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Role of Trans-Cranial Ultrasound in Correlation with MRI in Diagnosis of Neonatal Encephalopathy

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ABSTRACT

Background: Neonatal encephalopathy poses significant morbidity and mortality risks in newborns, necessitating early and accurate diagnoses to enhance outcomes. While trans-cranial ultrasound [TCUS] has gained attention as a non-invasive imaging technique, its efficacy compared to magnetic resonance imaging [MRI] for diagnosing neonatal encephalopathy is still uncertain.

Objective: This study aimed to assess the correlation between TCUS and MRI as diagnostic tools for neonatal brain encephalopathy in both term and preterm infants, focusing on their ability to identify various types of brain injuries.

Patients and Methods: Fifty neonates diagnosed with encephalopathy participated in this prospective study. Each infant underwent TCUS and MRI within 48 hours of clinical evaluation. Imaging results were analyzed in relation to clinical outcomes and categorized based on established criteria for neonatal brain injury. TCUS's sensitivity and specificity were calculated against MRI results, which acted as the gold standard.

Results: TCUS showed higher sensitivity than MRI for detecting lesions in key areas, such as the thalamus [81.8%], basal ganglia [80.0%], and periventricular white matter [92.1%]. However, its sensitivity was lower for lesions in the corpus callosum [75.0%] and cerebellar white matter [33.3%]. TCUS maintained high specificity [100.0%] for most lesions, particularly for periventricular and subcortical white matter. Both imaging techniques accurately identified all cases of germinal matrix hemorrhage.

Conclusion: TCUS serves as an effective first-line imaging tool for diagnosing neonatal encephalopathy, offering prompt results with high sensitivity and specificity. Nonetheless, MRI remains essential for comprehensive assessments, especially in complex cases, advocating for the combined use of TCUS and MRI in clinical practice to improve neonatal management

Keywords: Newborn; Encephalopathy; Magnetic Resonance Imaging; Ultrasound.

INTRODUCTION

Neonatal encephalopathy [NE] remains a significant contributor to neonatal mortality and morbidity. It refers to any diffuse brain disease that impacts brain function or structure [1].

Various imaging techniques have been evaluated for their effectiveness in detecting brain injuries, including Transcranial Ultra-sonography [TCUS], Computed Tomography [CT], and Magnetic Resonance Imaging [MRI] [2].

The application of MRI in assessing the developing brain is well established. It has demonstrated its value as a highly effective method for evaluating fetal and neonatal neurological conditions, thanks to its unparalleled sensitivity and superior tissue contrast [3].

MRI provided enhanced anatomical detail and greater sensitivity for detecting white matter lesions, consistently revealing abnormalities that were not identified by prenatal ultrasound, including cortical mal-formations, heterotopias, and posterior fossa abnormalities [4].

However, MRI is expensive, not portable, and time-consuming, which limits its use in non-academic centers, low-income countries, and for critically ill patients who cannot be safely transported [5].

Cranial ultrasound has developed rapidly since the 1980s. It has become a potent and cost-effective supplemental tool compared to MRI. Ultrasonography [US] is readily accessible, can be conducted at the bedside without the need for sedation, and can be repeated as frequently as needed. It has no side effects, and when carried out by a skilled sonographer using advanced equipment, it offers extensive anatomical and functional information [6].

Advancements in ultrasound technology, including various acoustic windows and timed sequential scanning, have led to high-quality imaging that enhances the identification of features indicative of developmental, metabolic, and infectious disorders. This technology effectively detects most hemorrhagic, ischemic, and cystic brain lesions, as well as calcifications, cerebral infections, and significant structural abnormalities in high-risk infants [7].

MRI has become a valuable complement to transcranial ultrasound in assessing neonates, particularly those who are preterm or have very low birth weight [8].

THE AIM OF THE WORK

The current study was designed to evaluate the correlation between trans-cranial ultrasound and magnetic resonance imaging [MRI] as a diagnostic tool for diagnosis of neonatal brain encephalopathy including the term and preterm infants and their ability to diagnosis of different types of brain encephalopathy.

PATIENTS AND METHODS

This study was performed between July 2021 and March 2022. It was completed at the department of Radiology, Al-Azhar University Hospital [New Damietta]. It included 50 neonates [12 males and 38 females]. Their ages ranged between one and 60 days.

