Research Article

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British Journal of Research
ISSN 2394-3718

2020
Vol.7 No.1:52

DOI: 10.36648/2394-3718.7.1.52

Neonatal Intracranial Hemorrhage with Computed Tomographic Correlation of Efficacy of Cranial Ultrasonography in Detection

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Received Date: January 01, 2020; **Accepted Date:** February 27, 2020; **Published Date:** March 05, 2020

Citation: Hossain MM (2020) Neonatal Intracranial Hemorrhage with Computed Tomographic Correlation of Efficacy of Cranial Ultrasonography in Detection. Br J Res Vol.7 No.1:52.

Abstract

One of the problems of neonatal neurology is the lack of clinical signs associated with the development of cerebral lesions in newborn infants. This has allowed gross intracranial lesions to go undiagnosed in the neonatal period and may be responsible for the persisting confusion over the causes of cerebral palsy. The neurological and developmental handicap is related to two major neurological insults; Periventricular Leucomalacia (PVL) and Intra-Ventricular Hemorrhage (IVH). Spontaneous hemorrhage in and around the cerebral ventricles is a phenomenon that occurs in premature neonates; is now being increasingly observed in high-risk term neonates. Ultrasonography (USG), Computed Tomography (CT) and Magnetic Resonance Imaging (MRI) are being routinely used to screen the neonate. This study was aimed to establish the diagnostic usefulness of cranial ultrasonography in the detection of neonatal intracranial hemorrhage compared to CT scan. 70 neonates were included in this study of which 50 (71%) were preterm and 20 (29%) were term neonates with a male predominance (86%). On Cranial Ultrasonography 44 (62.8%) neonates had intracranial hemorrhage among them 35 (79.5%) were preterm and 09 (20.5%) were term neonates. On CT scan 42 (60%) neonates had intracranial hemorrhage, of which 31 (74%) were preterm and 11 (26%) were term neonate. Compared to CT findings the cranial-ultrasonography diagnosis yielded a Sensitivity of 92.1%, Specificity of 80.9%. PPV of 92.1%, NPV of 89.4% and accuracy of 91.4%. The experience gained in this study would suggest that cranial-ultrasonography can be employed in screening the neonates for intracranial hemorrhage.

Keywords: Ultrasonography (USG); CT scan; Computed Tomography (CT); Magnetic Resonance Imaging (MRI)

Introduction

The undiagnosed gross intracranial lesion in the neonatal period may be responsible for the persisting confusion over the causes of cerebral palsy. The neurological and developmental handicap is related to two major neurological insults; Periventricular Leucomalacia (PVL) and Intracranial Hemorrhage (ICH) [1]. Spontaneous hemorrhage in and around the cerebral ventricles is a phenomenon that occurs in premature neonates [2]; is now being increasingly observed in high-risk term neonates [3]. It is due to the rupture of the fragile capillaries of the germinal matrix [4]. Ultrasonography (US), Computed Tomography (CT) and Magnetic Resonance Imaging (MRI) are being routinely used to screen the neonate for probable intracranial problems [5-8]. Sonography of the brain is now an integral part of the care in the neonate, particularly among high risk and unstable premature infants [9,10]. Current ultrasound technology allows rapid evaluation of infants in the intensive care nursery with virtually no risk [11]. Real-time ultrasound was first used in NICU in the year 1978 to detect IVH [12]. Since then, it is emerging as an alternative modality of investigation of choice in all high-risk neonates, because of several inherent advantages over CT viz; non-invasive, inexpensive easily repeatable, require no sedation, less time consuming [13]. However, sonography does not differentiate subarachnoid from subdural hemorrhage and it is also unlikely that small cortical hemorrhage will be detected. The advantages of CT include its easy availability and high spatial resolution. CT proved excellent anatomic resolution of the entire brain parenchyma. Besides, it is not operator dependent, relatively cheaper and can be more rapidly performed as compared to MRI. CT scan reliably distinguishes between subdural and subarachnoid bleed, which is difficult on sonography [14]. CT contributes significantly to the total radiation dose derived from medical imaging in children [15]. Yet few studies have attempted to compare the role of various imaging modalities in the diagnosis of intracranial hemorrhage in preterm and term neonates. So far, we know there is no such previous study done in our country. The purpose of this study was to establish the usefulness of cranial ultrasonography in the diagnosis of ICH correlated with CT findings.

