Original Research Paper

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Ultrasound

ASSESSMENT OF CRANIAL ABNORMALITIES IN NEONATES BY PERFORMING NEUROSONOGRAM

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KEYWORDS :

INTRODUCTION

Neurosonogram is the preferred modality to image the neonatal brain. The advantages of neurosonogram are numerous. It can be performed bedside with little disturbance to the infant, it is relatively safe, and can be repeated whenever needed, enabling visualization of ongoing brain maturation and the evolution of lesions.

Ultrasound is the least costly of all modalities and the most widely used in the neonatal intensive care unit (NICU). The modality is operator-dependent and should be performed by an experienced sonographer, neonatologist, or radiologist. Ultrasound machines are portable, and the images acquired bedside conveniently in the NICU, meets the definition of point-of-care testing. The cumbersome transport of the neonates to the computerized tomography (CT) or the magnetic resonance imaging (MRI) suite is avoided. In addition, ultrasound is cost-effective and considered a safer modality in the pediatric population due to the lack of harming effect of ionizing radiation, as in CT, as well as avoiding the need for sedation required for MRI.

In neonates, many sutures and fontanels are still open and these can be used as acoustic windows to “look” into the brain. In many cases, a final diagnosis and treatment guidance can be achieved with neurosonography, such as in neonatal germinal matrix hemorrhages and neonatal malformations.

Any neonate, regardless of birth weight, size, or gestational age, who has a greater than average chance of morbidity or mortality, due to fetal, maternal or placental anomalies or an otherwise compromised pregnancy, especially within the first 28 days of life is categorized as critically ill neonate. Neurosonogram plays an important role in assessing neurological prognosis of these high-risk infants.

Modern ultrasound equipment's, with variety of acoustic windows and sequential scanning yield high-quality images and aids the recognition of features suggestive of developmental, metabolic and infectious disorders.

It detects most of the hemorrhagic, ischemic and cystic brain lesions as well as calcifications, cerebral infections, and major structural abnormalities in critically ill neonates. It is also very helpful in the early diagnosis of the many etiologies of neonatal encephalopathy and seizures in the term infant and subsequent monitoring of progress of hypoxic-ischemic brain injury.

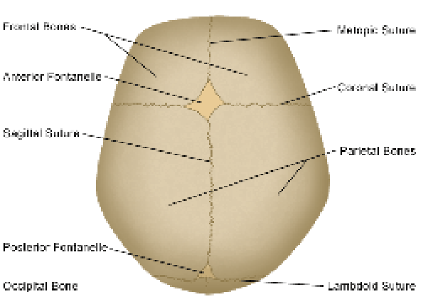
Most newborn intensive care unit centers perform serial cranial ultrasound evaluations early in the course of hospitalization for premature infants and often, a follow-up examination is done at a later age. These evaluations are done to document the presence of intracranial hemorrhage, to guide choice of therapies that may exacerbate the risk of further hemorrhage, and to counsel families about neurodevelopment outcomes.

Neurosonogram is also very helpful in assessing severity and neurodevelopment outcome in infants with hypoxic ischemic encephalopathy (HIE) and in seriously ill neonates with cerebral abnormalities, either congenital or acquired. It plays a role in decision making on continuation or withdrawal of intensive treatment.

The quality of neurosonography and its diagnostic accuracy depends on the ultrasound machine and also expertise of the examiner. When performed as per protocol, it is a reliable investigation for commonly occurring neonatal events. Neurosonogram can be initiated even immediately after birth and hence suitable for screening and can be repeated as often as possible without any adverse affects and hence helps in proper follow-up of babies with neurological problems.

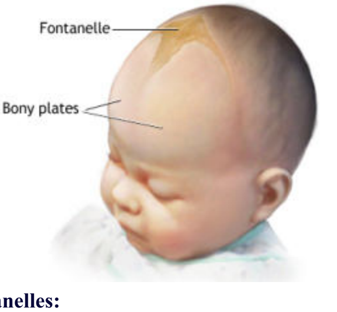
In this study, we discuss the applications and indications of neonatal cranial ultrasound. However, it also has several limitations: Quality of imaging depends on the skills and experience of the ultra-sonographer, some areas of the brain is difficult to visualize, and several abnormalities remain beyond its scope.

Normal Skull of the Newborn



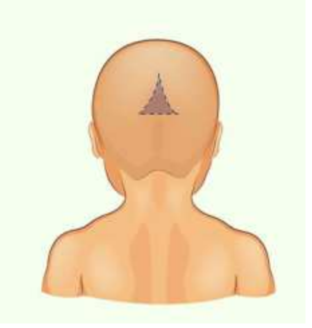
Anatomy

At birth, the newborn's skull consists of five major bones (two frontal, two parietal, and one occipital) that are separated by connective tissue junctions known as cranial sutures. The sutures function as seams, and they are highly necessary to facilitate the movement and molding of the cranium through the birth canal during labor. They also allow for rapid postnatal growth and development of the brain. However, the bones that shape the cranium begin unfused, leaving several gaps between the individual bones of the infant's skull. These gaps are composed of membranous connective tissue and are known as fontanelles. The Fontanelles are often referred to as “soft spots,” are one of the most prominent anatomical features of the newborn's skull. Six fontanelles are present during infancy, with the most notable being the anterior and posterior fontanelles. Fontanelle morphology may vary between infants, but characteristically they are flat and firm.