Patients were referred from the Neonatology Intensive Care Unit at Damietta Al-Azhar University Hospital, after fulfilling inclusion and exclusion criteria, obtaining due clearance from ethics committee.

The inclusion criteria encompassed neonates, both term and preterm, who were clinically diagnosed with brain injury, regardless of gender. The diagnosis of neonatal encephalopathy was established according to the guidelines set by the American College of Obstetricians and Gynecologists and the American Academy of Pediatrics [ACOG-AAP] task force.

Conversely, the exclusion criteria included any contraindications to MRI examinations or the use of contrast agents, as well as neonates who were critically ill with unstable vital signs. Additionally, neonates whose guardians were unwilling to provide valid and informed consent for participation in the study were also excluded.

Ethical Considerations:

The study received approval from the local ethics committee at our institution, and informed consent was obtained from the parents of all newborns prior to the start of the study.

All neonates underwent a comprehensive history taking from their parents, a review of any prior radiological examinations, a clinical examination conducted by the referring physician, and laboratory tests [such as serum creatinine levels].

Additionally, all patients underwent transcranial ultrasound imaging using GE Voluson E6 and GE VIVID T8 ultrasound machines with various transducers, including Micro-convex [8 MHz], Superficial [7–10 MHz], and High-frequency phased array [5–8 MHz].

Brain imaging was also performed using MRI with a Philips Medical Systems [Achieva 1.5 Tesla scanner - XR-Best, Netherlands 2010] and a standard head coil.

Transcranial ultrasounds were conducted in the NICU without sedation, utilizing multiple acoustic windows to visualize as much of the brain's central and peripheral structures as possible.

This was achieved by using the anterior and posterior fontanels, as well as views from the temporal, mastoid, and occipital regions.

A superficial transducer frequency was employed to detect cortical and/or subcortical abnormalities.

Conventional MRI scans were performed using axial and sagittal T1-weighted non contrast spin echo sequences. Subsequently, axial FLAIR and axial and coronal T2-weighted fast spin-echo images were acquired.

Statistical analysis was performed by the statistical package for social sciences [SPSS] version 20 [IBM®SPSS, Inc. Chicago, USA.

RESULTS

Fifty neonates were included in this study, with ages ranging from 1 to 60 days, consisting of 12 males [22.0%] and 38 females [78.0%].

High-quality MRI and TCUS examinations were conducted for all participants. These examinations were divided into two groups: ischemic and non-ischemic. Out of the 50 patients, 41 [82.0%] exhibited ischemic changes, while the remaining 9 cases showed non-ischemic lesions based on clinical and radiological follow-up results, as detailed in [Table 1].

All neonates examined displayed a range of clinical symptoms indicative of neonatal encephalopathy, including altered levels of consciousness, low Apgar scores, seizures, muscle tone abnormalities ranging from mild hypotonia to flaccidity, loss of complex reflexes such as the Moro and suck reflexes, vomiting, and abnormal pupillary reflexes, as shown in [Figure 1]. MRI examinations yielded positive results in 46 out of 50 neonates, while 4 cases were negative. TCUS was considered positive in 47 of the 50 neonates, with the remaining 3 showing negative results [Table 2] .

Table [1]: The variety of the studied lesions

Diagnosis	Frequency	Percent
Hypoxic Ischemic leukoencephalopathy	41	82.0%
Germinal matrix hemorrhage	2	4.0%
Intraventricular hemorrhage	1	2.0%
Encephalitis	2	4.0%
Arachnoid cyst	1	2.0%
Hydrocephalus	3	6.0%
Total	50	100.0%

