The utility of computed tomography and transfontanelle ultrasonography in various intracranial lesions in the newborns and infants

Computed tomography and transfontanel ultrasonography in infants

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Abstract

Aim: We aimed to diagnose intracranial lesions in infants by performing transfontanel ultrasonography (US) and computed tomography (CT), and to evaluate the efficacy of both methods with respect to each other.

Material and Methods: In this retrospective study, 111 infants were included between 2007-2011. The mean age of the participants was 2.2 months (range, 1 d-24 mo) and 42 (37.8%) of them were females, 69 (62.1%) of them were males. Both US and CT were used in 34.2 % of cases (n=38/111). Only US was used in 52.2% of cases (n=58/111) and only CT was used in 13.5% of cases (n=15/111).

Results: Intracranial hemorrhage was demonstrated in 39.6% of the infants (n=19/48) Congenital malformations were shown in 22.9% of the patients (n=11/48). Communicating and non-communicating hydrocephalus in 20.9% of the patients (n=23/111), periventricular leukomalacia in 9% of the patients (n=10/111), diffuse cerebral edema in 5.4% of the patients (n=6/111), central nervous system infections in 4.5% of the patients (n=5/111), acute ischemic infarct in 1.8% of the patients (n=2/111), and metabolic disease in 0.9% of the patients (n=1/111), were demonstrated.

Discussion: Intracranial hemorrhage was the leading finding, followed by congenital malformations and hydrocephalus in the present study. US and/or CT can be used effectively and interchangeably for the earlier diagnosis of infantile intracranial pathologies especially in cases where MRI is not available.

Keywords

Tomography; Ultrasonography; Infant; Intracranial Hemorrhage

Introduction

Early and correct diagnosis of infantile intracranial pathologies is essential for their correct and efficient treatment by pediatricians. Radiological methods such as plain radiographs, transfontanelle ultrasonography (US) and computed tomography (CT) are practical and less time-consuming diagnostic tools [1]. The US can provide real-time information about the anatomic location, size, and shape of lesions as well as their mass effect on adjacent structures [2]. However, the differential diagnosis can be difficult with US findings only [2]. Understanding the spectrum of appearances of the various intracranial lesions on both CT and US improves the diagnostic yield, enables one to understand their pathogenesis, and facilitates patient care [2]. In this study, we aimed to diagnose intracranial lesions in infants by performing transfontanelle US and CT, and to evaluate the efficacy of both methods with respect to each other.

Material and Methods

Our study population included 232 newborns and infants who were clinically suspected to have various types of intracranial pathologies and who underwent transfontanelle US and/or cranial CT between 2007–2011, in the first selection. A total of 121 subjects were excluded because of normal US and/or CT findings. Finally, 111 consecutive newborns and infants with positive transfontanelle US and/or cranial CT findings were included in this retrospective study. The study was conducted in accordance with the current Helsinki Declaration and the ethics granted by the institution. The parents or closest relatives of all the patients were informed about US and CT studies. Although the radiologist's opinion was asked about which method to choose for some patients, the clinician usually decided which radiological imaging method to choose. Accessing medical records between two dates in the past, two experienced radiologists have re-evaluated the radiological images. Our study was approved by the Ethics Committee of Mersin University Medical Research Ethics Committee with the board decision dated 19.12.2018 and numbered 2018/507. The mean age of the participants was 2.2 months (range, 1 d-24 mo), and 42 (37.8%) of them were females, 69 (62.1%) were males. Both US and CT were used in 34.2 % of cases (n=38/111). Only US was used in 52.2% of cases (n=58/111) and only CT was used in 13.5% of cases (n=15/111). The cranial US examinations of infants were performed with 3.5-3.75 MHz convex transducers, 3.75-7.5 MHz sector/microconvex transducers and 7.5-8.0 MHz linear transducers by using anterior and posterior fontanelles as acoustic windows (transfontanel approach) in every case and additionally through temporal bone (transtemporal approach) in case of need. Intravenous contrast material was administered when necessary during CT examinations. US examinations were performed by two experienced radiologists together, and CT images were interpreted by two experienced radiologists in consensus. The findings were verified by clinical results and/or cranial magnetic resonance imaging (MRI) and/or follow-up US and CT examinations.

Data analysis

The frequencies (percentage, n) of the patients according to the type of the lesions were obtained. All analyses were done with SPSS software (version 16.0; SPSS Inc; Chicago, IL, USA).

