Accuracy of transcranial ultrasound and color duplex in diagnosis of neonatal brain pathologies

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Abstract

The aim of the study: was to document the value of transcranial ultrasound and color duplex in detection of abnormalities in neonatal brain. This is cross sectional study was performed on 40 patients in neonates group with neurological sign or suspected sign for neurological lesion. All cases had cranial ultrasound. Our study was conducted from May 2016 to March 2017, in the Department of Radiodiagnosis, at Beni Suef university hospital; Patients were all selected from Benisuef university hospital; either picked up from the outpatient clinics or from the inpatient wards of neonatology unit and ICU unit. All the studied cases were subjected to: full history taking, full clinical Examination, investigations and transcranial ultrasound examination. This study showed that the Ultra-sound diagnosed 10 (25%) with normal brain and 30 (75%) with abnormal CUS findings. Among the abnormal CUS findings, 5(16.6%) with congenital abnormalities, 25(83.4%) with acquired lesions.

Keywords: Trans cranial ultrasound, trans cranial doppler.
Introduction

The fetal or preterm infant’s brain is vulnerable to both hemorrhagic and ischemic injuries during the late second and early third trimesters. This is due to vascular, cellular and anatomical features of the developing brain, and the tendency for preterm infants to experience periods of physiological instability at a time when they have limited cerebral circulatory auto regulation (1).

Several problems are associated with imaging of critically ill neonates. These include the choice of imaging technique, the timing of the imaging study, and transporting acutely ill neonates, many of whom require ventilator assistance and multiple indwelling catheters. As a result, there is a great need to a reliable tool for detecting congenital and acquired anomalies of the perinatal brain and the most frequently occurring patterns of brain injury in both preterm and full-term neonates (2).

Patients and Methods

This is cross sectional study was performed on 40 patients in neonates group with neurological sign or suspected sign for neurological lesion. All cases had cranial ultrasound.

Inclusion criteria

Full term or preterm infants clinically presented with neurological signs e.g. (convulsions, enlarged head, pathological jaundice, trauma, Obstructed labor, bleeding...)

Cranial ultrasonography (CUS) was introduced into neonatology in the late 1970s and has become an essential diagnostic tool in modern neonatology. The non-invasive nature of ultrasonography makes it an ideal imaging technique in the neonates. The fontanels and many sutures of the skull are still open, and these can be used as acoustic windows to “look” into the brain (3). Trans Cranial Doppler (TCD), first described in 1982, is a noninvasive ultrasound...
Device: All patients were examined using xario200 ultrasound device (TOSHIBA health care) that is equipped by convex probe, linear probe and microconvex probe.

Technique of examination

A. Transcranial Ultrasonography

Patient position: The patient lies supine with lateral tilting of his head to either side during most of the examination except scanning through the foramen magnum during which the patient is sitting with slight flexion of his head forwards.

Anterior fontanel: The anterior fontanel was used as the principal acoustic window using convex probe, and the scanning procedures included:

- Six standard coronal planes frontal lobes, frontal horns of the lateral Ventricles, foramen of Monro and the third ventricle, body of the lateral Ventricles, trigon of the lateral ventricle, and occipital lobes.
- Five standard Sagittal planes mid sagittal plane, left and right Parasagittal planes through lateral ventricles, right and left parasagittal Planes.

Temporal Window: Scanning through this approach was mainly used for transcranial Doppler examination of the middle cerebral artery in some cases and more clear view of the temporal lobe.

Posterolateral (mastoid) fontanel: Images of the posterior fossa were obtained through the posterolateral fontanels. The convex transducer was placed over the posterolateral fontanels. The transducer was then rotated.

tendency, multiple congenital anomalies, respiratory distress, physiological jaundice, persistent vomiting.

Exclusion criteria 2.2

Full term or preterm infant with no neurological sign or symptoms.

Still birth.