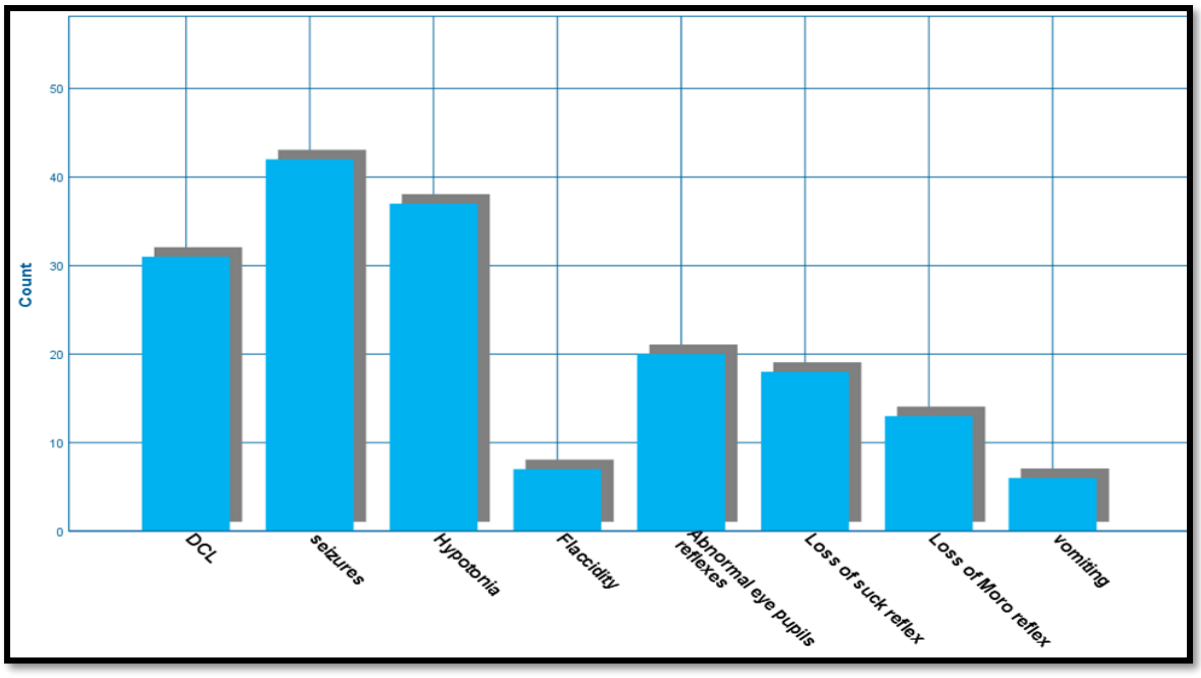
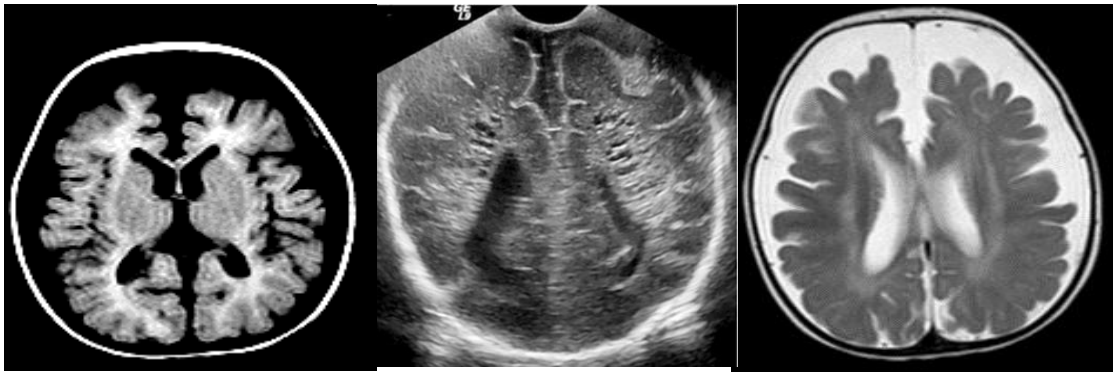


Figure [1]: Distribution of patient's clinical presentation

Table [2]: Correlation of TCUS findings with Brain MRI results in our cohort of 38 patients

Variable	Positive MRI	Negative MRI	Total
Positive TCUS	44	3	47
Negative TCUS	2	1	3
Total	46	4	50



[A] [B] [C]

Figure [2]: A case of periventricular hypoxic ischemic leukoencephalopathy of Female neonate 48-day old presented clinically by seizures and abnormal eye movements, with subsequent hypotonia. A Coronal Views [Anterior Fontanelle]: there is evidence of periventricular cystic changes within echogenic white matter, with mild ventricular dilatation, which is consistent with periventricular leukomalacia. B Axial T2 & FLAIR WIs: show diffuse cerebral atrophic changes with widening of ventricular system in additional to bands of hyperintense signals in periventricular white matter

DISCUSSION

Recognizing neonates who are at risk for developing moderate to severe encephalopathy early is crucial for initiating the appropriate supportive care and improving prognosis [9]. Neuroimaging techniques play a vital role in detecting and characterizing brain injuries. Transcranial ultrasound [TCUS] is a safe, cost-effective, and bedside method that allows for both early and repeated evaluations of brain development and the progression of lesions. By using the fontanelle as a window, TCUS is also effective for screening and follow-up assessments. For those who survive a cerebral injury, this approach helps optimize treatment during the neonatal period and beyond [10].

