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Role of neuro imaging in paediatric emergencies

[1]Dr. Abhinaya G, Junior resident, Department of Radiodiagnosis, Rajarajeswari Medical College and Hospital, Bangalore, Karnataka, India.

[2]Dr. Tanmayi Uppalapati, Junior resident, Department of Pediatrics, Rajarajeswari Medical College and Hospital, Bangalore, Karnataka, India.

[3]Dr. Gautam M, Professor and Head of department, Department of Radiodiagnosis, Rajarajeswari Medical College and Hospital, Bangalore, Karnataka, India.

[4]Dr. Adarsh E, Professor and Head of department, Department of Pediatrics, Rajarajeswari Medical College and Hospital, Bangalore, Karnataka, India.

Corresponding Author: Dr. Abhinaya G, Junior resident, Department of Radiodiagnosis, Rajarajeswari Medical College and Hospital, Bangalore, Karnataka, India.

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Abstract

Introduction: In neurologic emergencies in children, imaging is very often needed because of the limitations in gathering an accurate history as well as difficulties with performing the neurologic examination. In such a situation, the challenge for the physician is in deciding [1] if an imaging test is required emergently and [2] what is the most appropriate imaging test.

This article will focus on the neuroimaging for evaluation and diagnosis that has more common and specific occurrences in pediatric population.

Aim: To know the spectrum of pediatric cases presenting to the emergency department needing neuro imaging.

Objective: To identify the role of neuroimaging in pediatric emergencies.

Materials and methods: A combined prospective and retrospective study was conducted for a period of 18 months (March 2021 - August 2022), in children who presented to the emergency department at Rajarajeswari medical college and hospital, Bangalore and who underwent diagnostic imaging.

Results: A total of 45 cases were included in the study, of which traumatic cases were 9 and non-traumatic cases were 36. 36 non-traumatic cases were further subgrouped based on the etiological factors; of which 13 cases (36.1 %) had findings consistent with congenital abnormalities. The proportion of children with Hypoxic

ischemic encephalopathy, Accidents, Stroke, Infections and Neoplastic were 10 cases (27.7 %), 9 cases (25 %), 5 cases (13.8 %), 4 cases (11.1 %) and 4 cases (11.1 %) respectively.

Conclusion: Neuroimaging is the key in pediatric emergencies. The advancement in newer modalities of technology should be put into use more as a combined approach in diagnosis, management and prognostication as well as for early intervention to improve functional and psychological outcome.

Keywords: Pediatric emergencies, pediatric neuro imaging, MRI brain.

Introduction

CT is considered the modality of choice in situations when determination of etiology needs to be done emergently, because of deteriorating neurologic status secondary to suspected hemorrhage during trauma, and in uncooperative patients. CT is also very useful for detection of calcifications, bony structures, and before a lumbar puncture to rule out a mass or bleeding.[3]

MR imaging is superior to CT in the evaluation of epilepsy, tumors, white matter pathology, and infection/ inflammation in the brain. MR imaging is generally performed without contrast, except in cases of a known brain tumor or suspicion of a tumor is very high, ataxia, and when suspecting infection.[3]

When evaluating vascular pathology, MR angiography is preferred in children to avoid radiation exposure; but CT may be indicated in specific conditions, such as vasculitis.

A fast MR imaging scan, consisting of 1 or 2 sequences, is now used, instead of CT, in many institutions. Most children who are present with headaches do not require any advanced neuroimaging. Neuroimaging should be reserved for children who have an abnormal neurologic examination (e.g., ataxia, papilledema, or diplopia), new-onset thunderclap headache, associated with morning vomiting or failure in improvement after 4 weeks of symptomatic treatment. [3]

The differential diagnoses in the child considered for emergent neuroimaging can be roughly divided into the following groups, as shown in Table 1. These groups are specific to (1) the pediatric patient, (2) the imaging features of the suspected or known condition, and (3) the diagnostic algorithms that are selected in performing the examination.