Materials and Methods

This cross-sectional study was carried out in the Department of Radiology and Imaging of Dhaka Shishu (Children) hospital in collaboration with department Radiology and Imaging from

January 2019 to December 2019, on 70 neonates referred from the neonatal unit and NICU with clinical suspicion of the intracranial ischemia or hemorrhage. Informed written consent was obtained from the parents/guardian of the patients, included in this study. The time gap between performing cranial ultrasonography and CT scans was a maximum of 48 hours. Clinical data included estimated gestational age, gender, birth weight, mode of delivery, age at imaging and time between imaging. Cranial ultrasonography was done by a USG machine using 4 MHz to 6 MHz phased array transducer and 8 MHz linear high-frequency transducers. Standard images in sagittal and coronal planes were obtained through anterior fontanelle; posterior sagittal and coronal images were obtained via the posterior fontanelle, wherever required. Noncontract CT scan was done, using a reduced tube current setting to reduce the mean radiation dose to the patient. Each sonogram and CT images were separately and independently reviewed by at least two of the researcher who was blind to the patient's history and previous radiology report. The intra-ventricular hemorrhage was graded by the classification of Papile et al. [16]; Grade-1 hemorrhage confined to the germinal matrix, Grade-II: intra-ventricular hemorrhage without dilatation of the ventricles, Grade-III: intra-ventricular hemorrhage with dilatation of the ventricles; and Grade-IV: intra-parenchymal hemorrhage with or without intra-ventricular hemorrhage. Extra axial hemorrhage-subdural/subarachnoid/epidural-hemorrhage was also assessed. An abnormality was considered present when at least two observers had the same diagnosis.

Result

The main objective of the study was to establish the diagnostic usefulness of cranial ultrasonography in the detection of neonatal intracranial hemorrhage. The USG findings were compared with CT findings, taking CT as a gold standard. A total number of 70 patients who were clinically suspected having Intracranial Hemorrhage (ICH) or ischemia were included purposively in this study. Out of 70 patients, 71% were male and 29% (20) were female. The male to female ratio was 2.5:1. Gestational age ranged from 32 weeks to 40 weeks with an average of 35.5 ± 1.95 weeks. There were preterm 71% (50) and the term was 29% (20) of the patient's **(Table 1)**. Birth weight ranged from 1.7 kg to 3.5 kg with an average of 2.59 ± 0.4 kg; 45% were in low birth weight group **(Table 2)**. Mode of delivery was 74% NVD and 26% (18) were LUCS. Age at imaging ranged from 01 days to 12 days with an average 3.1 ± 2.9 days.

Table 1: Distribution of cases according to their gestational age (N=70).

Gestational age group (in weeks)	No
≤ 32	4
>32-<37	46
37-40	20

Table 2: Distribution of cases according to their birth weight (N=70).

Birth weight group (in kg)	No
1.5-2.0	8
2.1-2.5	24
2.6-3.0	24
3.1- 3.5	14

Table 3: Distribution of cases of ICH according to the location and imaging modality (N=70).

Modality	IVH	Extra axial	Total
CT	35	7	42 (60%)
USG	39	5	44 (62.8%)

Table 4: Distribution of cases of ICH according to source and maturity diagnosed by CT (N=70).

Source	Preterm	Term	Total
Germinal matrix	19 (76%)	7 (70%)	26
Choroid plexus	04 (16%)	3 (30%)	7
Parenchymal vessel	02 (8%)	0	2

Table 5: Distribution of cases of ICH according to their birth weight (N=70).

Imaging findings	Birth weight group (in kg)							
	1.5-2 (n=8)		2.1-2.5 (n=24)		2.6-3.0 (n=24)		3.1-3.5 (n=14)	
	CT	USG	CT	USG	CT	USG	CT	USG
IVH-1	1	2	8	9	3	4	2	2
IVH-2	1	1	4	5	4	7	2	1
IVH-3	1	1	1	1	2	2	1	1
IVH-4	0	0	2	1	2	1	1	1
Extra axial	0	0	2	0	3	3	2	2
Total	3	4	18	17	14	17	8	7
Percentage (%)	37.3	50	75	70	58	70	57	50

The time between USG and CT scans ranged from 20 hours to 48 hours with an average of 35.5 ± 8.56 hours. Out of 70 patients, USG revealed ICH in 62.8% (44) cases **(Table 2 and Figure 1)** where CT diagnosed 60% (42) as ICH **(Table 3)**. On CT there were 35 cases of IVH and 7 cases of extra-axial hemorrhage **(Table 1)**. In the US there were 39 cases of IVH and 5 cases of extra-axial hemorrhage **(Table 2)**. Among the CT diagnosed 42 cases of ICH, USG revealed 95.2% (40) cases

correctly as ICH and 4.7% (2) cases were wrongly diagnosed as no ICH. USG diagnosed 71% (5) cases extra-axial hemorrhage; those were also diagnosed by CT **(Table 4)**.