Anterior Fontanelles:

The anterior fontanelle is the largest of the six fontanelles, and it resembles a diamond-shape ranging in size from 0.6 cm to 3.6 cm with a mean of 2.1 cm. It forms through the juxtaposition of the frontal bones and parietal bones with the superior sagittal sinus coursing beneath it. Two frontal bones join to form one-half the anterior fontanelle with the metopic suture serving as the parallel divider between the paired bones. Next, the parietal bones are positioned against each other to complete the fontanelle. The positioning of the two parietal bones against each other gives rise to the sagittal suture. Finally, the alignment of the frontal bones against the parietal bones establishes the coronal suture. The average closure time of the anterior fontanelle ranges from 13 to 24 months. In addition to being the largest, the anterior fontanelle is also the most important clinically. This structure offers insight into the newborn's state of health, especially hydration and intracranial pressure status. A sunken fontanelle is primarily due to dehydration. Furthermore, a bulging fontanelle may indicate a rise in intracranial pressure, suggesting multiple pathologies: hydrocephalus, hypoxemia, meningitis, trauma, or hemorrhage.



Posterior Fontanelle:
Unlike the anterior fontanelle, the posterior fontanelle is triangular and completely closes within about six to eight weeks after birth. This structure arises from the juncture of the parietal lobes and occipital lobe. Through this placement, the lambdoid suture forms. On average, the posterior fontanelle is 0.5 cm in Caucasian infants. Often, the delayed closure of the posterior fontanelle is associated with hydrocephalus or congenital hypothyroidism.

Mastoid Fontanelle:
The mastoid fontanelle, a paired structure, can be found at the intersection of temporal, parietal, and occipital bones. Additionally, the mastoid fontanelle also has the name of the posterolateral fontanelle. These fontanelles may close anywhere from six to eighteen months of age.

Sphenoid Fontanelle:
Similarly, the sphenoid fontanelle is also a paired fontanelle. Its location can be on either side of the skull at the convergence of the sphenoid, parietal, temporal, and frontal bone. It is also known as the anterolateral fontanelle. Their closure occurs at approximately the sixth-month mark after birth.

Fundamentals Of Ultrasound
It is defined as sound frequencies that are beyond the range the range of normal human hearing, which is between 20 Hz and 20 kHz Thus ultrasound refers to sound frequencies greater than 20 kHz. Diagnostic ultrasound uses short sound pulses at frequencies of 1 to 20 million cycles/sec that are transmit into the body to examine soft tissue anatomic structures.

Principle:
In medical ultrasound, the piezoelectric vibrating source within the transducer is a ceramic element that vibrates in response to an electrical signal. The vibrating motion of the ceramic element in the transducer causes the particles in the surrounding tissue to vibrate. In this way the ultrasound transducer converts electrical energy into mechanical energy as patients are examined.

Properties Of Ultrasound:
Ultrasonic waves cannot travel through vacuum. These waves travel with a speed of sound in a given medium.

Amplitude:
The maximum pressure elevation in the upward or downward direction is called the pressure amplitude. It is used to quantify the strength of the wave.

Wavelength:
It is the distance between the two crests or troughs.
It is the distance the sound travels during one complete cycle of the wave.

Period:
Period is the time taken for one complete cycle of oscillation. It is the inverse of the frequency and its unit is second.

Speed:
Speed of the wave, C=frequency (f) x wavelength (λ)

$c = f \times \lambda$

Speed Of Sound In Tissues:

MATERIAL	SPEED OF SOUND (m/s)
LUNG	600
FAT	1460
BLOOD	1560
MUSCLE	1600
LENS OF EYE	1620
SKULL BONE	4080

Acoustic Pressure:
The maximum pressure elevation is called acoustic pressure.
- It is quantify the strength of ultrasound

Acoustic Power:
- It is the rate at which the energy is transmitted from the ultrasound source into the medium.
- Used to quantify to the amount of acoustical energy transmitted from the ultrasound source into the medium, its unit is W or mW.

Acoustic Intensity:
Ø It is the ultrasonic power per unit area. Unit of acoustic intensity is W/m2
Ø It is used to quantify the spatial distribution of the ultrasonic power in a beam.

Acoustic Impedance:
- Acoustic impedance (Z) is one of the factors which determiner's the amount of sound energy reflected from or transmitted through different body materials.
- Unit of Z is rayl.fis the acoustic wave. Its unit is Pascal.

Equipment:
The ultrasound machine should be a transportable real-time scanner, allowing bedside examinations without the need to transport the baby It should be equipped with transducers that are appropriate for CUS, adapted software for CUS and Doppler assessments and a reliable digital storage system.

Settings need to be optimized for neonatal brain imaging. It is recommended that preprogrammed presets be used for CUS imaging in both preterm and full-term neonates. These settings can be further optimized in individual cases and under certain circumstances.

Transducer:
The use of a convex (CV) or curved array transducer is recommended. The transducer should be appropriately sized for an almost perfect fit on the anterior fontanelle. To allow good contact between the transducer and the skin, ultrasound gel is used. If the fontanelle is very small, a smaller phased array (PA) probe can be used, but the field of view is smaller and the image quality less than that of the CV probe.