Table 1 : Paediatric Central Nervous System Emergencies [4]

Acute Hydrocephalus
Trauma
Accidental
Nonaccidental
Non-traumatic vascular events
Arterial ischemic stroke
Venous thrombosis
Embolic stroke
Vasculitis
Dissection
Migraine
Hypoxic-ischemic injury
Strangulation
Cardiorespiratory insufficiency
Near-drowning

Electrolyte and hormonal imbalances
Hypoglycemia
Hyponatremia
Hypocalcemia
First-time seizure and status epilepticus
Infection
Congenital
Acquired
Complications and sequelae
Demyelination
Acute disseminated encephalomyelitis (ADEM)
Multiple sclerosis (MS)
Metabolic disease (acute presentation)
Iatrogenic, toxic and drug-related injury
L-asparaginase
Cyclosporine
Methotrexate
Recreational drugs
Carbon monoxide
Neoplastic disease (acute presentation)
Encephalopathy in hematologic and oncologic disease
Posterior reversible encephalopathy (PRES)
Posttransplant lymphoproliferative disorder (PTLD)

Need for study

It is difficult to examine and diagnose pediatric emergencies due to incomplete history hence there is need for neuroimaging for prompt diagnosis and management at the earliest.

Aims and objectives

To know the spectrum of pediatric cases presenting to the emergency department needing neuroimaging and to identify the role of neuroimaging in pediatric emergencies.

Materials and methods

- **Study period:** 18 months (March 2021 - August 2022)
- **Study design:** Combined Prospective and Retrospective hospital-based study.

Inclusion criteria

Children of age 1month - 14 years presenting to emergency department at Raja Rajeswari medical college and hospital, Bangalore and who underwent diagnostic imaging.

Exclusion criteria

- Children in whom imaging was done for conditions other than emergencies.
- Cases without specific findings in imaging.

Methodology

Cases were selected based on inclusion and exclusion criteria and a single center study was done using the scanners, imaging software and medical records. Cases were investigated with MRI scans of the brain via 1.5T Siemens scanner after making the child sleep or sedated. The sequences used were: Axial T1, Axial T2, Axial FLAIR, Axial DWI, Axial ADC, Axial SWI, Axial PHASE, Sagittal T1 and Coronal FLAIR. CT scan of the brain was done only when indicated on 128 slice

Siemens Somatom Perspective scanner. Informed con sent shall be taken from the patient's parents.

Results

A total of 45 cases were included in the study, of which traumatic cases were 9 and non-traumatic cases were 36. (Table 3)

31 cases underwent MRI brain imaging and 17 cases underwent CT brain imaging which guided towards diagnosis and management of these children. (Table 2)

36 non-traumatic cases were further sub grouped based on the etiological factors; of which 13 cases (36.1 %) had findings consistent with congenital abnormalities. The proportion of children with Hypoxic ischemic encephalopathy, Accidents, Stroke, Infections and Neo plastic were 10 cases (27.7 %), 9 cases (25 %), 5 cases (13.8 %), 4 cases (11.1 %) and 4 cases (11.1 %) respectively as shown in (Table 4).

Imaging	No.of cases
CT SCAN	17
MRI	31

Table 2: Neuroimaging modality performed

Causes	No. of cases	Percentage (%)
Traumatic	9	20
Non-traumatic	36	80

Table 3*:* Distribution based on traumatic or non-traumatic history.

Etiology of non-traumatic emergencies	No. of cases	Percentage (%)
Congenital structural mal formations of brain	13	36.11
Hypoxic ischemic encephalopathy	10	27.77
Accidents	9	25
Stroke	5	13.88
Infections	4	11.1
Neoplastic	4	11.1

Table 4: Distribution based on etiology in non-traumatic cases.

Discussion

Non-traumatic neurological emergencies

Seizures and status epilepticus [5,6,7] (Figure 1 and 2)

Convulsion is a symptom corresponding to the sudden and involuntary contraction of the striated musculature. An epileptic seizure is the clinical expression of a hypersynchronous electrical discharge, whether convulsive or not. Epilepsy is a chronic disease characterized by the recurrence of epileptic seizures.

No imaging is indicated in the event of simple febrile convulsions, i.e. generalized, first epileptic seizure of short duration if the neurological examination is normal and if there is no acute context (apart from a simple fever).

On the other hand, some acute attacks require emergency brain imaging, depending on accessibility and the suspected pathology.

In newborns and infants; convulsions must always be investigated for anoxoischemic lesions (fetal suffering, "near miss" or vascular accident), traumatic (Silverman, obstetrical trauma), infectious (meningitis is often non-febrile at this age), even metabolic lesions, or of ischemic vascular origin. (Figure 1)

- The existence of focal neurological signs or intracranial hypertension raises the suspicion of an intracranial tumor.

