Emergency Paediatric Head and Neck

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Abstract

Imaging in the emergency setting is a distinct entity from other types of radiology practice, with its own challenges and pitfalls. There are unique imaging features in emergency paediatric head and neck imaging, of which radiologists ought to be aware to ensure timely and accurate reporting of these diseases. In this chapter, we will discuss these specific features and provide the reader with useful advice.

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Abbreviation

CCJ	Craniocervical junction
CSF	Cerebrospinal fluid
CT	Computed tomography
DWI	Diffusion weighted imaging
GMH	Germinal matrix haemorrhage
HIE	Hypoxic ischaemic encephalopathy
MCA	Middle cerebral artery
MRI	Magnetic resonance imaging
MRS	MR-spectroscopy
NAI	Non-accidental injury
SWI	Susceptibility weighted imaging

1 Imaging Modalities in Paediatrics

1.1 Plain Film

Outside of non-accidental injury (NAI) (see chapter "Acute Stroke: Management"), plain film plays a limited role in the assessment of non-traumatic paediatric emergency imaging (Culotta et al. 2016).

1.2 CT/CTA

For definitive diagnosis of the various presentations discussed in this chapter, CT and MRI are the investigations of choice. The recommended protocol for adequate assessment of the paediatric head is multiplanar 0.5 mm slice acquisition with 3D reformats if skull lesions are under assessment.

1.3 MRI

MRI assessment is a powerful tool for initial presentation or further characterisation of lesions within the head. It is recommended that local protocol is followed regarding the specific sequences to acquire.

1.4 Points for Consideration

- Pathology of the paediatric head and neck, especially in trauma, can be very subtle and difficult to assess. Without using the appropriate imaging modality and, with regards to CT, the appropriate reconstruction algorithms, it can be impossible to see certain pathologies.
- Plain radiographs—every effort should be made to make this patient group feel comfortable and settled to ensure adequate images without the need for repeat imaging, with its associated dose penalty (Halliday et al. 2016).
- Good communication with paediatricians will provide a wealth of knowledge and clinical expertise. Often, the information on a request card will be limited and insufficient to provide useful, diagnostic report; contact with the referring clinician can make a substantial difference.
- "Children are not little adults". This is common knowledge in paediatrics, and it is just as relevant in paediatric radiology.

2 Traumatic Pathology

2.1 Head

CT is the modality of choice for traumatic head pathology. The authors of this chapter feel it is essential to obtain thin slice (0.5 mm) acquisitions with 3D bone reformats to reduce the possibility of missing subtle pathology, or mistaking them for normal anatomy or variants.

Fractures, sutures, and wormian bones are the most common causes of a cortical 'defect' in a child's skull seen on CT (Sanchez et al. 2010). Excellent knowledge of the paediatric cranial sutures, as seen in Fig. 1, is essential to differentiate between fracture and normal anatomy.

Sutures will show ossification along their length and will have a complex 'zig-zag' serrated edge. Viewing the soft tissue windows helps to highlight any extracranial subcutaneous collection/haematoma to help direct your assessment to the adjacent skull in search of a fracture.

Wormian bones are often small and sometimes numerous bones are seen within normal cranial sutures, for example, mostly commonly along the lambdoid suture. They may also be seen centrally within the fontanelles as bony islands. Wormian bones can be a normal anatomical variant, but sometimes associated with con-