Results

Using US and/or CT, intracranial hemorrhage (Figures 1, 2) was demonstrated in 39% of the infants (n=43/111). Congenital intracranial malformations (Dandy-Walker malformations, lissencephaly-pachygyria, schizencephaly, semilobar holoprosencephaly, occipital meningocele, choroid plexus cysts, mega cisterna magna formations) were shown in 19.8% of the patients (n=22/111). Communicating and non-communicating hydrocephalus (postinfectious and posthemorrhagic hydrocephalus (Figure 3), congenital hydrocephalus due to achondroplasia and Dandy-Walker malformation, hydrocephalus due to glial tumour in the posterior fossa) in 20.9% of the patients (n=23/111), periventricular leukomalacia in 9% of the patients (n=10/111), diffuse cerebral edema in 5.4% of the patients (n=6/111), central nervous system infections in 4.5% of the patients (n=5/111), acute ischemic infarct in 1.8% of the patients (n=2/111), and metabolic disease in 0.9% of the patients (n=1/111), were demonstrated.
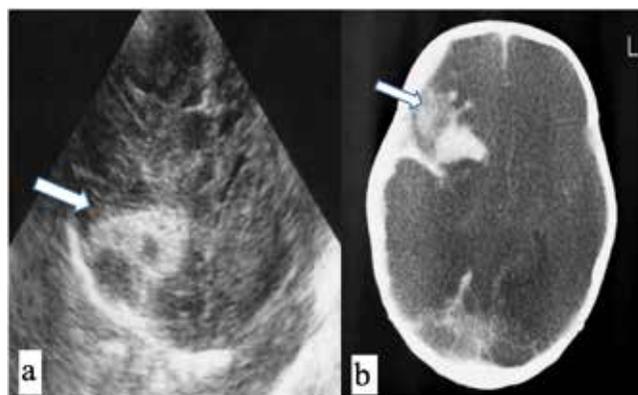

Figure 1. Demonstrated acute intraparenchymal hemorrhage a) Cranial US as hyperechogenic mass in the right frontal lobe. (arrow), b) Axial CT of the patient revealed acute intracerebral hematoma within the right frontal lobe associated with subarachnoid hemorrhage. With CT we were also able to demonstrate acute right frontal subdural hematoma. All were hyperdense (arrow). Diffuse cerebral edema is also seen.
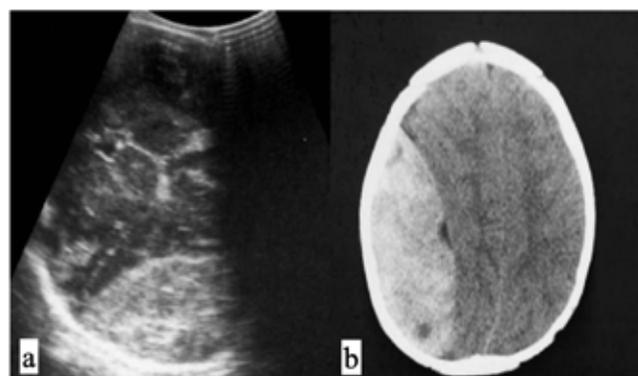

Figure 2. Epidural hematoma a) biconvex shape of acute right parietal epidural hematoma in a traumatized infant due to falling on the ground was easily identified on this axial US image. The hematoma is highly echogenic b) Axial CT of the patient confirmed acute right parietal epidural hematoma, which is hyperdense and biconvex. The infant underwent emergency surgery.
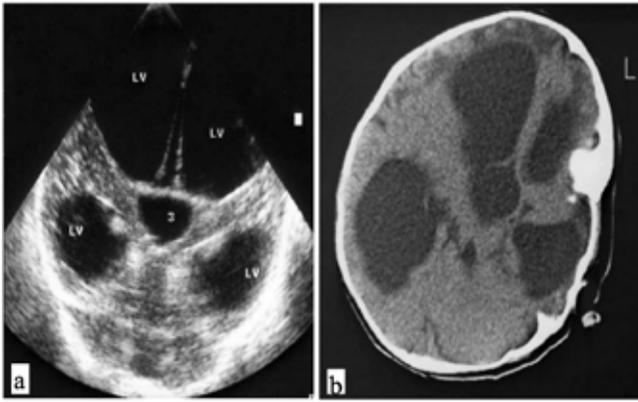
Figure 3. Communicating hydrocephalus a)Transfontanel coronal US image of a 9- month- old infant with advanced communicating hydrocephalus who has been treated for streptococcic meningitis four weeks ago. US demonstrated ventricular dilatation as clearly as CT (LV: left ventricle, 3: 3rd ventricle) b) axial CT demonstrates severe communicating post-meningitis hydrocephalus.