- The traumatic context
- Atypical febrile convulsions, i.e. focal, prolonged for more than ten minutes, occurring before the age of 1 year or after the age of 5 years.

The ulterior motive is then an encephalitis (herpetic or other) or even an abscess or an empyema.

More rarely, the appearance of acute neurological signs in a context of chronic epilepsy: cerebral vascular accident in the context of a tuberous pink scale of Bourneville, for example.

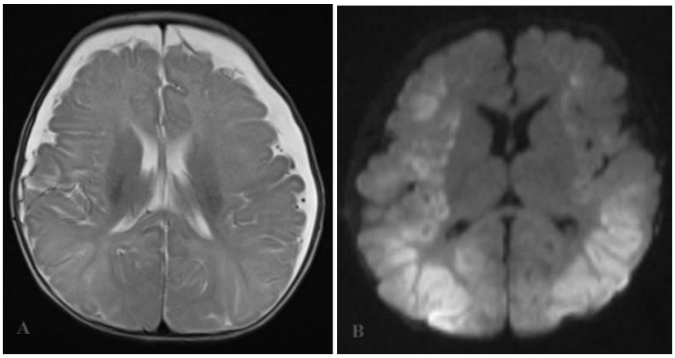


Figure 1: A 3-month-old female patient presenting with recurrent seizures and fever.

A. T2W axial MR image showing subdural effusion along bilateral fronto-parieto-temporal convexities.

B. DWI axial MR image showing areas of acute infarct (hyperintense) in bilateral cerebral hemispheres.

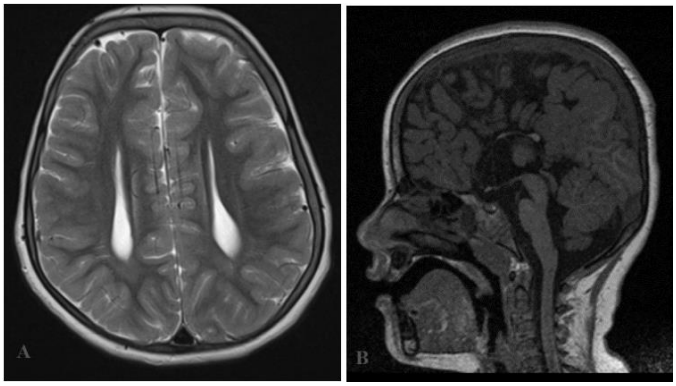


Figure 2: Dysgenesis of corpus callosum with Colpocephaly in a 6-year-old female preterm born child presenting with seizures.

T2W axial MR image showing widely spaced parallelly oriented bodies of bilateral lateral ventricle (“racing car sign”) and dilated trigones.

T1W sagittal MR image showing absent genu and rostrum of corpus callosum with markedly hypoplastic body and splenium.

Infection [8] [Figure 3]

Meningitis is the most common form of intracranial infection in pediatrics. In children and adolescents, the diagnosis is evoked on classic signs: fever, headache, vomiting, stiff neck. The diagnosis is based on the results of the lumbar puncture. Meningitis in children, whether bacterial or viral, does not require imaging except in cases of: — Diagnostic doubt; — Suspicion of a complication (cranial nerve palsy, shock, convulsions).

When performed, imaging may show simple enhancement of the meninges after injection of contrast product. Above all, it makes it possible to detect complications: acute hydrocephalus, ventriculitis, vascular thrombosis of arterial and/or venous origin, empyema, cerebritis and abscess.

These complications are particularly common in newborns and infants and ultrasound is a good screening examination in this context, to detect hydrocephalus and ventriculitis, characterized by the presence of intra-ventricular debris and septa. Arterial and venous infarctions, abscesses at the stage of PR suppurative encephalitis have a nonspecific hyperechoic aspect.