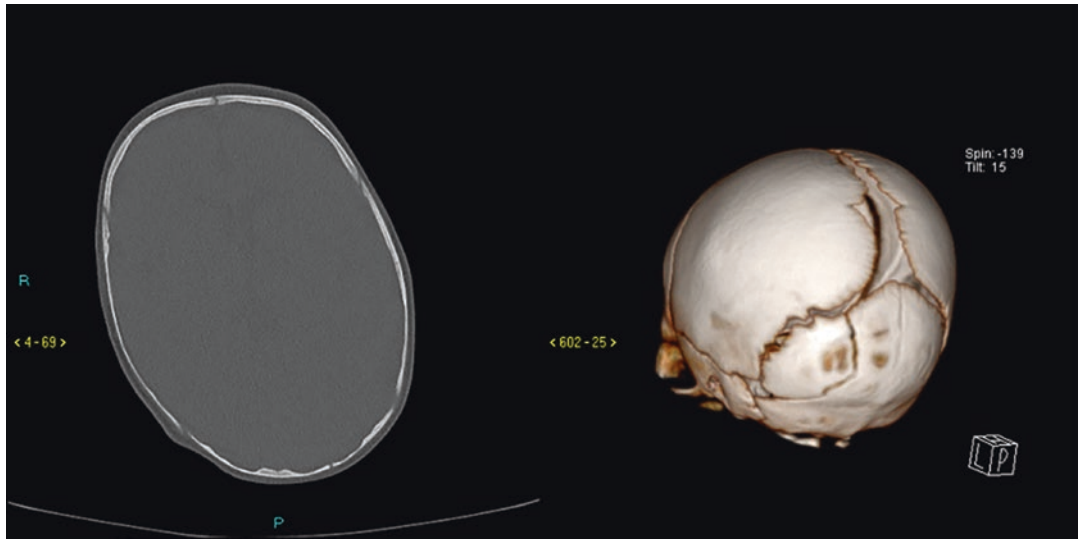

Fig. 1 Left: Thin slice CT head (bone reformat) showing an asymmetrical defect in the left occipital bone. Right: 3D reconstruction demonstrates an accessory left occipital suture

ditions such as osteogenesis imperfecta and Down syndrome; however, it is usually considered normal if less than 10 are present up to the age of 6 months (Marti et al. 2013).

Traumatic intracranial haemorrhage follows similar principles to imaging adult head trauma; however, clinical signs and symptoms may differ and neurological assessment may be less reliable. It is important to have a low threshold to image children who have suffered traumatic head injury. Extra-axial haematoma is less common in children due to the shallow position of the middle meningeal artery and the adherent strength of the dura mater to the inner skull. Although not as common, it should not be disregarded that an extra-axial arterial haematoma can be life-threatening. Subdural haematoma is more common (Araki et al. 2017), especially in NAI cases as discussed previously. Other consequences of traumatic brain injury include brain parenchymal contusions, subarachnoid haemorrhage, and intraventricular haemorrhage, which should be evaluated in a similar way to adult imaging.

2.2 Cervical Spine

In this section, we will focus on the key features of traumatic injury that are unique to children (Lustrin et al. 2003). First, children suffer more from craniocervical junction (CCJ) injuries and more upper cervical injuries than adults. In fact, 90% of cervical fractures below age 8 are located between the CCJ and the fourth cervical vertebra (McAllister et al. 2019). However, in the adult population, there is a rough equal distribution of injury in the upper and lower cervical spine.

The relative prevalence of soft tissue injury/dislocation and fractures represents another important distinction between adult and paediatric cervical injuries. For patients under the age of 8, soft tissue injuries and dislocations constitute the majority of traumatic injuries (McAllister et al. 2019). However, in the adult population, this is reversed, with fractures being vastly more common than soft tissue injuries or dislocations.

The reason for the difference between injury pattern is due to the following key mechanical differences in the growing child:

- Large head:body ratio results in translation of momentum-related injury to the upper cervical vertebra.
- The fulcrum of movement in the paediatric c-spine is at C2-C3, whereas in adults it is C5-C6.
- The ligaments in children have great laxity, which is useful for growth, but it can predispose to dislocation.

- The cervical articular facets and the CCJ have a noticeable more horizontal orientation in children, which again predisposes to dislocation.

Atlanto-occipital dislocation is an injury worthy of particular attention as it is often fatal, and often difficult to diagnose on CT imaging, especially when an associated fracture is not present (Riascos et al. 2015). The Powers Ratio, the Basion-Axis Interval, and the Dens-Basion Interval have been considered as means of identifying an atlanto-occipital dislocation; however, their sensitivity is not sufficiently high to reliably exclude this serious finding. In our experience, the occipital condyle to C1 interval distance of more than 3 mm is the optimal means of identifying atlanto-occipital dislocation (Bertozzi et al. 2009). Care should be taken when making this measurement. In the unfused skeleton of young children, the medial and lateral aspects of the occipital condyle to C1 have notably different intervals. Taking measurements at the medial aspect will falsely overestimate the interval as there is non-ossified hyaline cartilage in this space that cannot be appreciated on CT imaging. Therefore, in order to avoid false positives, measurements should be taken at the lateral aspect of the occipital condyle to C1 interval (Figs. 2 and 3).

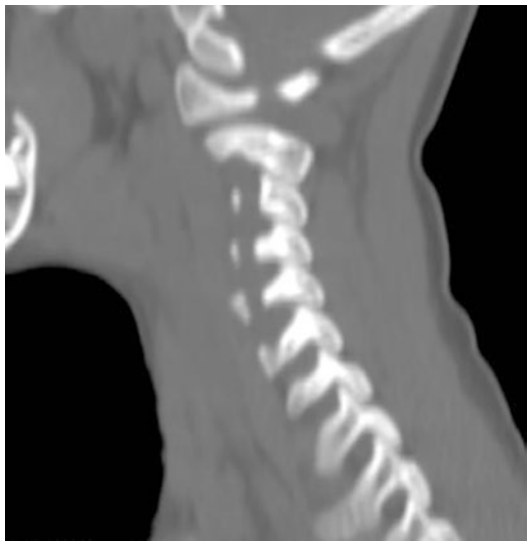

Fig. 2 Normal occipital condyle to atlas distance

Specific attention should be paid to the predental space. The predental space is anatomical compartment between the odontoid peg and the anterior arch of the C1 vertebra. It should measure less than 5 mm in patients 8 years or under and should be less than 3 mm in patients over 8 years. If the described interval is increased, disruption of the transverse ligament and/or a fractured C1 vertebra should be suspected (Fig. 4).