Patients were subjected to the following:

Clinical assessment

- Gestational age, weeks (mean _ SD)
- Body weight, g
- Length at birth, cm
- Head circumference at birth, cm
- Premature rupture of membranes
- Mode of delivery: normal vaginal delivery/cesarean section
- Gender
- Antenatal steroids given for mother
- Vitamin K given for infant
- Resuscitated at birth (bag/mask or Neopuff)
- Intubated at birth
- Initial diagnosis of perinatal asphyxia
- Respiratory distress/congenital pneumonia
- Infants treated only with Continuous
- positive air way pressure (CPAP)
- Infants need to mechanical ventilation
- Received blood transfusion
- Vital signs (pulse & respiratory rate)

Imaging investigations

All patients were subjected to Transcranial ultrasound examination.

Methods: All sonographic examinations were performed at department of radio diagnosis at Beni Suef university hospital.
RI during the first year of life. After fontanelle closure, the mean RI decreases to between 0.50 and 0.60 (6).

**Statistical methodology**

- Analysis of data was done by IBM computer using SPSS (statistical program for social science) as follows;
  - Description of quantitative variables as mean, SD and range.
  - Description of qualitative variables as number and percentage.
  - Unpaired t-test was used to compare quantitative variables, in parametric data (SD < 50 % mean)
    - P value > 0.05 insignificant
    - P < 0.05 significant
    - P < 0.01 highly significant [20].

Posterior Fontanel: The posterior fontanel was palpated and the convex transducer placed in the middle of the fontanel, with the marker in the horizontal position to obtain a coronal plane and in the vertical position to obtain a sagittal plane. Scanning through the posterior fontanel was of a high value mainly in assessing the posterior fossa in newborn patients with meningo-myelocele and suspected to have Chiari malformation.

**B. Transcranial Doppler Examination**

Transcranial color coded Doppler was especially applied to assess vascular lesions in all examined patients. By scanning through the anterior fontanel to image, flow in the circle of Willis in both coronal and sagittal scans using convex probe. The MCA can be assessed in its echogenic fissure in the axial plane through temporal approach using linear probe. RI was calculated for MCA&ACA.

Resistance index (RI) is peak systolic flow velocity (PSV) minus end diastolic velocity (EDV) divided by (PSV). The overall mean RI of the major intracranial vessels namely ICA, ACA and MCA in normal term neonates is 0.726. There is a known downward trend of the
Results

Table (1) showed that a total number of 40 neonates under the study with minimum age 30 weeks and maximum 40 weeks with mean age 37.65 weeks, minimum birth weight 1100 grams and maximum 3500 grams with mean 2847.50. Minimum Length at Birth (cm) and Head circumference at Birth (cm) of (44cm, 33cm) and maximum of (52cm, 55cm) with mean 48.25 and 39.05 respectively.

**Table (1):** Description of Gestational Age, Birth Weight, Length and Head Circumference at Birth and time of examination of Neonates under the Study:

| Parameter                  | N  | Min  | Max  | Mean       | Std. Dev |
|----------------------------|----|------|------|------------|----------|
| Gestational Age (w)        | 40 | 30.00| 40.00| 37.650     | 1.889    |
| Birth Weight (gm)          | 40 | 1100 | 3500 | 2847.50    | 540.056  |
| Length at Birth (cm)       | 40 | 44.00| 52.00| 48.25      | 2.509    |
| Head circumference at Birth (cm) | 40 | 33.00| 55.00| 39.05      | 6.341    |
| Time of examination (day)  | 40 | 2.00 | 27.00| 15.48      | 7.547    |

Figure (1): shows sex distribution among neonates under the study.

Table (2) showed mothers under the study that were free of diseases 17 (42.5%) while 6(15%), 7 (17.5%), 6(15%), 2 (5%) and 2 (5%) were suffering from DM, pre-eclampsia, HTN, heart diseases and rheumatic diseases, respectively.

**Table (2):** Characteristics of mothers under the study:

| Characteristic                        | Number | Percent |
|---------------------------------------|--------|---------|
| Medical co-morbidities of mothers:    |        |         |
| No morbidity                          | 17     | 42.5%   |
| DM                                    | 6      | 15%     |
| HTN                                   | 7      | 17.5%   |
| Pre-eclampsia                         | 6      | 15%     |
Table (3) shows that there is a significant association between mother comorbidity and positive cranial ultrasound findings. The P value equals 0.0405 <0.05.