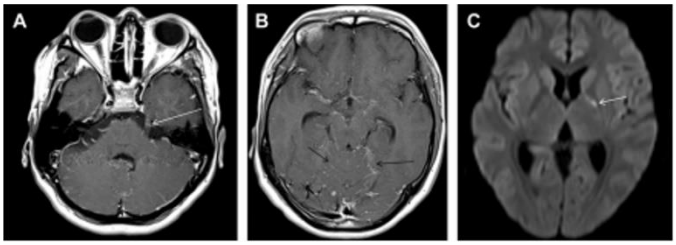


Figure 3: Meningitis in a case of 11-year-old male presenting with fever and multiple cranial neuropathies,

confirmed as meningitis. Postcontrast axial T1W (A, B) and DWI (C) MR images of the brain demonstrating leptomeningeal enhancement in the basilar cisterns and along the cerebellar folia. Enhancement of the left trigeminal nerve is noted. Enhancement of multiple other cranial nerves at the base of the skull were noted. Small focus of restricted diffusion suggestive of an acute lacunar infarct is noted in the left globus pallidus.

Headache

Headache is one of the most frequent causes of consultation in pediatrics [9]

— Permanent or increasing pain frequency or intensity.

— Pains at night or on changes of position, on defecation, on exertion; — Change in behavior and/or character; — Epilepsy or abnormal neurological examination.

In pediatrics, posterior fossa tumors are more common than supratentorial tumors (medulloblastoma, cerebellar astrocytoma, ependymoma) and are more common in children under 10 years of age.

Subarachnoid hemorrhage is rare and should lead to the search for a vascular malformation of the arteriovenous type. The aneurysm is exceptional in pediatrics.

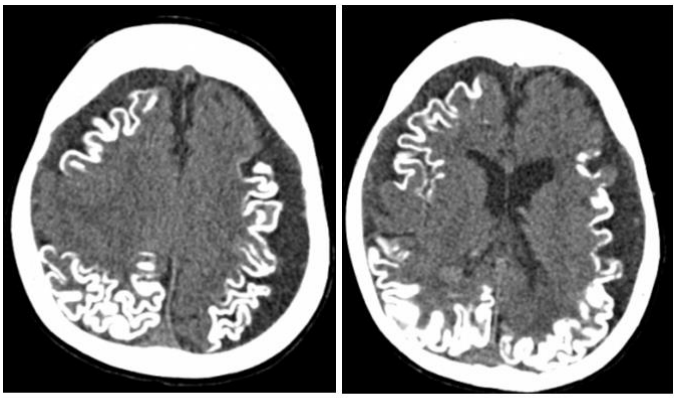
Chiari I malformations can be responsible for headaches, which have the particularity of expressing themselves essentially on exertion.

In case of fever, headaches may be related to meningitis, meningoencephalitis, abscess. These are much more frequently febrile headaches with or without meningeal syndrome accompanying banal, viral, seasonal infections.

More rarely, headaches may be related to cerebral venous thrombosis, ophthalmological pathology, carbon monoxide poisoning.

In daily practice, non-enhanced CT scan is most often sufficient to rule out a tumoral pathology or an exceptional intracerebral hematoma. [Figure 4].

MRI is more effective in looking for a Chiari 1 malformation, unruptured vascular malformations, or even carotid or vertebral dissection. It is of course essential in a second time, for the assessment of extension of a tumor.



A B

Figure 4*:* Struge Weber syndrome in a 9-year-old male patient presenting with recurrent seizures, glaucoma and developmental delay. MDCT brain axial images showing gyri form cortico-subcortical calcifications in bilateral cerebral hemispheres, enlarged bilateral choroid plexus, left cerebral hemi atrophy and diffuse calvarial thickening.

Acute neurological deficit

The clinical symptoms are often acute motor deficit, hemiplegia or monoplegia, or aphasia. We are mainly looking for a cerebrovascular accident (CVA) (Figures 5).

As for adults, the emergency scanner is sometimes normal in the first hours. MRI with MRI Angio shows characteristic abnormalities in diffusion sequence. There are many causes of stroke in children: heart disease embolism genes, sickle cell disease, thrombosing diseases, arterial malformations.

An increasingly recognized etiology is postinfectious vasculopathy, particularly post-varicella. In this case, a characteristic inflammatory lesion of the M1 segment of the sylvian artery with unilateral infarction of the basal ganglia (often the putamen and/or the caudate nucleus). These strokes can be observed up to 4 months after the initial infection. They generally evolve favorably with almost total regression of the symptoms, due to cerebral plasticity, which is all the greater when the child is young.