Having covered these specific differences between paediatric and adult cervical spine imaging, it is important to also remember that many of the principles from adult imaging also apply. Assessment of cervical alignment using the anterior vertebral line, posterior vertebral line, spinolaminar line, and posterior spinous line is a useful way of identifying dislocations and fractures (Guarnieri et al. 2016). Evaluating the prevertebral soft tissue for thickening is an important clue for occult fractures. Radiologists should also pay close attention to the airway as foreign bodies causing airway obstruction are a rare, but important finding.

3 Non-traumatic Pathology

3.1 Cerebrovascular Disease and Stroke

Although much more commonly a disease of adults, stroke is becoming increasingly common in the paediatric population, possibly due to the increased sensitivity of imaging modalities, with incidences up to 3/100,000. Children often present slightly later than adults (over 24 h) with non-specific lethargy, coma, irritability often obscuring more subtle focal neurological deficits (Clinical Standards and Quality Improvement team 2017).

Childhood stroke is differentiated into ischaemic and haemorrhagic aetiologies shown in Box 1 (Tables 1 and 2; Figs. 5, 6, and 7).

Ultrasound is less widely used for childhood stroke in the acute setting, but a hyperechoic vascular territory may be seen in neonates with open sutures (Donahue et al. 2019). Ultrasound is

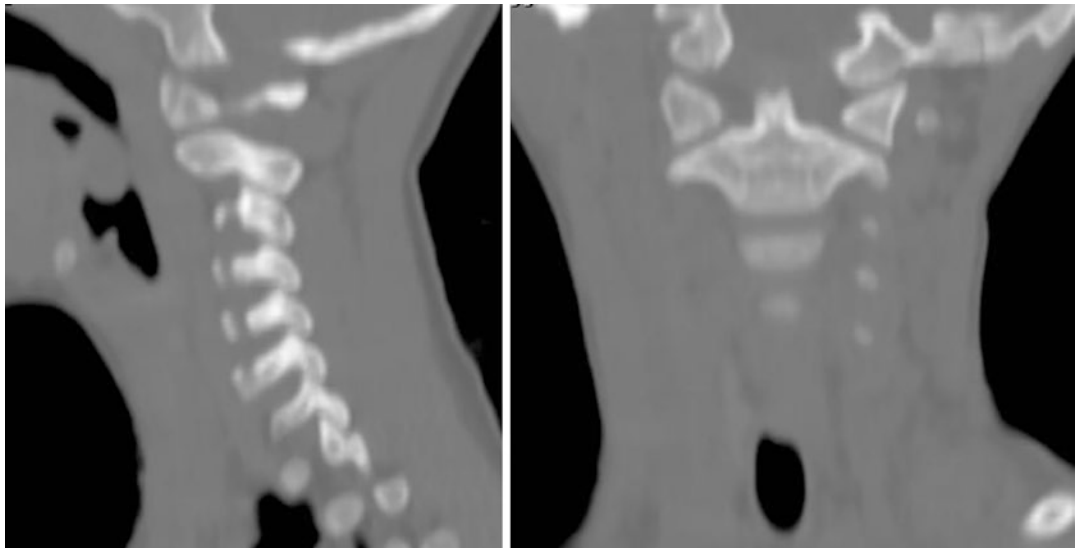

Fig. 3 Sagittal and coronal CT reformats showing a widened occipital condyle to atlas distance