Table 6: Distribution of cases of ICH according to their gestational age (N=70).

Imaging findings	Gestational age group (in week)					
	≤ 32 (n=4)		>32-<37(n=46)		≥ 37 (n=20)	
	CT	USG	CT	USG	CT	USG
IVH-1	1	1	10	12	3	4
IVH-2	1	1	6	9	4	4
IVH-3	1	1	3	3	1	1
IVH-4	0	0	3	2	2	1
Extra axial	0	0	4	2	3	3
Total	3	3	26	28	13	13
Percentage (%)	75	75	56	60	65	65

Table 7: Validity table (N=70).

USG finding	CT finding		Total
	ICH Present	ICH Absent	
ICH Present	40 TP	04 FP	44
ICH Absent	02 FN	24 TN	26
Total	42	28	70

USG detected 9% (6) cases falsely as ICH (3 cases of IVH-I and 3 cases of IVH-II); USG was unable to detect 28.5% (2) cases extra-axial hemorrhage which were revealed by CT **(Table 5)**. Furthermore, 2 small intra-parenchymal hemorrhages were missed on USG which were revealed by CT **(Table 6)**. Regarding the source of ICH in this study, the germinal matrix was the source in 76% of preterm and 70% of term neonates **(Table 6)**. Compared to CT diagnosis, cranial USG yielded Sensitivity 92.5%, Specificity 85.7%, Positive predictive value 90.9%, Negative predictive value 93.3% and accuracy of 91.4% **(Table 7)**.

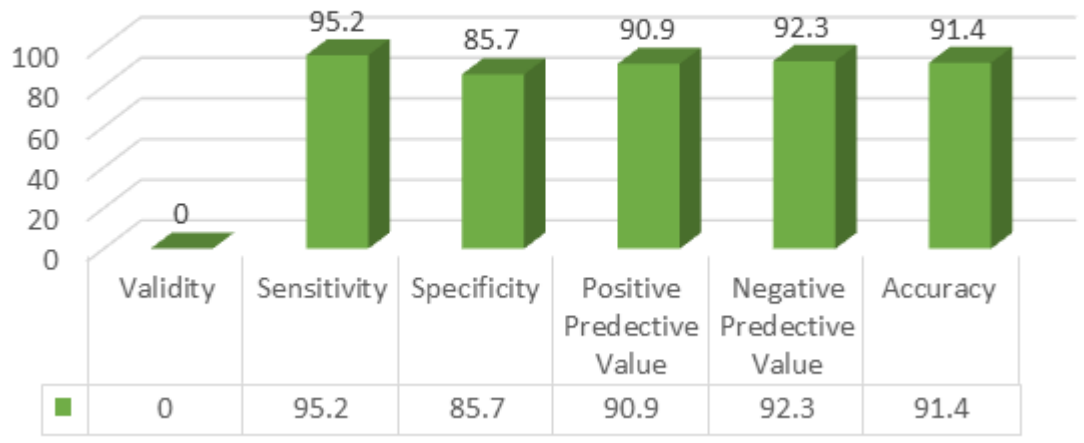

Figure 1: Validity of cranial sonography in the detection of ICH.

Discussion

Neonatal intracranial hemorrhage is a significant problem and also responsible for significant morbidity and mortality. This cross-sectional study was carried out to see whether the cranial ultrasonography is a useful method to detect neonatal intracranial hemorrhage. Because patients were necessarily included in this study only when CT scan was ordered by NICU or neonatology ward because of clinical suspicion of HIE or IVH; there was strong selection bias toward the neonate who, although ill, could be safely moved for CT scan as opposed to the neonate who tended to be less stable and to have multiple medical difficulties. Blankenberg et al. [17] studied neonates to compare the efficacy of cranial USG relative to CT and MRI for the diagnosis of ischemia and ICH. In the present study there were 40 neonates with male preponderance; M: F=2.5:1. The male preponderance of this study was also observed in previous studies [13,18]. Khan et al. [18] also studied 100