More rarely, the acute neurological deficit may be related to neuritis (Guillain-Barré syndrome), unrecognized trauma, a tumor, or even a metabolic disease or encephalitis.

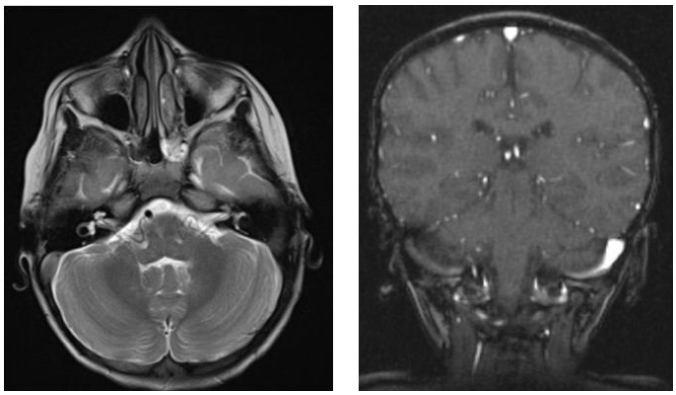


Figure 5: A 5-year-old male patient presenting with vomiting, drowsiness and neck pain.

A. T2W axial MR image showing lack of flow void in the right transverse sinus, sigmoid sinus and jugular bulb.

B. MRV coronal MR image showing lack of flow related enhancement (thrombosis) in the right transverse sinus, sigmoid sinus and jugular bulb.

Acute spinal cord syndrome [10] (Figure 6)

This is the only real emergency in MRI. Spinal cord compressions are often caused by extramedullary tumors; the most common being neuroblastoma. Peri medullary hematomas are possible in certain contexts, in hemophiliacs and during obstetrics. Intramedullary tumors are mostly seen in adolescents and are responsible for progressive symptomatology.

In the absence of intradural tumor, one must think of myelitis, in particular of inflammatory origin; in this context, it is necessary to carry out a complete study of the spine with STIR sequences, looking for plaques or intramedullary signal abnormalities (transverse myelitis, MS plaques). In this context, it is essential to perform at least one FLAIR sequence on the brain in search of subclinical supra or sub tentorial plaques.

The other causes of myelitis are of infectious origin, post-infectious or of ischemic origin.

Non-traumatic acute recurrent torticollis must also eliminate a tumor of the cervical cord, a tumor of the posterior fossa or a Chiari I malformation.

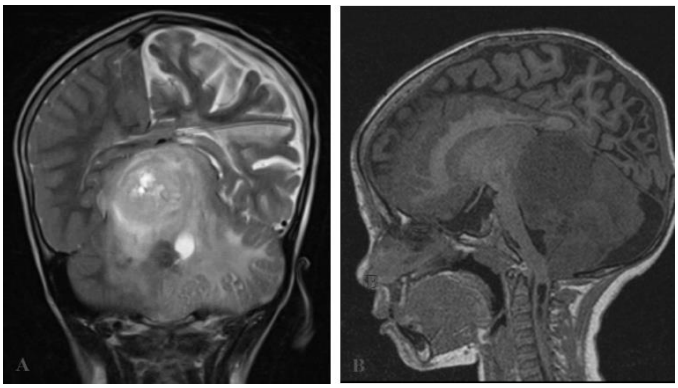


Figure 6: Known case of Neurofibromatosis type1 in a 6-year-old female patient presenting with recurrent seizures and s/p VP shunting.

A. T2W coronal MR image and B. T1W sagittal MR image showing following findings –

- Bulky cerebellum and multiple ill-defined enhancing lesions with moderate perilesional edema and causing mass effect -? gliomas.
- Left cerebral hemisphere appearing relatively bulky with prominence of cortical sulci and gliosis in the left occipital lobe.

- Prominent cisterna magna.

Hydrocephalus

Acute Hydrocephalus

Hydrocephalus can be caused by either overproduction of cerebrospinal fluid (CSF) by a tumor such as choroid plexus papilloma, by an obstruction to normal CSF flow, or by decreased CSF absorption. The latter two problems result in "obstructive hydrocephalus." Obstructive hydrocephalus can be further divided into communicating hydrocephalus, where there is obstruction to CSF flow or diminished CSF absorption, and noncommunicating hydrocephalus, where there is intraventricular obstruction to CSF flow. [11]

In the emergency setting, there are 2 common scenarios that often warrant imaging: (1) the child with shunted hydrocephalus, and (2) the acute presentation of noncommunicating hydrocephalus.