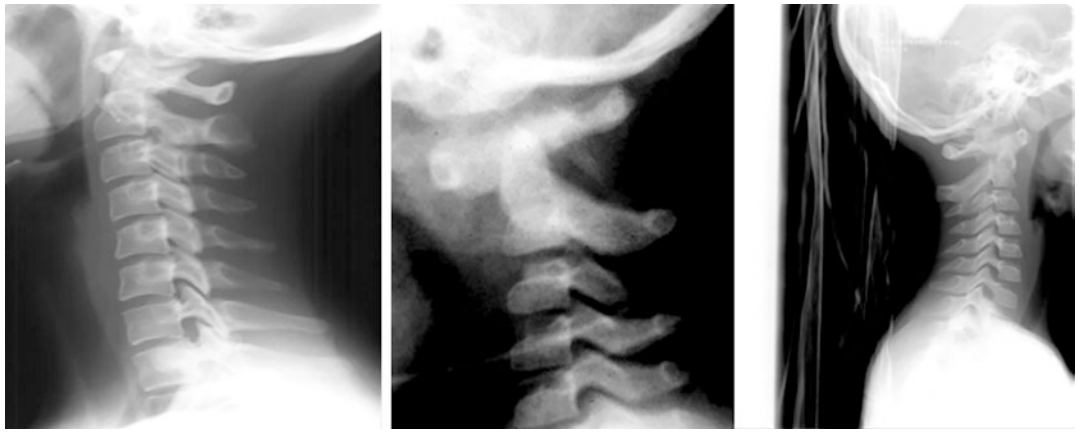

Fig. 4 Left: lateral C-spine X-ray showing predental space. Middle: lateral c-spine X-ray showing a widened predental space. Right: lateral c-spine X-ray showing a fractured odontoid process

Table 1 Ischaemic causes of childhood stroke

• Cardiac disease (50%)
• Infections (Varicella)
• Arterial dissection
• Moyamoya-type arteriopathy (sickle cell disease, neurofibromatosis type 1, or idiopathic)
• CNS vasculitis.
• Coagulopathy
• Idiopathic (~25%)
• Venous sinus thrombosis due to infection, fever, dehydration, coagulopathies (Dlamini et al. 2010)

Table 2 Haemorrhagic causes of childhood stroke

• Haemorrhagic disease of the newborn
• Ruptured arteriovenous malformation
• Ruptured cavernoma

utilised for screening of children with sickle cell disease and Doppler assessment of the circle of Willis provides information on vascular stenosis or occlusion (Fig. 8).

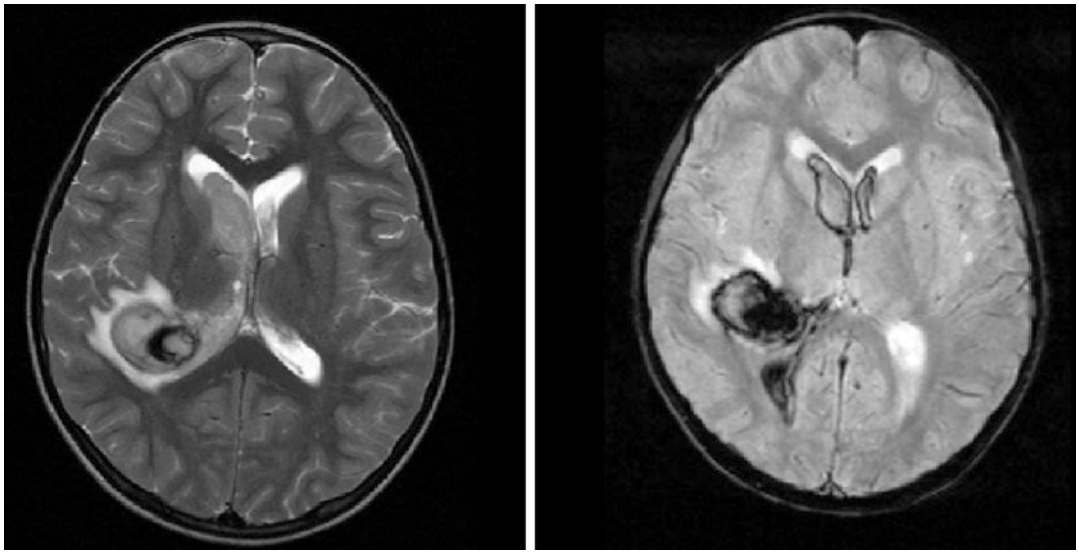

Fig. 5 Acute intracerebral haemorrhage. Right: Axial T2 MRI showing intermediate signal haematoma with extension into the right lateral ventricle. Left: Axial T2* Gradient Echo showing low signal hemosiderin within the haematoma