neonates with M: F=1.2:1. Soni et al. [13] also studied 111 neonates with an M: F=1.39:1. In the present study, all of the respondent neonates underwent a CT scan of the head within 33.5 ± 8.5 hours of cranial ultrasonogram, ranged 20-48 hours. Khan et al. [18] also performed CT and cranial USG within 48 hours of each other. In a study of Blankenberg et al. [19], cranial USG and CT scans were performed within 24 hours of each other (average 14.4 ± 9.6 hours). Incidence of intracranial hemorrhages has previously been reported in 20%-75% preterm neonates [4,20-22] and few term neonates [3,23,24]. ICH observed predominantly in the preterm neonates in the present study. In the present study, ICH was observed in 75%, 56% and 65% neonates with gestational age ≤ 32 weeks, >32-37 weeks and ≥ 38 weeks receptively **Table 6**. Khan et al. [18] observed 83% ICH in preterm neonates of less than 32 weeks of gestational age. Pevsner et al. [25] observed ICH in 9%, 52%, 20%, 14% and 3% neonate with birth weight of <1 Kg, 1 Kg-1.5 Kg, >1.5 Kg-2.0 Kg, >2.0 Kg-2.5 Kg and >2.5 Kg respectively. Mack et al. [21] reported ICH in 20% preterm neonates with a birth weight of 810 g-2040 g. Soni et al. [13] observed ICH in 33.5%, 23.5%, 18.7% and 25.3% neonates with birth weight of 1.0 Kg-1.5 Kg, >1.5 Kg-2.0 Kg, >2 Kg-2.5 Kg and >2.5 Kg respectively. Like the previous researchers in the current study, the incidence of ICH among the LBW neonates was more, but the incidence in normal weight neonates shows higher than the findings of previous researchers. Leach et al. [2] had demonstrated that the source of IVH is the germinal matrix in more than 90% neonates. Papile et al. [16] from their study concluded that IVH in preterm classically emanates from small vessels, principally capillaries in the sub-ependymal germinal matrix, which is richly vascular structure and is more pronounced in the fetus of 6-8 months gestation. Now it is increasingly being reported in term neonates too. Soni et al. [13] observed that the germinal matrix was the source of IVH in all their preterm cases and 64% of the term cases. In the present study germinal matrix was the source of IVH in 76% preterm and 70% term neonates, the remaining site of hemorrhage in preterm were choroid plexus and brain parenchyma in 16%, 8% cases respectively and in the term neonates the choroid plexus in 30% cases **(Table 4)**. The observation of the present study compares favorably with the observation of previous researchers. Is the present study comparing with CT diagnosed ICH, cranial ultrasonography yielded a sensitivity 95.2%, specificity 85.7%, accuracy 91.4%, positive predictive value 90.9% and negative predictive value 92.3%. The results of the present study are similar and in some instances more promising than the study result of previous researchers. Epilman et al. [26] observed the sensitivity of the US was 100%, specificity 33% and accuracy 91%. The test parameters of the present study compare favorably with their findings. Khan et al. [18] observed the sensitivity of cranial USG was 100%. The sensitivity of 95.2% observed in the present study is promising like their study. Blankenberg et al. [19] found the sensitivity of cranial sonography 47% in the detection of ICH. In the present study, the sensitivity of cranial USG is 95.2%, which is much higher than their findings. Sauerbrei et al. [20] found the sensitivity of USG in detecting intracranial hemorrhage was 96%. The sensitivity of 95.2% in the present is similar to their findings. McIntosh [27] mentioned that sensitivity in detecting IVH by USG is 83%. In the present study, the sensitivity of cranial USG was 95.2%, which is greater than their findings. In a retrospective study, Epilman et al. [28] found accuracy, sensitivity, and specificity of US imaging were 53%, 74%, and 19% receptively. The results of the present study are much higher and promising than their study.

Conclusion

In this prospective study, findings of cranial ultrasonography correlated well with the CT findings. Cranial ultrasonography provides a highly sensitive and relatively specific means of detecting intracranial hemorrhage. Cranial ultrasonography fares a little poorly in the detection of extra-axial hemorrhage. Furthermore, cranial ultrasonography is very useful for the detection and monitoring of complications of ICH such as hydrocephalus, porencephalic cyst, PVL, ventricular septation and clots and block in the CSF pathway, by serial sonographic evaluation. It concludes that cranial ultrasonography is an effective method in the evaluation of ICH. In this study sample lacks representation of the population; further studies comparing USG, CT and MRI with larger sample size will document the efficacy of cranial ultrasonography better and will help to better define the role of cranial ultrasonography.

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