Well-fitting CV probe, positioned on the anterior fontanelle. (b) Coronal CUS scan at the level of the bodies of the lateral ventricles performed in extremely preterm infant gestational age (GA) 25 weeks.

The higher the transducer frequency, the better the near-field resolution. A lower transducer frequency will provide a lower resolution, but a better penetration. The ultrasound system should therefore be equipped with multifrequency transducers (5–7.5(8)–10 (11) MHz).

Neonates have relatively small heads. Therefore, high-quality images can usually be obtained with the transducer frequency set at 7.5–8 MHz. In most neonates this enables good visualisation of the whole brain. For better evaluation of the most superficial structures and/or in very tiny infants with tiny heads, we advise performing additional scanning, using a higher frequency up to 10 or 11 MHz, thus obtaining a higher near-field resolution. If, on the other hand, deeper penetration of the beam is required, as in larger, older infants or infants with thick, curly hair or to obtain a better view of the deeper structures, additional scanning with a lower frequency (around 5 MHz) is recommended.

Scan Depth:
When starting the CUS examination, depending on the size of the head, adaptation of the depth of the scan window may be necessary to obtain an image that fills the sector window and shows the whole depth of the brain.

Gain:
The gain can be adjusted to adapt the overall brightness of the image and to avoid too bright or too dark images. Time gain compensation can be used to adjust the gain in specific areas of the image, i.e. superficial and deeper structures.

Transducer Frequency:
As mentioned, neonatal CUS images are obtained with a high frequency transducer. This enables the most optimal visualization of the supratentorial structures. Further increase of transducer frequency can improve the near-field resolution of superficial structures and optimize image quality in preterm infants with small heads. In larger infants or when visualizing deeper structures, a lower transducer frequency may be required to provide sufficient penetration.

Focus Point:
Apart from adapting transducer frequency, the focus point can be adjusted to improve image quality. At the depth of the focus point, the ultrasound beam is the narrowest and this improves the resolution. The focus point should therefore be positioned at or just below the area of interest. Most modern transducers have multiple focus points. This improves resolution over a larger area of the brain. However, when increasing the number of focus points, the frame rate decreases, and this can lead to slower processing of the cranial ultrasound images.

METHODS:
Inclusion Criteria
Neonates With Complaints Of
- Seizures
- Metabolic acidosis
- Cranial disorders
- Babies with Intrauterine Growth Restriction, Hypoxic Ischemic Encephalopathy, sepsis, Dysmorphism and Congenital Heart Disease.

Exclusion Criteria
- Intubated Neonates
- Critically ill neonates
- Neonate with birth weight less than 750grams

Indications
Indications for neurosonography in preterm or term neonates and infants include but are not limited to evaluations for the following entities:
Screening
- Intracranial haemorrhage (< 1000-1250grams, < 28 weeks GA
- Hypoxic ischemic encephalopathy = PVL (focal white matter lesions)
- Birth trauma
- prenatally detected abnormality

Follow up
- Intracranial haemorrhage
- Ventriculomegaly (Hydrocephalus)
- Extra axial collection
- Vascular abnormalities

Initial evaluation in
- Seizures
- Congenital malformations
- Intra uterine growth retardation
- Abnormal increase in head circumference
- CNS infection
- Microcephaly, macrocephaly
- Superior sagittal sinus thrombosis
- Craniosynostosis

Premature infant if
- < 1500 grams / and or < 32 weeks gestational age.

Contraindications
There are no contraindications to neurosonography

Methodology:
Study Design
This retrospective study was conducted with a sample size of 100 participants,

Study Period: The study was carried out over a one-year period from 2017-2018.

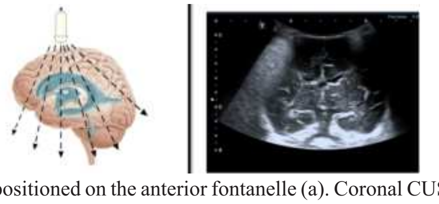
Study Location:
The study was conducted in the Department of Radiology and Imaging Sciences at the Sri Ramachandra Institute of Higher Education and Research in Chennai, Porur-600116

Cranial Usg Technique
Sonographic examinations of the brain are performed through the anterior fontanelle in both the coronal and sagittal planes. Informative images can be obtained through the posterior and mastoid fontanelle as well.

Good skin to transducer coupling can be achieved by acoustic coupling gel.Standard brain evaluation includes Sagittal and Coronal planes through the anterior fontanelle. Coronal scans may be useful in the posterior fontanelle as well in order to compare ventricular size.

The transducer should be held firmly between the thumb and index finger, and the lateral aspect of the hand should rest on the infant's head for stability.

Anterior Fontanelle Views
Neurosonography starts with gray-scale imaging performed via the anterior fontanelle in the coronal and sagittal planes. In addition to the standard planes, the whole brain should be scanned to obtain an overview of the brain's appearance. This allows assessment of the anatomical structures and detection of subtle changes and small and/ or superficially located lesions. Besides the standard views, for any suspected abnormality, images should be recorded in two planes.



LA probe, positioned on the anterior fontanelle (a). Coronal CUS scan (b) at the level of the bodies of the lateral ventricles performed with CV probe in extremely preterm infant gestational age (GA) 25 weeks, scanned on the second day after birth. The whole brain is well depicted.