MRI imaging provides superior visualization of soft tissues and is a well-established tool for assessing the timing, severity, and extent of neonatal brain injury. It also plays a crucial role in predicting neurological outcomes [11].

The current study found that TCUS diagnosed all cases of germinal matrix hemorrhage and demonstrated superior sensitivity compared to MRI for lesions in the thalamus [81.8%], basal ganglia [80.0%], and peri-ventricular white matter [92.1%]. However, TCUS had lower sensitivities for lesions in the corpus callosum [75.0%], cerebellar white matter [33.3%], cerebral cortex [33.3%], and subcortical white matter [50.0%]. TCUS showed high specificity [100.0%] for most lesions, except for certain types, which had lower values.

Genedi *et al*. [12] concluded in their study that transcranial ultrasound [TCUS] demonstrated relatively higher sensitivities for detecting lesions in the basal ganglia [81.2%] and thalamus [88.2%]. This finding is consistent with our study, which reported TCUS sensitivity for germinal matrix hemorrhage at 100.0%, for lesions in the subcortical white matter at 50.0%, and for lesions in the cortex at 28.6% and corpus callosum at 37.5%.

Our findings align with those of **Karoor *et al*.** [13] who determined that transcranial ultrasound [TCUS] is more effective at identifying central abnormalities compared to peripheral lesions. TCUS serves as a valuable screening tool and provides a more convenient option for patient follow-up in acute and critical care settings. However, it may not identify as many lesions as magnetic resonance imaging [MRI] [14], which can lead to a significant underestimation of injury severity. MRI remains the gold standard for imaging the infant brain [15], and TCUS is essential for most neonates suspected of having parenchymal brain injury or neurological symptoms [16].

MRI is a crucial and definitive assessment method due to its superior sensitivity and ability to differentiate pathologies. Diffusion-weighted imaging [DWI] [17] often detects ischemic brain injury earlier than conventional MRI techniques [18].

In our study, MRI identified the etiology of neonatal encephalopathy [NE] in our patient cohort, revealing 41 cases consistent with hypoxic-ischemic encephalopathy [HIE], with TCUS corroborating MRI findings in 39 cases. DWI was the only positive sequence that indicated mild to moderate HIE patterns, whereas the other conventional MRI sequences and TCUS were negative.

Hypoxic-ischemic encephalopathy [HIE] is the most commonly encountered pathology, allowing us to categorize the types of brain lesions into two groups: ischemic lesions [88%] and non-ischemic lesions [12.0%]. Additionally, both MRI and TCUS accurately diagnose all cases of germinal matrix hemorrhage in our study. Cranial sonography is crucial for the initial assessment of infants suspected to have encephalitis and for tracking any potential complications related to the disease. MRI can provide valuable insights into the

neurological impacts of brain injuries in encephalopathic neonates. Therefore, we recommend that the optimal radiodiagnostic protocol for neonatal encephalopathy [NE] includes a combination of both transcranial ultrasound [TCUS] and magnetic resonance [MR] imaging.

We encountered several limitations during this study. Firstly, working with critically ill neonates posed challenges, particularly in terms of transporting them from the neonatal intensive care unit [NICU] to the MRI facility. This required specialized transport equipment and trained personnel to provide continuous clinical care during the MRI scan. Secondly, the relatively small sample size in our study was due to difficulties in obtaining concurrent MRI and TCUS studies for many patients. This was often the result of rapid deterioration and death or complications during transfer to the MRI scanner related to their unstable medical conditions or issues with the transport equipment.

Conclusion: TCUS is an initial & important screening tool in the diagnosis of neonatal encephalopathy in the neonates with the suspected brain injury; whose examination with MRI & sedation is very difficult. However, early MRI compared with TCUS is valuable manner to detect the cause & extent of brain injury more than one method alone.

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