**Table (3): Relation between presence of mother comorbidity & cranial ultrasound findings:**

| Presence of mother co morbidity | Normal CUS | Abnormal CUS | Total | P value |
|---------------------------------|------------|-------------|-------|---------|
| Normal mother                   | 7 (17.5%)  | 10 (25%)    | 17 (42.5%) | 0.0405 |
| Co morbidity                    | 3 (7.5%)   | 20 (50%)    | 23 (57.5%) |
| Total                           | 10 (25%)   | 31 (75%)    | 40 (100%)  |

Table (4) reveals that the majority of the studied group (75%) has abnormal US findings. While (25 %) with normal US findings.

**Table (4): Percentage distribution of the studied group regarding US Findings:**

| US findings | No (40) | Percent (100.0%) |
|-------------|---------|------------------|
| Normal      | 10      | 25.00%           |
| Abnormal    | 30      | 75.00%           |

**Table (5): The number of patients with each type of the brain lesion:**

| Group        | No. of patients |
|--------------|-----------------|
| Congenital   | 5               |
| acquired     | 25              |

**Table (6): Findings in Ultrasound (congenital lesion):**

| Congenital lesions       | No. of patients | Percentage in relation to total studied neonates |
|--------------------------|-----------------|-------------------------------------------------|
| Dandy Walker             | 1               | 2.5%                                            |
| Chiari malformation      | 1               | 2.5%                                            |
| Germinal matrix cyst     | 1               | 2.5%                                            |
| Arachnoid cyst           | 1               | 2.5%                                            |
| Cavum septum pellucidum  | 1               | 2.5%                                            |

**Table (7): Finding in Ultrasound (Acquired lesion):**

| U.S. Findings                        | No. of patients | Percentage in relation to total studied neonates |
|--------------------------------------|-----------------|-------------------------------------------------|
| Hypoxic ischemic encephalopathy (HIE)| 10              | 25%                                              |
| IVH grade I                          | 3               | 7.5%                                             |
| IVH grade III                        | 1               | 2.5%                                             |
Table (8): Percentage distribution of the studied group according to mode of delivery:

| Mode of delivery | No(40) | Percentage |
|------------------|--------|------------|
| NVD              | 8      | 20%        |
| CS               | 32     | 80%        |

Table (8) shows that majority of the studied group (80%) were delivered by cesarean section.

Table (9): Relation between Mode of delivery between normal & abnormal ultra-sound findings:

| Mode of delivery | Normal CUS | Abnormal CUS | Total |
|------------------|------------|--------------|-------|
| NVD              | 5(12.5%)   | 3(7.5%)      | 8(20%)|
| CS               | 5(12.5%)   | 27(67.5%)    | 32(80%)|
| Total            | 10(25%)    | 30(75%)      | 40(100%)|

This table reveals that among those neonates delivered by CS, there is more percentage of abnormal US findings (67.5%) vs (12.5%). While among neonates that delivered by NVD there is more percentage of normal US findings (12.5%) vs (7.5%).

Table (10): Distribution of ultrasound findings within the abnormal studied group according to the maturity of the neonates:

| US findings           | Preterm neonates | Full term neonates |
|-----------------------|------------------|--------------------|
| IVH Grade I           | 3(7.5%)          | 0(0.0)%            |
| IVH Grade III         | 1(2.5%)          | 0(0.0)%            |
| Subdural hemorrhage   | 0(0.0)%          | 1(2.5)%            |
| Intracerebral hematoma| 0(0.0)%          | 1(2.5)%            |
| PVL                   | 1(2.5%)          | 0(0.0)%            |
| HIE                   | 0(0.0)%          | 10(25%)            |
| Hydrocephalus         | 0(0.0)%          | 8(20%)             |
| Congenital lesions    | 0(0.0)%          | 5(12.5%)           |

This table illustrates that all cases of IVH grade I (3 cases)(7.5%), all cases of IVH grade III (1 case)(2.5%) & all cases of PVL (1 case)(2.5%) were found in preterm neonates. While all cases of HIE(10 cases)(25%), all cases of hydrocephalus (8 cases)(20%), all cases of intracerebral hematoma (1 case)(2.5%), all cases of subdural hemorrhage(1 case)(2.5%) & all cases with congenital lesions (5 cases) (12.5%) were found in full term neonates.