Coronal Planes
The anterior fontanelle is palpated, and the transducer is positioned in the middle of the fontanelle in a way that the left side of the brain will be projected on the right side of the monitor and vice versa . The probe is subsequently angled sufficiently forwards and backwards to scan the entire brain from the frontal lobes at the level of the orbits to the posterior parietal and occipital lobes. Generally, six to eight coronal images are obtained, beginning at the anterior frontal lobes and extending to the occipital lobes posterior to the lateral ventricle trigones.

Coronal Protocol
Sonographic Findings
Ultrasound depicts the choroids plexus as a very echogenic structure inside the ventricular cavities surrounding the thalamic nuclei. The size of the choroids plexus depends on the gestational age of the infants. The plexus is very large in very premature infants, and it should not be mistaken for intraventricular hemorrhage. The gestation and term, the size is approximately 2 to 3 mm at the body of the lateral ventricles and 4 to 5 mm at the atria.

Occasionally a thin and very echogenic formation can be seen in the midline immediately below the septum pellucidum. This echogenic image corresponds to the choroid plexus extending into the third ventricle. The septum pellucidum appears as a midline hypoechoic to cystic structure separating the bodies and frontal horns of the lateral ventricles. The septum constitutes the internal wall of the bodies and posterior part of the frontal horns. The cavum septum pellucidum is anterior to the corpus callosum. In the premature fetus, less than 32 weeks, the third ventricle is prominent and easily seen on sonography.

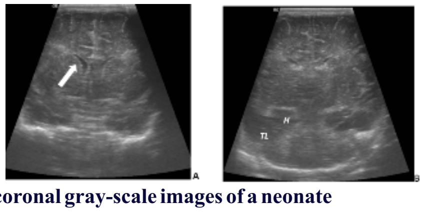
Coronal and modified coronal views also visualize the basal ganglia and the white matter. In the premature infants the caudate nuclei may have higher echogenicity than the rest of the brain parenchyma. In these infants, the nuclei should not be mistaken for subependymal hemorrhages. The thalamic ganglia are located laterally to the third ventricle, and they are visualized as areas of low echogenicity. The white matter is situated between the lateral ventricles and the cortex. The white matter has low echogenicity with thin echogenic streaks that correspond to small vessels. This area is known as "watershed zones", which are the terminal ends of the vessel bed and may be used to describe the periventricular white matter.

Modified Coronal Studies Of The Ventricles And Posterior Fossa

The modified coronal plane demonstrates the body of the lateral ventricles, the third ventricle and the posterior fossa.

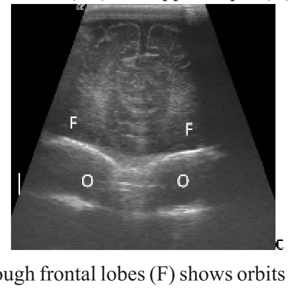
Position Of Transducer

To obtain this view, the transducer is positioned over the anterior fontanelle with an angle of approximately 30 to 40 degrees between the scanning plane and the surface of the fontanelle. If the anatomical structures are difficult to image because of overlapping bones in the fontanelle, the posterior fontanelle is used as an alternative window to image the choroid plexus and lateral ventricles.

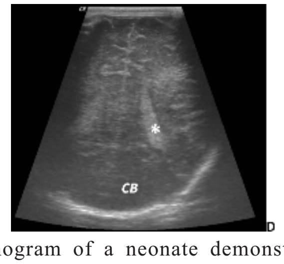


Normal coronal gray-scale images of a neonate

A-Sonogram through frontal horns shows corpus callosum, seen as hypoechoic midline structure outlined by echogenic superior and inferior borders. **B**-Sonogram at level of quadrigeminal plate illustrates temporal lobes (TL) and hippocampus (H)



C-Sonogram through frontal lobes (F) shows orbits (O) located within interhemispheric fissure.



D- Normal sonogram of a neonate demonstrates cerebellar hemispheres(CB) and hyperechoic choroid plexus (asterisks) within lateral ventricles.

E- Sonogram through cerebral convexities reveals normal layers of cortex, which should be seen throughout brain.

Sagittal Planes

The transducer is again positioned in the middle of the anterior fontanelle but now rotated 90° with the marker pointing towards the baby's mid-face. The anterior part of the brain will be projected on the left side of the monitor. First, a good view of the midline is obtained. The transducer is subsequently angled sufficiently to the right and the left to scan out to the Sylvian fissure and insula on both sides. Because the lateral ventricles fan out posteriorly, the transducer should be positioned with the back part slightly more lateral than the front part. The second and fourth parasagittal planes enable visualisation of, respectively, the right and left lateral ventricle over its entire length. The third and fifth parasagittal planes show the insula . While scanning in the sagittal planes, it is important to mark which side of the brain is visualised. This can be done by using the body marker application or by an annotation.

Sagittal And Parasagittal Protocol

Position Of Transducer

To obtain these studies, the transducer is positioned over the anterior fontanelle with the scanning plane following the sagittal suture.

Sagittal studies provide the most extensive visualization of the brain. The straight sagittal study shows the midline structures in the supratentorial and intfratentorial compartments. The straight midline view should be obtained before performing the right and left parasagittal studies. This view is a guide to determine if a parasagittal study corresponds to the right or left side.