Discussion

On US, intracranial acute hemorrhage is seen as highly echogenic and relatively homogeneous mass [3], as in the cases of the present study. By the time, intracranial (intracerebral, intraventricular, subdural, epidural etc.) hematoma becomes more hypoechoic and in about eight weeks it is readily seen as a cystic structure on US [4]. On CT, intracranial hematoma is seen hyperdense for a period of about one week, as it was in our study, then becomes isodense [5]. US is very important for the diagnosis of neonatal and infantile cranial hemorrhages and for their follow-up [6]. Germinal matrix has a rich vascular supply, its fragile vessel walls can get damaged after metabolic and blood pressure changes. In turn, subependymal, intraventricular, intraparenchymal hemorrhages may occur and porencephalic cysts besides hydrocephalus can develop after these hemorrhages [2, 7]. Intracerebral hemorrhages are commonly seen in frontal and parietal lobes of the cerebral hemispheres. Compared with CT and magnetic resonance imaging (MRI), US is less sensitive to detect subdural and epidural hemorrhages [8], though in one of our cases we were able to demonstrate a large epidural hematoma easily with US. Compared with other types of intracranial hemorrhages, US has the least efficacy in the detection of subarachnoid hemorrhages. As indirect findings, enlarged fissures and sulci and their increased echogenicity may raise suspicion for subarachnoid hemorrhage [1-5].

Regarding the congenital intracranial malformations that could be detected in the present study, lissencephaly (agyria-pachygyria complex) is a congenital migration anomaly of gray matter of brain that is characterized by the lack or few sulci, shallowing of the present sulci, thickened appearance of the gray matter and decreased amount of white matter [9]. We could effectively demonstrate all the above-mentioned findings related to lissencephaly (agyria-pachygyria complex) on transfontanelle US of one case in our study. Schizencephaly is a full-thickness cerebrospinal fluid-filled parenchymal cleft lined by gray matter extending from subarachnoid space to subependyma of lateral ventricles [10]. Dandy-Walker malformation is characterized

by an enlarged posterior fossa, a cystic lesion in the posterior fossa, which is in communication with the fourth ventricle, vermian aplasia or hypoplasia, and cerebellar hypoplasia [11-13]. We could be able to demonstrate all these findings on CT images of the related cases in the present study. Hydrocephalus (ventriculomegaly) also associates this malformation due to congenital atresia of the foramina of Luschka and Magendie. CT is superior to US in assessing the enlargement of posterior fossa shapes of bony structures, sizes of cerebellum and vermis compared to other intracranial structures [11-13]. CT provides the view of the whole cranium in the same field of view, which is quite helpful to make a comparison [11]. This is less satisfactory for US, but allows dynamic examination [14] and unlike CT, we are able to make examinations in every plane in which acoustic windows are suitable. Choroid plexus cysts are non-neoplastic cystic structures that may be unilateral or bilateral [15]. They can be diagnosed in utero, in the infantile period or even in young adults coincidentally [16]. They are often larger than 3 mm and can reach a diameter of 25 mm. But they have an average diameter of 4.5 mm. If the cyst is large enough, hydrocephalus may develop as a complication [15-17]. Choroid plexus cysts, besides other congenital malformations such as semilobar holoprosencephaly, occipital meningocele, mega cisterna magna formations, were also well depicted on US examinations of the cases in the present study.

Hydrocephalus may result from obstruction of cerebrospinal fluid (CSF) flow, inadequate absorption or overproduction of CSF [18]. Hydrocephalus may be communicated or non-communicated [18]. Non-communicated hydrocephalus may develop as a result of some of the infections, hemorrhages, tumors, cysts and congenital anomalies [18]. Communicated hydrocephalus may develop as a result of subarachnoid hemorrhages, meningeal carcinomatosis or infections [18, 19]. Regarding one of the infants in the present study, US could be able to demonstrate advanced hydrocephalus, which developed within one month after the onset of meningitis. Moreover, the CT which was obtained after US was in total accordance with US findings.

Periventricular leukomalacia is periventricular white matter necrosis due to hypoxia and ischemia. Sonographically, in the early period, periventricular white matter echogenicity increases [20, 21]. But in the later stages, cystic changes occur. Different degrees of cerebral atrophy and ventricular dilatation develop eventually. In the very early periods, CT is not as effective as expected. About 12 hours after the onset of infarct, hypodense areas are apparent with CT [6]. In later periods, periventricular hypodensity becomes much more apparent (20-21). During the subacute stage, pathologic contrast enhancement, especially in the periphery of the infarct, can be detected with CT [6]. Regarding acute cerebral infarcts in infants, US shows echogenic parenchyma, lack of arterial blood flow signals in Doppler imaging, mass effect due to edema, effacement of gyri and sulci [19]. In our relevant cases, both US and CT could be able to demonstrate the above-mentioned changes.