Child with Shunted Hydrocephalus

The child with known shunted hydrocephalus can present with nausea, vomiting, irritability, fever, altered level of consciousness, or increased seizure frequency. Papilledema, cranial nerve palsies, hyperactive reflexes, and ataxic gait may be found on examination. Infants may present with increased head circumference, a bulging fontanelle, or splayed cranial sutures. Neurosurgical consultation is mandatory if shunt malfunction is clinically suspected. Ultrasound can be considered in the young infant with large, open fontanelles in this setting. However, in most cases, CT is the modality of choice because of its ready availability, ability to detect changes in ventricular size and configuration, easy identification of intracranial hemorrhage or infarction, shunt catheter discontinuity in the skull and upper neck, and catheter migration. A low-dose CT technique can be used to minimize radiation risks in these patients, especially those in whom multiple CT scans are required over their life span. [12,13].

Acute Presentation of Noncommunicating Hydrocephalus (Figure7)

Noncommunicating hydrocephalus is caused by intraventricular obstruction of CSF flow. Obstruction sites are most located where the CSF pathway is narrowest, namely at the foramen of Monro, cerebral aqueduct, and fourth ventricle and its outflow foramina. In the child, tumors are a common cause of such obstruction. [14]

MRI is the imaging modality of choice in these cases, although CT can identify many of these lesions as an initial screen in the emergency room and can demonstrate hydrocephalus. Though rare, primary and secondary tumors (leptomeningeal metastases) in the spine and spinal cord can cause hydrocephalus. The spine should therefore be imaged in all cases of new-onset unexplained hydrocephalus. [14]

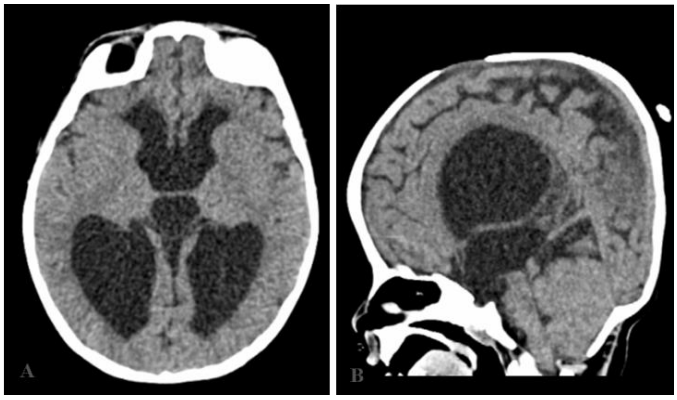


Figure 7: A 1-year-old female patient who is post-operative case of meningomyelocele with hydrocephalus.

A. Axial CT image and B**.** sagittal CT image showing –

- Dilated bilateral lateral ventricles and third ventricle, with normal sized fourth ventricle – s/o obstructive hydrocephalous.

- Diffusely atrophic bilateral cerebral parenchyma.
- Widening of diaphragm sella.
- Thinning of corpus callosum.

Traumatic neurological emergencies

Head trauma: (Figure 8)

Head trauma is the most common neurological emergency in pediatrics. The master's classification used in adults is ill-suited, because vomiting is very frequent in children, even after minimal trauma. Thus, the decision tree used in most pediatric centers has been simplified: skull X-ray is only indicated in the event of proven or suspected abuse.[15]

The brain scan is indicated at the slightest sign of seriousness:

- Repeated or worsening vomiting aggressive, or prolonged for several hours; - Focal neurological signs; - Altered state of consciousness; - Loss of consciousness; - Penetrating lesion or severe wound of the face; - Polytrauma; - Abuse, looking for intracranial lesions.

In children under 2 years of age, intracranial lesions with few or no symptoms are relatively frequent, and the clinical examination is more difficult, which calls for caution [16].

Thus, in children under 2 years of age, the clinical signs considered predictive of intracranial lesion are expanded and include, in addition to the previous items, the presence of a skull fracture marked by swelling of the scalp, drowsiness, irritability or any change in usual behavior, a bulging fontanel, seizures, young age and no clear history of trauma [15,17,18].