The supratentorial structures shown by the sagittal studies aare the corpus callosum, septum pellucidum and the third ventricle. The corpus callosum appears as two thin parallel lines separated by a thin echogenic space. The genu and splenium of the corpus callosum can be identified as the anterior- dorsal and posterior portions, respectively. The cingulated sulcus is found anterior and parallel to the corpus callosum. This is a helpful landmark to identify; as with agenesis of the corpus callosum, it is randomized or spiraled because of the midline defect.

The septum pellucidum appears as an anechoic structure immediately below the corpus callosum. The third ventricle is normally anechoic and is located inferiorly to the septum. The echogenic choroid plexus appears to enter the top ventricle through the foramen of monro. The suproptic recess of the third ventricle is seen as a triangular non echogenic structure extending inferiorly and anteriorly towards the suprasellar region.

In the straight sagittal plane, the infratentorial structures visualized are the cerebellar vermis, the fourth ventricle, the cisternal magna, the supracerebellar and quadrigeminal cisterns, and the brain stem. The vermis of the cerebellum appears as a very echo-dense formation, separated from the occipital bone by an anechoic space that corresponds to the cistern magna.

The other cisterns also are anechoic spaces located above and behind the cerebellar vermis. The fourth ventricle appears as a small "v" with the vertex oriented posteriorly inside the echogenic vermis. The fourth ventricle is limited anteriorly by the brain stem. The brain stem has low echogenicity, with an echo-dense anterior border demarcated by the basilar artery.

Parasagittal Studies:

Position Of Transducer:

After having studied the midline, the transducer is moved / angled slightly to the left and right sides to visualize the cerebellar hemispheres in the parasagittal plane. The cerebellar hemispheres appear as round, low echogenic formations with moderate hyperechoic surfaces. The parasagittal views are obtained by angulating the transducer to the right or left side of the skull.

METHODS:
Four parasagittal studies should be performed.

The first parasagittal image should be close to the midline to visualize the caudate nuclei in detail since subependymal hemorrhages begin in the germinal matrix that is located at the level of these ganglia. These views image the frontal horn and the body of the lateral ventricles, the thalamus, the head of the caudate nucleus and the choroid plexus.

The frontal horns and bodies of the lateral ventricles appear as narrow sonolucent cavities. The height of the bodies of the ventricles normally is less than 7 mm at the level of the mid thalamus. The floor of the lateral ventricles is determined by the boundary between the very echogenic choroid plexus and the less echogenic thalamus. The plexus appear to end at the thalamic-caudate groove, which is the most common location of subependymal hemorrhages.

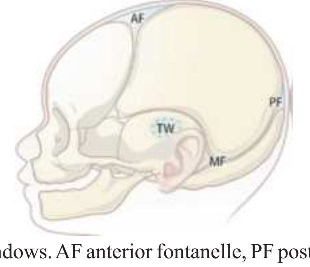
The second parasagittal image is made slightly lateral to the first image and includes the entire ventricular cavity. Since the ventricular cavity is not entirely parallel to the midline, the transducer must be rotated slightly counter clockwise to form an acute angle with the sagittal suture anteriorly.

These views show the entire ventricular horns; the choroid plexus, including the glomus; the thalami; the caudate nuclei; and the white matter superior and anterior to the lateral ventricles.

The third parasagittal view images the white matter located lateral to the lateral ventricles. This view is useful in studying intraparenchymal hemorrhages, porencephaly and periventricular leukomalacia.

A fourth parasagittal view should demonstrate the lateral most aspect, the sylvian fissure, middle cerebral artery and insula.

Supplemental Acoustic Windows
If only the anterior fontanelle is used as an acoustic window, deeper brain structures further away from this fontanelle may not be sufficiently visualised. Lower scan frequencies will enable deeper penetration, but detailed information is lost. Better visualization can be obtained by scanning through acoustic windows that are closer to these structures, thus allowing the use of higher-frequency, high-resolution transducers and visualization from different angles.



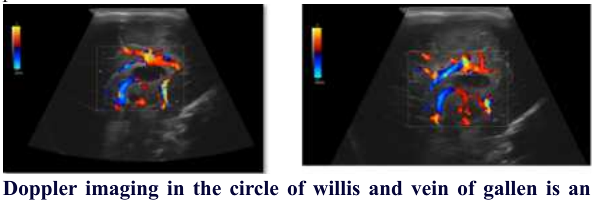
The acoustic windows. AF anterior fontanelle, PF posterior fontanelle, MF mastoid (or posterolateral) fontanelle, TW temporal window.

In order to avoid excessive manipulation of the infant, it is recommended to use only those acoustic windows that are easily accessible (i.e. if the infant is positioned on its left side, only the right-sided windows are used and vice versa). The examination can be continued when the infant is in another position.

Posterior Fontanelle
The posterior fontanelle, located between the parietal and occipital bones , enables a good view of the occipital horns of the lateral ventricles, the occipital and temporal parenchyma and the posterior fossa structures. Using this fontanelle, the posterior fossa can be visualised in the coronal and sagittal planes. The posterior fontanelle is palpated and the transducer placed in the middle of the fontanelle in a horizontal position to obtain a coronal plane and rotated 90° to the vertical position to obtain a sagittal plane. Scanning through the posterior fontanelle enables more accurate detection of hemorrhage in the occipital horns of the lateral ventricles, injury to the occipital and temporal lobes, cerebellar hemorrhage (CBH) and posterior fossa malformations.