Congenital intracranial infections are toxoplasmosis, Herpes simplex type 2 infections, Rubella and Cytomegalovirus infections. In almost all of these so-called TORCH group infections, intracerebral calcifications occur, which can be

demonstrated both on US and CT, as we did in the present study. Acquired infections are meningitis, ventriculitis, encephalitis, abscesses and extracerebral infections (subdural empyema etc.) [22-24]. In ventriculitis, US examination can detect hydrocephalus, echogenic structures within ventricles, increased echogenicity of the ventricle walls and fibrous septations within the ependymal lining [22]. US can not help in the diagnosis of uncomplicated meningitis, though in some cases increased echogenicity and thickening of the sulci may be noticed [22-24]. On US, intracerebral abscesses are hyperechogenic in the early periods, but gain mixed echogenicity later on. US is not as effective as CT in the detection of extracerebral abscesses and empyemas [22, 23]. Especially, contrast enhancement of meningeal structures and the walls of infectious lesions and collections helps us to identify abscesses, meningitis, ventriculitis, subdural and epidural empyemas easily with CT [22]. On contrast-enhanced CT images of our relevant cases, subdural and epidural empyemas and associated hydrocephalus could clearly be depicted. However, we couldn't reveal subdural and epidural empyemas clearly with US, but could demonstrate ventricular dilatation.

On US, cerebral edema may be seen as blurred parenchymal images, diffuse and increased parenchymal echogenicity, though it is sometimes subjective to evaluate the echogenicity of the parenchyma [3-5]. On CT, cerebral edema can be seen as decreased density of cerebral parenchyma, loss of distinction between gray and white matter, the shift of midline structures and compression of the ventricles [6]. In one of our cases, we could clearly demonstrate diffuse cerebral edema associated with intracranial hematoma in a traumatized infant.

Intracranial tumors are rare in infants [18]. On US, most tumors are seen as hyperechoic lesions, though some may have mixed echogenicity [19]. In very few cases they may be anechoic [19]. Intratumoral calcifications are seen as echogenic foci [18, 19]. Craniopharyngioma, dermoid tumor, pinealoma, astrocytoma, papilloma of choroid plexus, ependymoma, primitive neuroectodermal tumors are among the intracranial tumors of the infantile period [1]. CT is very helpful in diagnosis, assessing the contrast enhancement pattern, extension and complications of tumors, evaluation of the bony structures of the skull, detection of intratumoral calcification [2-6]. In two of our cases with glial tumors in the posterior fossa, CT was helpful not only in demonstrating the tumor, but associating hydrocephalus as well. US was helpful in revealing obstructive hydrocephalus in these cases, however, we consider that small tumors, particularly in the posterior fossa, can be overlooked with US.

Getting access to CT and preparing an infant for a CT scan is easier than using MRI [5]. CT provides faster examination (literally seconds for a brain examination) with better monitoring (particularly in unstable neonates) and has fewer equipment-related contraindications than MRI [8]. In MRI, the need for sedation in infants is an important and ongoing problem [6-8]. We consider that modality decisions should be based on available resources and patient status, in addition to diagnostic yield.

Ultrasonography is a non-invasive and non-ionizing imaging modality. Unlike CT, it provides real-time images in all planes.

Sedation is not required. The bed-side examination is possible for the patients that are attached to monitors and life-support units. We concluded that US was useful to demonstrate most of the infantile intracranial lesions, especially the ones that need periodic evaluation. CT is found superior to US in demonstrating extraaxial fluid collections such as subdural empyemas and subdural, subarachnoid hemorrhages. CT helps to evaluate the whole intracranial structures within that field of view and compare them with each other. The contrast enhancement patterns of the lesions help a lot for differentiation of them with CT. Calcifications can easily be detected with CT, and bony structures are evaluated more accurately.

The present study had some limitations mostly because of its retrospective design. Firstly, our sample size was not large enough to divide the patients into subgroups according to different pathologies, which would help us better see and check the efficacy of both US and CT in different pathological situations and conditions. Secondly, we could not take each patient to CT scanning after US to avoid unnecessary ionizing radiation. This is also true for some patients who underwent CT but could not be evaluated by US because of their critical and unfavorable clinical status. Thirdly, due to patient-related factors and/or because it is unnecessary from the point of making the diagnosis, we could not correlate our findings with the MRI in every case, which would also be helpful in providing more detailed information about the intracranial lesions of the patients. However, we consider that our results proved the usefulness and practicality of both US and CT in our patient groups. We could not correlate our findings with MRI.

In conclusion, intracranial hemorrhage was the leading finding, followed by congenital malformations and hydrocephalus in the present study. US and/or CT can be used effectively and interchangeably for earlier diagnosis of infantile intracranial pathologies, especially in cases where MRI is not available.

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