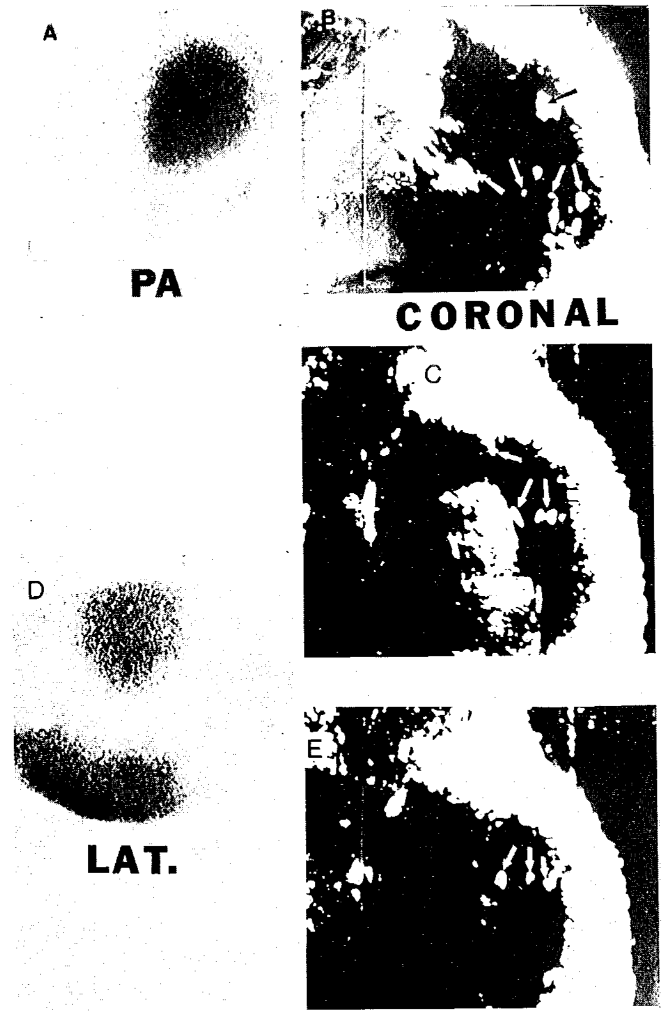

Figure 5.

Isotope scans, A and D, of this 3 year old with a recurrent right parietal ependymoma give the appearance of inoperability. A large cyst with heavily reflecting walls (white arrows) and small mural nodule (black arrow) was suspected from ultrasound scans made through the intact skull. Surgery proved this to be correct. Artifactual reflections provided the usual confusion in ultrasound scans through the intact skull, but the persistence and location of the cyst wall reflection provide enough confidence in the diagnosis to advise surgery.

ough the information provided seemed reliable, there were
ical or pathological confirmations of the diagnosis, except
wo tumors. The anatomical structures mentioned were accu-
ntified by using transparent overlays from atlases of excis-
cut as nearly as possible in the same planes as the two-di-
ultrasound scans. Unfortunately, no atlases of the infant
been found, but the available adult brain outlines fit sur-
well. This technic was helpful in confirming anatomical
that appear reasonably certain on ultrasound tomograms,
o point out additional structures not previously recognized.

DISCUSSION

ty to visualize brain detail in infants with two-dimension-
und was predicted by Kazner (17) and others. Kossoff and
re able to identify gross anatomical structure of fetal
tero in 1972 (18), and in 1974 demonstrated horizontal and
in atlases of normal infants (19). Their technic has be-
epted screening test for infant brain diagnosis in Sydney,
20).

ther investigators (1-29), including the Dussiks (7,8)
rst to apply ultrasound to medical diagnosis, have report-
nsional brain imaging. Good diagnostic information has
ped recently in hundreds of patients. The scans recorded
vestigators provide valuable information to the trained
e not been convincing to those less accustomed to reading
rain tomograms. The structural and pathological detail
ncreases each year. The clear information, possible to
fants, should move this diagnostic instrumentation for-
pidly in the near future.

ge aperture focus ultrasound transceivers used by Kossoff
authors of this report, have provided the clearest and
d brain scans in infants. The large size of the trans-
makes it almost mandatory to use a water bath to provide
pling, even though contact scanning would be more conven-
the patient and the ultrasonographer. Somer's (16)
transceiver system is applied directly to the scalp and
sing the same instrument demonstrated most of the impor-
ic information available to the large aperture transcei-
. Whether the additional information available to the
eivers will be worth the additional trouble in applica-
to be seen. The mild restraint, and soporific effect of
r bath may well offset the benefit derived from the ease
anning, particularly in tiny infants with soft heads, or
ents with head injuries. Additional exploration and im-
ovation will undoubtedly bring about significant advances

in the areas of patient handling as well as data acquisition and dis-
play.

Computerized axial tomography, using x-ray, has revolutionized the diagnosis of brain disorders. Whether ultrasound methods can provide additional useful information remains to be seen. Two-dimensional ultrasound brain tomography appears to have its place when dealing with very young infants, and possibly restless head injury victims. Rapid and continuous development of both computerized axial tomography and ultrasound instrumentation can only compliment each other, to benefit individuals seriously ill and disabled by brain pathology.

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