Transcranial Doppler Sonography In Neonates
Transcranial Doppler sonography can be performed using the anterior fontanelle as well as additional acoustic windows, depending on the location of the vessels of interest. Good-quality images of vessels can be obtained with the micro CV probe. The high-frequency LA transducer is very useful to visualize superficial vessels at or near the brain's convexity (e.g. the superior sagittal and transverse sinuses). The arterial and venous structures can be screened for patency with color Doppler techniques, typically in the coronal and sagittal planes, respectively. Power Doppler is less often used but may be applied to screen for regions of hyper- or hypo vascularity.

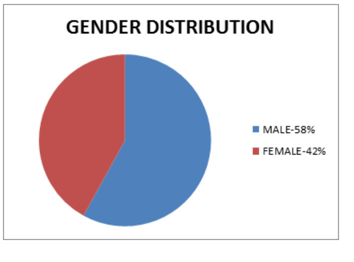
When performing Doppler measurements, it is important that the baby is comfortable, not crying or making maneuvers that might alter flow, especially while venous patterns are assessed, since these may be affected by movements. Doppler measures velocity and not flow. The diameter of the vessels is generally too small to calculate flow. In cerebral arteries, blood flow should always be forward; backflow is abnormal and seen in various clinical conditions. While performing colour Doppler imaging, a colour map depicting movement is superimposed on the grey-scale ultrasound image This color map shows blood flow with directional information. Blood flowing towards the probe is represented by a red signal, while blood flowing away from the probe is represented by a blue signal. Many modern machines also have power Doppler and microvascular imaging techniques. These techniques are more sensitive and will detect smaller vessels but sometimes lack directional information. The most common Doppler index used is the resistance index (RI), defined as: peak systolic velocity end diastolic velocity/ peak systolic velocity. It is important to realize that the RI differs to some degree in arteries of different calibers. Serial measurements are therefore only useful if performed in the same vessel at the same location. For a general measurement, the anterior cerebral artery is preferred as it is easily accessible from the anterior fontanelle with a low angle of intonation and therefore with good reproducibility. Normal RI values range between 0.65 and 0.85. Reference values of indices in different vessels are available for preterm and full-term infants.



Doppler imaging in the circle of willis and vein of gallen is an essential part of imaging

RESULTS
Table: 1
Gender Distribution

MALE	FEMALE
58	42

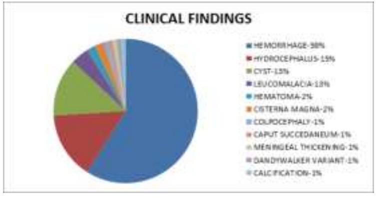


Graph: 1

Table: 2

CLINICAL FINDINGS	NO OF CASES
Hemorrhage	*59*
Hydrocephalus	*15*
Cyst	*13*
Leucomalacia	*4*

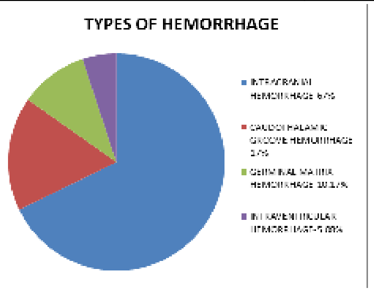
Cisterna Magna	*2*
Hematoma	*2*
Meningeal Thickening	*1*
Calcification	*1*
Colpocephaly	*1*
Dandy Walker Variant	*1*
Caput Succedaneum	*1*



Graph: 2

Table: 2a
Types Of Hemorrhage

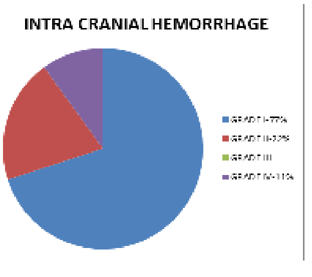
TYPES OF HEMORRHAGE	NO OF CASES
Intracranial hemorrhage	*40*
Caudothalamic groove hemorrhage	*10*
Germinal matrix hemorrhage	*06*
Intraventricular hemorrhage	*03*



Graph: 2a

Table: 2b
Grading Of Intracranial Hemorrhage

INTRA CRANIAL HEMORRHAGE	NO OF CASES
Grade I ICH	*28*
Grade II ICH	*08*
Grade III ICH	*0*
Grade IV ICH	*04*



Graph: 2b

Observations

Subependymal Hemorrhage is one of the most common hemorrhagic lesion in preterm newborn infants. There is an increased risk of subependymal hemorrhage in infants less than 32 weeks of gestational hemorrhage and less than 1500 grams birth weight. These lesions affect 30% to 50% of infants less than 32 weeks of gestational age. Subependymal hemorrhage causes bleeding in the germinal matrix. The most frequent location is at the caudo thalamic groove. If bleeding continues the hemorrhage enlarges pushing the ependyma into the ventricular cavity, which can then become completely occluded by the SHE. Eventually it ruptures through the ependyma into the ventricular cavity forming Intraventricular hemorrhage.

Sonographic Findings

Intraventricular hemorrhage and subependymal hemorrhage are easily detected as echogenic structures since fluid and clotted blood have higher acoustic impedance than the brain parenchyma and the CSF. The acute hemorrhage will appear more echogenic than the chronic hemorrhage. A subependymal hemorrhage is usually seen at the thalamic caudate notch as a very echogenic lesion pushing up the floor and external wall of lateral ventricles with partial obliteration of ventricular cavity.