Table (11): Frequency of trans-cranial Doppler diagnosis among neonates under the study:

| RI          | Number | Percent |
|-------------|--------|---------|
| Normal      | 26     | 65%     |
| Decreased RI| 6      | 15%     |
| Increased RI| 8      | 20%     |
Table (11) showed that 26 (65%) from the total 40 case were of normal RI, 6 (15%) were decreased RI & 8 (20%) were increased RI.

**Table (12):** Relation between trans-cranial Doppler and diagnosis by Ultra-Sound:

| U.S diagnosis                  | Normal RI  | Increased RI | Decreased RI | Total |
|--------------------------------|------------|--------------|--------------|-------|
| Normal                         | 10(25%)    | 0(0.0%)      | 0(0.0%)      | 10(25%) |
| HIE                            | 2(5%)      | 2(5%)        | 6(15%)       | 10(25%) |
| Hydrocephalus                  | 2(5%)      | 6(15%)       | 0(0.0%)      | 8(20%) |
| Intracranial hemorrhage        | 6(15%)     | 0(0.0%)      | 0(0.0%)      | 6(15%) |
| Congenital lesions             | 5(12.5%)   | 0(0.0%)      | 0(0.0%)      | 5(12.5%) |

**Table (13):** Relation between Doppler findings in normal patients and abnormal patients.

|                  | Normal patient | Abnormal patient | Total  | P value |
|------------------|----------------|------------------|--------|---------|
| Normal Doppler   | 10(25%)        | 16(40%)          | 26(65%)| 0.0216  |
| Abnormal Doppler | 0(0.0%)        | 14(35%)          | 14(35%)|         |
| Total            | 10(25%)        | 30(75%)          | 40(100%)|         |

The P value equals 0.0216. The association between rows (groups) and columns (outcomes) is considered to be statistically significant.

**Table (14):** Relation between Doppler findings in normal cases and acquired lesions:

|                  | Normal patient | acquired lesions | Total  | P value |
|------------------|----------------|------------------|--------|---------|
| Normal doppler   | 10(25%)        | 11(27.5%)        | 21(52.5%)| 0.0038  |
| Abnormal doppler | 0(0.0%)        | 14(35%)          | 14(35%)|         |
| Total            | 10(25%)        | 25(62.5%)        | 35(87.5%)|         |

The association between normal and abnormal Doppler in normal neonates and neonates with acquired lesions is considered statistically significant. P value equals 0.0038.
Discussion

Cranial ultrasound is considered the most available and easily repeatable technique for imaging the neonatal brain in both the preterm and full term infants. Its diagnostic accuracy depend on various factors; the suitability of the ultrasound machine for neonatal cranial work, the use of optimal settings and probes, appropriate scanning protocols, the use of a variety of acoustic windows, the scanning experience of the examiner. Besides, not least, knowledge of normal anatomy and the echogenicities of different tissues in normal and pathological situations (7).

We designed a cross sectional study on 40 patients in neonates group with definite or suspected neurological lesion based on clinical examination. All cases had cranial ultrasound. We divided our patients into two groups according to CUS diagnosis: normal CUS group and abnormal CUS group. The purpose of this study is to document the value of neonatal transcranial ultrasound and transcranial Doppler as a method of diagnosis of brain pathologies such as hemorrhagic, ischemic & congenital anomaly events in neonates.

This study showed that the Ultra-sound diagnosed 10 (25%) with normal brain and 30 (75%) with abnormal CUS findings. Among the abnormal CUS findings, 5 (16.6%) with congenital abnormalities, 25 (83.3%) with acquired lesions. So, we divided the abnormal group into two subgroups: Subgroup (A) includes the congenital lesion cases: Dandy Walker (2.5%), Chiari malformation (2.5%), germinal matrix cyst (2.5%), arachnoid cyst (2.5%), cavum septum pellucidum (2.5%). Subgroup (B) include the acquired lesion cases: Hypoxic ischemic encephalopathy (HIE) 10 patients (25%), IVH grade I 3 patients (7.5%), IVH grade III one patient (2.5%), subdural hemorrhage one patient (2.5%), intracerebral hemorrhage one patient (2.5%), PVL one patient (2.5%), Hydrocephalus 8 patients (27.5%).