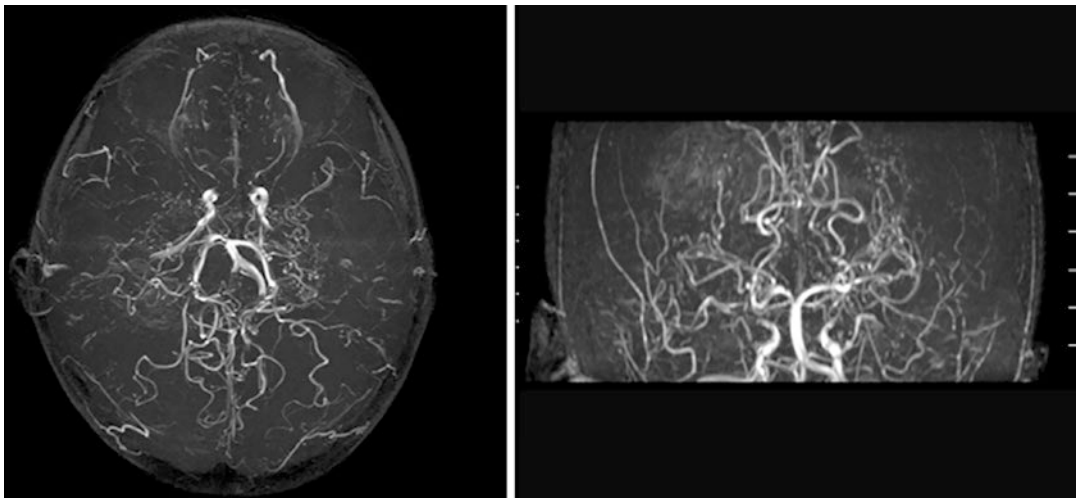

Fig. 6 Moyamoya disease. Time of Flight 3D vessel reconstruction shows tapering of the distal internal carotid arteries and multiple small vascular collaterals

An acute presentation with the clinical features described above would prompt initial investigation with CT, much the same as the adult population, to exclude haemorrhagic causes. The imaging findings in childhood stroke are similar to those in adults including loss of grey-white matter differentiation, dense middle cerebral artery (MCA) sign, insula ribbon low attenuation (Tomandl et al. 2003), acute low T1 signal, high T2 FLAIR signal, and restricted diffusion on DWI (Allen et al. 2012).

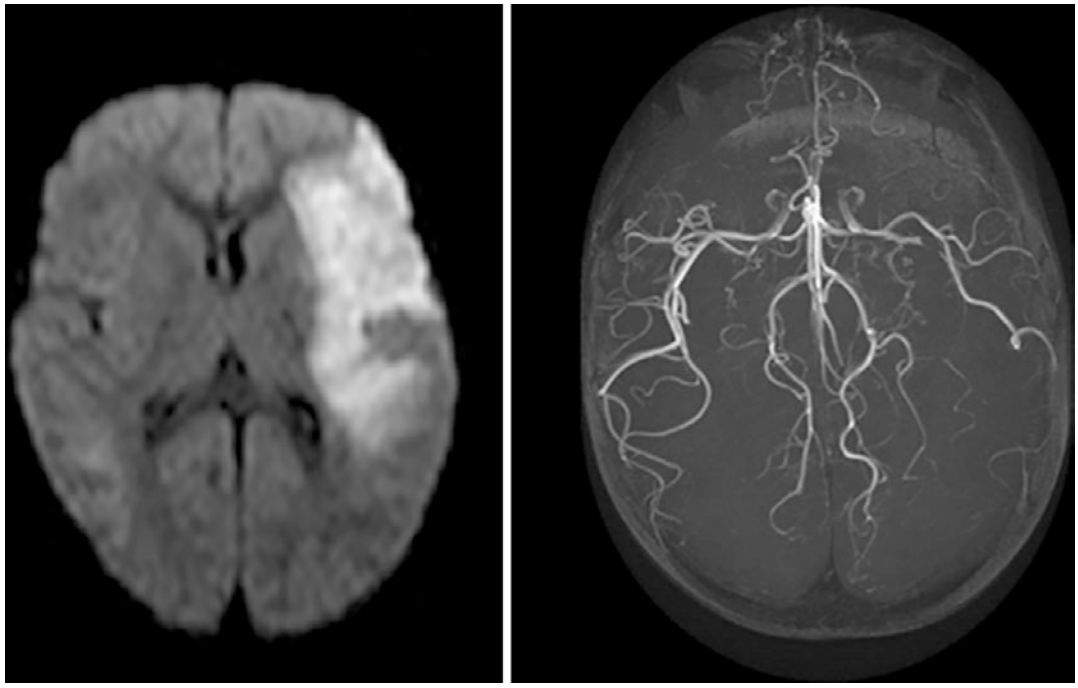

Fig. 7 Acute Left MCA Infarct. Right: MRI diffusion weighted imaging shows restricted diffusion in the left MCA territory. Left: 3D vessel reconstruction showing an abrupt end to the left MCA, suggestive of a filling defect caused most likely by a thrombus