Intraventricular hemorrhage appears as echogenic structure inside the anechoic ventricular cavities. Depending upon the amount of blood the ventricle can be full and dilated.

Imaging through anterior fontanelle may not detect small Intraventricular hemorrhage since Intraventricular blood tends o settle down in posterior horns. These small IVH can be diagnoses when the occipital horns are visualized in the coronal plane from the mastoid or from the posterior fontanelles. Since the fontanelles are closer to the occipital horns than the anterior fontanelle the occipital horns are within the focal range within the transducer greater amount of ultrasonic energy can reach the sedimented red blood cells.

Periventricular Leukomalacia (PVL), or white matter injury of prematurity affecting the periventricular zones, typically results in cavitation and periventricular cyst formation.

PVL is most common in premature neonates (less than 34 weeks gestational age with a median gestational age of 30 weeks) and <1500 grams at birth.

Sonographic Findings

On ultrasound, hyperechoic areas are firstly identified in a distinctive fashion in the periventricular area, more often at the peri trigonal area and in an area anterior and lateral to the frontal horns (periventricular white matter should be less echogenic than the choroid plexus).

These are watershed areas that are sensitive to ischemic injury. Follow-up scans in the more severely affected patients may reveal the development of cysts in these areas, known as cystic PVL (when cystic PVL is present, it is considered the most predictive sonographic marker for cerebral palsy).

One of the methods used for grading of periventricular leukomalacia based on sonographic appearances is as:

- **Grade 1:** areas of increased periventricular echogenicity without any cyst formation persisting for more than 7 days
- **Grade 2:** the echogenicity has resolved into small periventricular cysts
- **Grade 3:** areas of increased periventricular echogenicity, that develop into extensive periventricular cysts in the occipital and frontoparietal region
- **Grade 4:** areas of increased periventricular echogenicity in the deep white matter developing into extensive subcortical cysts.

Choroid Plexus Cysts (**CPCs**) are cysts that occur within choroid plexus of the brain. They are the most common type of intraventricular cyst. The fluid produced by the cells of the choroid plexus fills the ventricles and then flows around the brain and the spinal cord to provide a cushion of fluid around these structures.

CPCs can form within this structure and come from fluid trapped within this spongy layer of cells, much like a soap bubble or a blister. CPCs are often called "soft signs" or fetal ultrasound "markers" because some studies have found a weak association between CPCs and fetal chromosome abnormalities. The fetal brain may create these cysts as a normal part of development. They are temporary and usually are gone by the 32nd week of pregnancy. **Sonographically,** choroid plexus cysts appear as echo lucent cysts within the echogenic choroid.

Chiari Malformations are a group of defects associated with congenital caudal 'displacement' of the cerebellum and brainstem.

Sonographic Findings

Downward displacement and enlargement of the fourth ventricle, prominent massa intermedia, obliteration of cisterna magna, inferior pointing of anterior horns of lateral ventricles and the interdigitation of the falx cerebri

Dandywalker Malformation (dwm) is the most common posterior fossa malformation, characterized by the triad of:

- hypoplasia of the vermis and cephalad rotation of the vermin remnant

- cystic dilatation of the fourth ventricle extending posteriorly
- enlarged posterior fossa with torcular-lambdoid inversion (the torcula lying above the level of the lambdoid due to abnormally high tentorium).

Sonographic Findings

Antenatal sonographic features that would suggest the diagnosis include the combination of:

- marked enlargement of the cisterna magna (≥10 mm)
- complete aplasia of the vermis
- a trapezoid-shaped gap between the cerebellar hemispheres

Antenatal ultrasound may falsely over diagnose the condition if performed before 18 weeks, as the vermis has not properly formed.

Hydrocephalus is the buildup of fluid in the cavities (ventricles) deep within the brain. The excess fluid increases the size of the ventricles and puts pressure on the brain. Cerebrospinal fluid normally flows through the ventricles and bathes the brain and spinal column. But the pressure of too much cerebrospinal fluid associated with hydrocephalus can damage brain tissues and cause a range of impairments in brain function. Hydrocephalus present at birth (congenital) or shortly after birth may occur because of any of the following:

- Abnormal development of the central nervous system that can obstruct the flow of cerebrospinal fluid
- Bleeding within the ventricles, a possible complication of premature birth
- Infection in the uterus during a pregnancy, such as rubella or syphilis, that can cause inflammation in fetal brain tissues.

There are two types of hydrocephalus:

- Communicating hydrocephalus is the build-up of pressure from too much CSF that is not being properly absorbed.
- Non-communicating hydrocephalus is the build-up of pressure from CSF when a blockage occurs within the brain.

Sonographic Findings

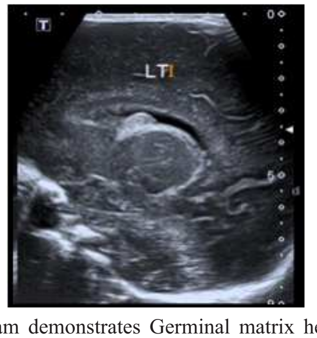
- Hydrocephalus presents an anechoic appearance on ultrasound
- Dilatation of the Posterior Horn of the Lateral Ventricle
- Compression and thinning of the choroid plexus due to the increased CSF pressure.
- Displacement of medial and lateral walls of lateral ventricles

Representative Cases

Case 1

Germinal Matrix Hemorrhage

2-month-old male infant with H/O developmental delay and transient tachypnea.