Thus, the younger the child, the more severe the clinical signs, the greater the shock (road accident, fall from a great height or on a hard surface, swelling of the scalp), easier the scanner should be performed. [19]

MRI is useful especially in case of discrepancy between the clinical state and the circumstances of the accident (from the perspective of abuse), or in case of normality of the scanner. In the absence of easily available MRI, a second CT scan 24 hours from the first is necessary in the event of discrepancy between the clinical state and a first normal imaging.

Finally, the cranial scanner must be systematically supplemented by sections on the cervical spine if the cranial trauma is serious (Glasgow < 8).

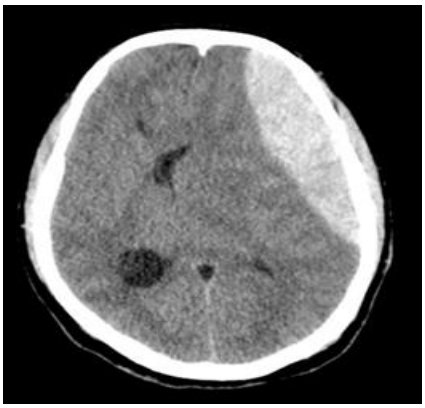


Figure 8: A 12-year-old child with history of trauma, Axial CT brain shows a large biconvex epidural hematoma in the left fronto-temporal region causing mass effect and midline shift.

There is linear fracture in right temporal and frontal bone with associated blow out fracture of right orbit.

Peripartum emergencies

This is a particularly difficult age group, not technically where the immobilization of children is generally easy without any sedation, but clinically where the symptoms are mild. Imaging should always be easy, at the slightest clinical sign, which is often limited to seizures.

Obstetrical trauma is not the domain of ultrasound but of CT scan; subarachnoid hemorrhage and hematoma of the tentorium of the cerebellum are common, but we can also observe diffuse subdural hematomas and embrittlement.

The diagnosis is very simple, and the clinical evolution of these traumatic lesions is generally very favorable (subject to a neurosurgical opinion) (Figure 9).

On the other hand, cerebral lesions resulting from acute fetal distress are difficult to diagnose in term neonates because of the almost non-existent myelination: the scanner is difficult to interpret; ultrasound is not very effective in full-term newborns because the lesions can be peripheral or cortical (unlike premature babies)

MRI is necessary and poses the problem of the transport of these children, of surveillance in the machine. The lesions observed are mainly located in the gray nuclei, the thalamus and the posterior arms of the internal capsules as well as in the cortex, mainly in the peri Rolandic regions. They pose the problem of their prognosis and the hypersignal in T1 is a pejorative element [20] Acute fetal distress can also be accompanied by an "adult type" stroke. Half of these strokes have no etiology found, despite an exhaustive investigation, and they are in the vast majority of cases in the superficial and deep Sylvian territory. Convulsions without fever can also be the expression of meningitis already complicated by encephalitis lesions and/or arterial and venous infarctions.

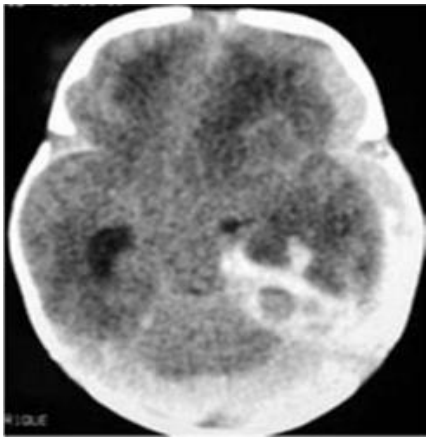


Figure 9: Compressive peri cerebellar hematoma, hemorrhage from the tentorium of the cerebellum, left fronto-temporal subdural hematoma driving back the midline with engagement under the falcoriel of the left lateral ventricle

Conclusion

Physicians not formally trained in radiology play a critical role in the evaluation of children presenting to the ED with neurologic emergencies. Knowledge of the imaging protocol and findings, pearls, pitfalls, and differential diagnosis for some of the common pediatric neurologic emergencies can allow for prompt diagnosis, which can potentially be lifesaving.

Neuroimaging is the key in pediatric emergencies. The advancement in newer modalities of technology should be put into use more as a combined approach in diagnosis, management and prognostication as well as for early intervention to improve functional and psycho logical outcomes.

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