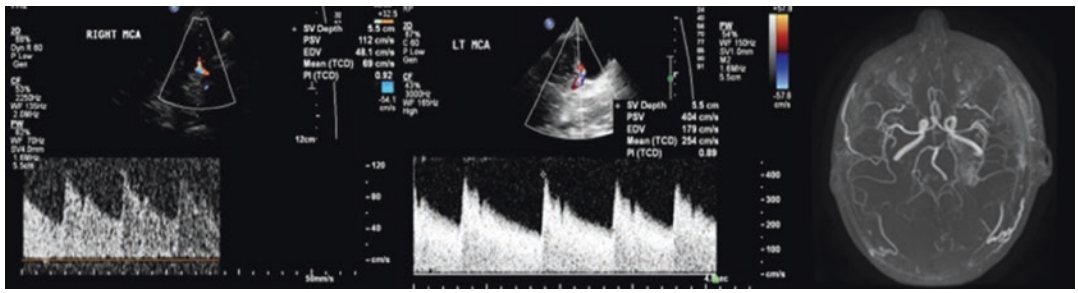

Fig. 8 Right: normal right MCA flow. Middle: stenotic flow in the left MCA. Left: 3D vessel reconstruction showing a narrowed left MCA

4 Non-traumatic Intracranial Haemorrhage

Trauma is the most common cause of paediatric intracranial haemorrhage; however, there are a few important non-traumatic aetiologies which could lead to similar emergency presentations.

4.1 Germinal Matrix Haemorrhage (GMH)

GMH is the most common non-traumatic cause of intracranial haemorrhage in neonates and rarely occurs beyond 32 weeks. It can be due to a number of differing conditions such as coagu-

lopathy, increased central venous pressure, and capillary fragility.

Grading of GMH is done by sonographic assessment and split into four classifications. Grade 1 GMH is high echogenicity confined to the caudothalamic groove. Grade 2 sees extension into normal-sized ventricles up to half full. In grade 3, the ventricles dilate, and in grade 4, there is parenchymal haemorrhage (Roelants-van Rijn et al. 2001). Grade 3 GMH holds a mortality of up to 20% with grade 4 increasing up to 90% (Figs. 9, 10, 11, and 12).

4.2 Cavernous Malformation

Cavernous malformations, which were once known as cavernous haemangiomas or cavernomas, are dilated vascular channels that can occur in either the brain or the spinal cord. These

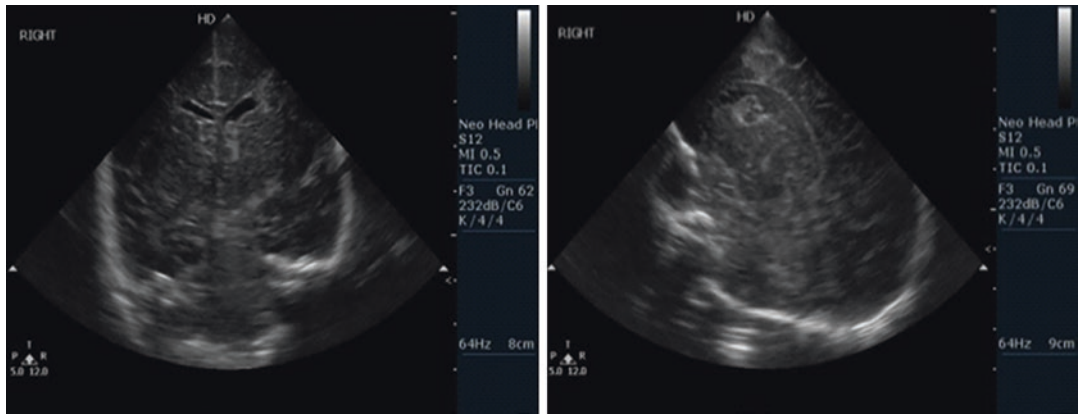

Fig. 9 Grade I Germinal Matrix Haemorrhage. Intracranial ultrasound, coronal (left) and sagittal (right) views, showing high echogenicity haemorrhagic material at the caudothalamic groove