Sagittal sonogram demonstrates Germinal matrix hemorrhage in a preterm infant.

Case: 2

Leucomalacia

6 week old premature girl with H/O respiratory distress

Coronal sonogram in a 6 week old premature girl identifies periventricular hypercechogenecity.

Case: 3

Hydrocephalus

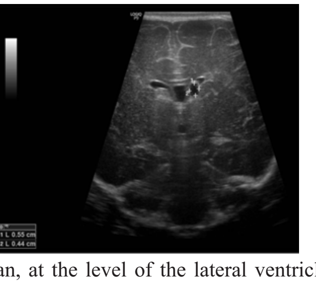
1 day old preterm male with H/O low birth weight and secondary apnea

Coronal CUS scan, at the level of the bodies of the lateral ventricles, performed through the AF with a CV probe in a preterm infant with severe post hemorrhagic ventricular dilatation

Case: 4

Choroidplexus Cyst

3 day old female infant with H/O congenital rubella syndrome.

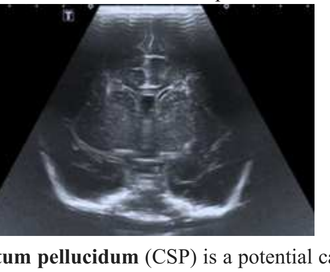


Coronal CUS scan, at the level of the lateral ventricles, performed through the AF in a 3 day old female infant, shows a choroid plexus cyst

Case: 5

Cavum Septum Pellucidum

1 day old male infant with H/O fever and sepsis



The **cavum septum pellucidum** (CSP) is a potential cavity between the membranous leaves of the **septum pellucidum**, separated by at least 1 mm, and is considered a normal anatomical variation

DISCUSSION

Serial cranial ultrasound examinations were performed in our institution during early hospitalization for premature infants, and often follow-up examinations were done at a later age. These examinations are done to evaluate the presence of intracranial hemorrhage to choose the ideal treatment plan that may exacerbate the risk of further hemorrhage, and to counsel families about neurodevelopment outcomes.

Review of few literature and published articles have emphasized that a significant correlation exists between the degree of prematurity and the increased risk of intracranial hemorrhage. The incidence of ICH is related to both gestational age and birth weight.

Daneman et.al proved that cranial ultrasound remains an extremely useful modality for the evaluation of the full-term neonatal brain. This retrospective study aims at proving the same.

De Vries and Cowan et.al have suggested that neurosonogram and MRI are complementary to eachother, with cranial ultrasound as an especially useful tool in the early stages when the infant is unstable for transport and ultrasound may be sufficient for major clinical decisions.

Dinakara Prithiviraj, et.al reported that majority of the cases were preterm infants, and this was also true with this study.

This study shows intracranial hemorrhage in 59 cases of which 47% were preterm neonates and 19 % were of gestational age less than 34 weeks. These findings reflect the findings of study done by Humsene, et.al, Choudhary V, et.al and Niranjan Nagaraj, et.al. Common causes of neonates who were referred for neurosonogram examinations were preterm cases, respiratory distress, birth asphyxia, hyperbilirubinemia, sepsis and seizures.

Hemorrhage was the commonest abnormality observed in the present study, in which majority of the cases were preterm infants. Of these grades I hemorrhage was the most common manifestation. Hydrocephalus was the next common pathology observed. Periventricular leukomalacia was evident in few preterm babies and in babies with history of Hypoxic ischemic injury. Choroid plexus cysts were seen in few preterm cases and neonates with history of respiratory distress and cases with low birth weight. Other findings in this study included prominent cistern magna, colpocephaly, dandy walker variant and meningeal thickening.

This study highlights the conducive and diagnostic efficiency of cranial ultrasound in high risk neonates in NICU. Neurosonogram is the baseline modality for examining the newborn brain, keeping in mind the low invasiveness as well as easily available ultrasound that can be repeated at any time. It provides valuable information that influences the neuro developmental outcome. Cranial ultrasound is efficient in detecting brain damage at the earliest to facilitate clinical decisions and prognosis. The cranial ultrasound findings play a crucial role in planning rehabilitation strategies for the management of critically ill newborn infants.

Advantages of neurosonogram are that it can be easily performed bedside, no radiation exposure risk, can be repeated whenever needed, enabling visualization of ongoing brain maturation and the evolution of lesions. Most important can be performed without sedation and it is cost effective as well.

This study was done in a tertiary care hospital. This study recommends that cranial ultrasound should be mandatory in screening all neonates who are at high risk. point of care ultrasound is effective in diagnosis, management as well as prediction of many short- and long-term outcomes which is useful for patient counseling and early interventions.

This study had limitation like follow up studies of these neonates was not possible which is actually necessary to assess the neurological outcome of babies with both normal and abnormal cranial ultrasound findings.

CONCLUSION

This retrospective study concludes that neurosonogram is an important radiological investigation in assessing neonatal brain and it effectively captures morphology of brain damage, enabling early intervention and treatment, and may improve clinical outcomes.

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