In a study conducted by Ziaul and his colleagues (8) upon 103 preterm neonates, 56 (54.3%) had normal CUS findings and 47 (45.63%) had abnormal CUS findings. Among the abnormal CUS findings, 22 (21.4%) had cerebral edema, 17 (16.5%) had IVH and 8 (7.8%) had ventricular dilatation. This difference arises because they studied only premature neonates as they are high-risk group for intracranial lesions but we studied premature and full term neonates with clinical signs of neurological disorders because we thought that there are many cases with intracranial lesions in full term as preterm neonates.

Neonatal intracranial hemorrhagic and hypoxic lesions can be divided as those
This result coincide with the study of Malloy (12) who stated that among infants delivered at 32 to 36 weeks gestation, an increased risk for neonatal mortality and morbidity exists among those delivered by primary cesarean section compared with vaginal delivery. The mechanism by which the cesarean section increases the risk for neonatal mortality is not clear, but the particular morbidities examined suggest that the mechanism, at least for the morbidities, may be related to the impact of cesarean section on respiratory adaptation. This result may contradict the study conducted by Elisa and her coworkers (13) who stated that there was no significant association between abnormal cranial ultrasonography and the mode of delivery. The study of Henrietta and his workmates (14) stated that Doppler flow measurements may help to distinguish between vascular structures and non-vascular lesions and CCD can be applied to study cerebral hemodynamics through assessing the major intracranial arteries as well as the large veins. In our study, Transcranial color-coded Doppler was especially applied to assess vascular lesions in all examined patients to measure RI of ACA or MCA. We found abnormal RI in acquired lesions including HIE&hydrocephalic patients occurring in the preterm & full term neonates. In the preterm, the major lesions are germinal matrix hemorrhage (GMH)/intraventricular hemorrhage (IVH) and periventricular leucomalacia (PVL) which is similar to those found by Laura and his coworkers (9).

In the term infants the major problems are hypoxic-ischemic encephalopathy/injury (HII) and intracranial hemorrhage. Which is similar to those found by Gupta (10). Intracranial hemorrhage is uncommon in term infants and when it occurs is generally unrelated to the germinal matrix hemorrhage, which is similar to those found by Siu and his collaborators (11). In our study, we found that number of male patients exceeded that of females being 29 male patients and 11 female patients representing 72.5% and 27.5% of all patients respectively. However the significance of this finding is questionable. In order to detect the comorbidities associated with abnormal ultrasound findings, the study reveals significant association between abnormal TCUS and mode of delivery as the neonates delivered by cesarean section (CS) have a higher percentage (27/32, 84.3%) of abnormal ultrasound finding compared to those born with NVD who have higher percentage (5/8, 62.5%) of normal ultrasound findings.
Our study declared that HIE was more associated with decreased or increased RI.

This results are confirmed with the results made by Liu and his workfellows (15) who stated that in HIE groups, the blood flow velocities decreased or increased markedly according to the degree of cerebral hemodynamic disturbance, RI increased or decreased accordingly.

Our study showed that hydrocephalus was more associated with increased RI.

This result is supported by Kolarovszki and his associates (16) who revealed that hydrocephalus negatively affects the cerebral blood flow. End-diastolic blood flow velocity is decreased and resistive index increased.

CCD and TCD were very beneficial in detecting vascularity of the lesions and assessment of the intracranial vessels: for example, it was used to study the vascularity of brain lesions and to assess the increased intracranial tension in the hydrocephalic patients which is similar to those found by Henrietta and his colleagues (14).

American Academy of Neurology and the Practice Committee of Child Neurology recommended routine cranial ultrasonography screening on all newborns born before 30 weeks of gestational age. The Canadian Pediatric Society suggests the need for cranial ultrasonography before 32 weeks of gestational age. According to Meijler (17),

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