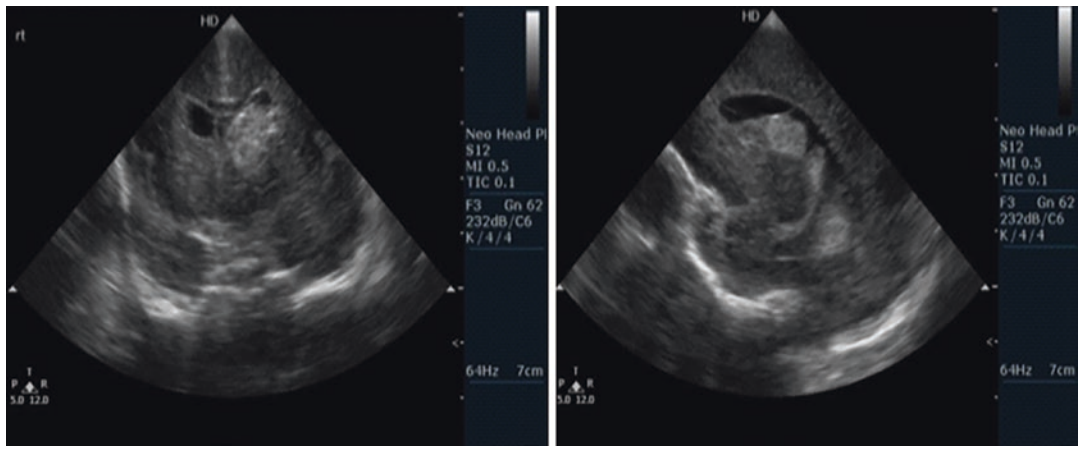

Fig. 10 Grade II Germinal Matrix Haemorrhage. Haemorrhagic material is seen extending from the caudothalamic groove into the left lateral ventricle, without dilation of the ventricles

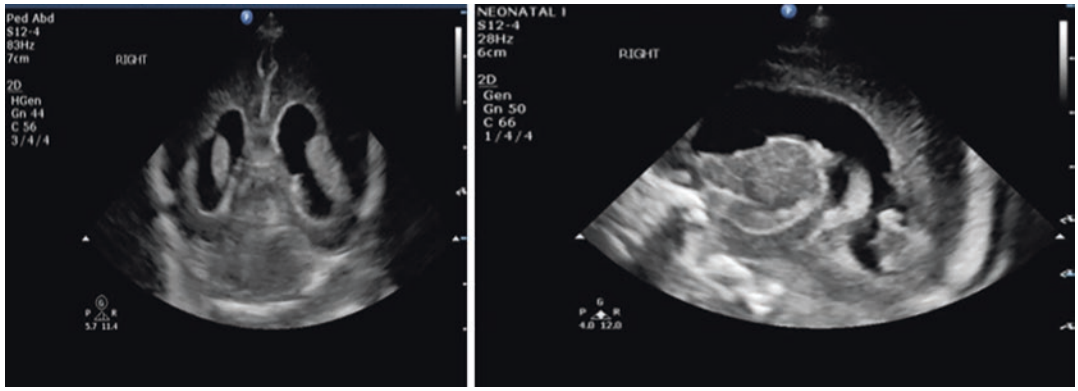

Fig. 11 Grade III Germinal Matrix Haemorrhage. Haemorrhagic material extending from the caudothalamic groove into both lateral ventricles with associated bilateral ventricular dilation

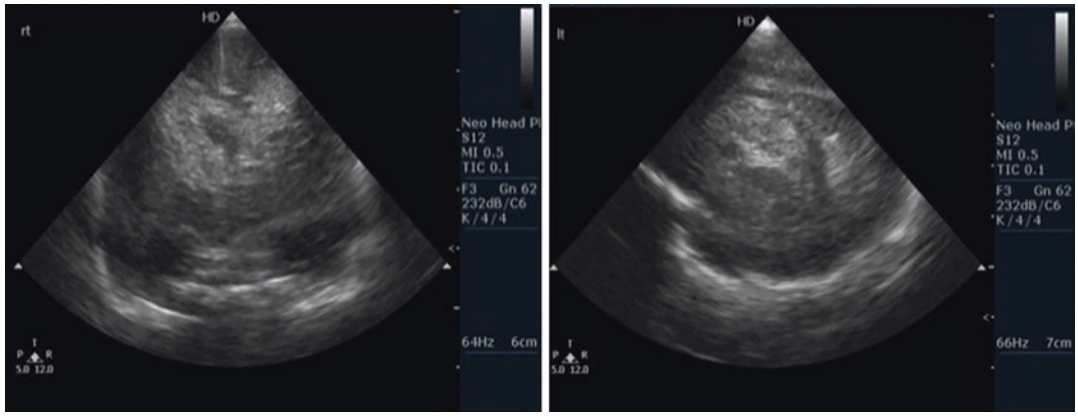

Fig. 12 Grade IV Germinal Matrix Haemorrhage. High echogenicity haemorrhagic material seen to completely opacify the bilateral dilated ventricular system, with periventricular intra-parenchymal haemorrhage

dilated vascular channels are partially thrombosed and surrounded by blood products (haemosiderin). Cavernous malformations typically arise sporadically, but can be inherited. In cases of familial inheritance, there is a greater likelihood that these lesions will be multiple as opposed to solitary. The clinical concern associated with cavernous malformations is their predilection to haemorrhage, which ranges from microscopic subclinical bleeding to life-threatened haemorrhage.

Cavernous malformations are associated with developmental venous anomalies. These are a collection of abnormal cerebral veins, which increase the risk of haemorrhage beyond that of an isolated cavernous malformation.

A rounded hyperdense lesion on CT is consistent with a cavernous malformation; however, this imaging modality does not show the characteristic features of this finding. MR imaging is the modality of choice for cavernous malformations. The characteristic findings include a "popcorn" appearance on T1 weighted imaging indicating blood of different ages, with a low signal rim on T2 due to the haemosiderin, and signal drop out on either susceptibility weighted imaging or gradient echo sequences (Wang et al. 2017). The above describes the appearance of

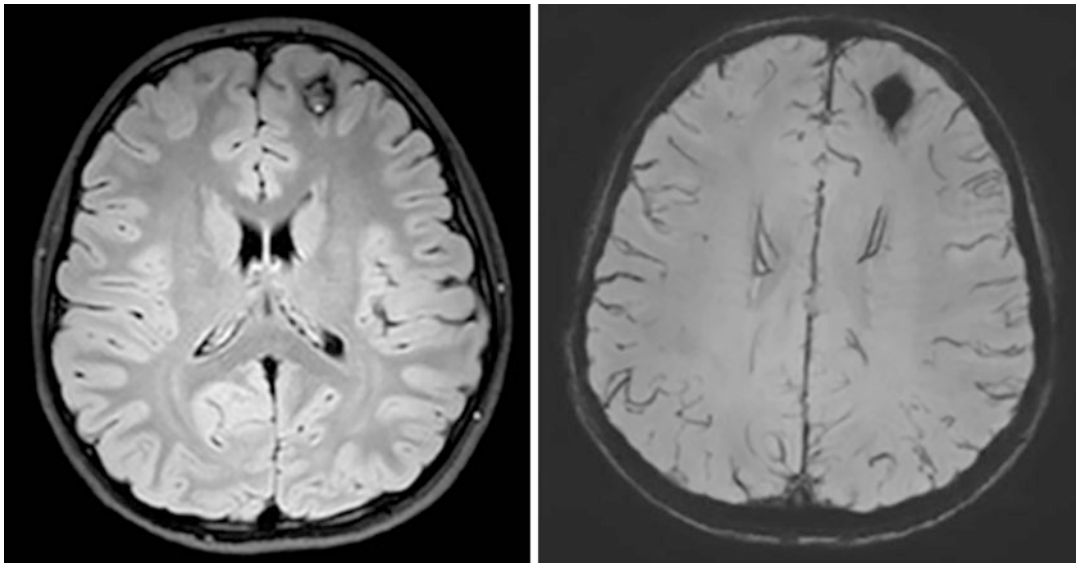

Fig. 13 Cerebral cavernous malformation. Left: Axial susceptibility weighted image (SWI) showing striking hypointense "blooming" artefact surrounding "popcorn" mixed signal core. Right: SWI showing uniform blooming artefact throughout the lesion

cavernous malformations in their non-pathological state. In the emergency setting, the presentation will include a haemorrhage accompanying the lesion (Fig. 13).

4.3 Hypoxic Ischaemic Encephalopathy (HIE)

Hypoxic ischaemic insult can lead to brain injury in neonates in up to 2 in 1000 live births. The two patterns of disease (central and peripheral) are dependent on the severity and duration of hypoxia.

Central HIE is associated with severe hypoxia of short duration, leading to injury within the hippocampus, basal ganglia, thalamus, and perirolandic region. Peripheral HIE occurs more insidiously with less obvious aetiologies, primarily affecting the less metabolically active watershed regions.

CT features of HIE include early loss of grey-white differentiation and low density within the deep grey nuclei with late features of encephalomalacia/volume loss (Shahina et al. 2017).

The best imaging modality is MRI with DWI and MR-spectroscopy (MRS) after the first 24 h: T1 and T2 will return normal signal in the acute setting (1–2 days), but then both increase from day 3; DWI shows restricted diffusion in the first week and MRS shows low N-acetyl aspartate (NAA) and high lactate in affected areas (Shahina et al. 2017) (Fig. 14).

4.4 Hydrocephalus

Hydrocephalus is a term used to describe a clinical finding that has various aetiologies. Hydrocephalus refers to an excessive volume of cerebrospinal fluid (CSF) contained within the ventricular spaces. The majority of causes can be divided into non-obstructive and obstructive aetiologies (Cinalli et al. 2005):

- Non-obstructive hydrocephalus is also known as communicating hydrocephalus. This collection of diseases are caused by an irritant-inducing fibrosis and therefore occlusion of the subarachnoid drainage mechanism. The "irritant" is most commonly haemorrhage, but can also be suppurative meningitis, or neoplastic exudates.

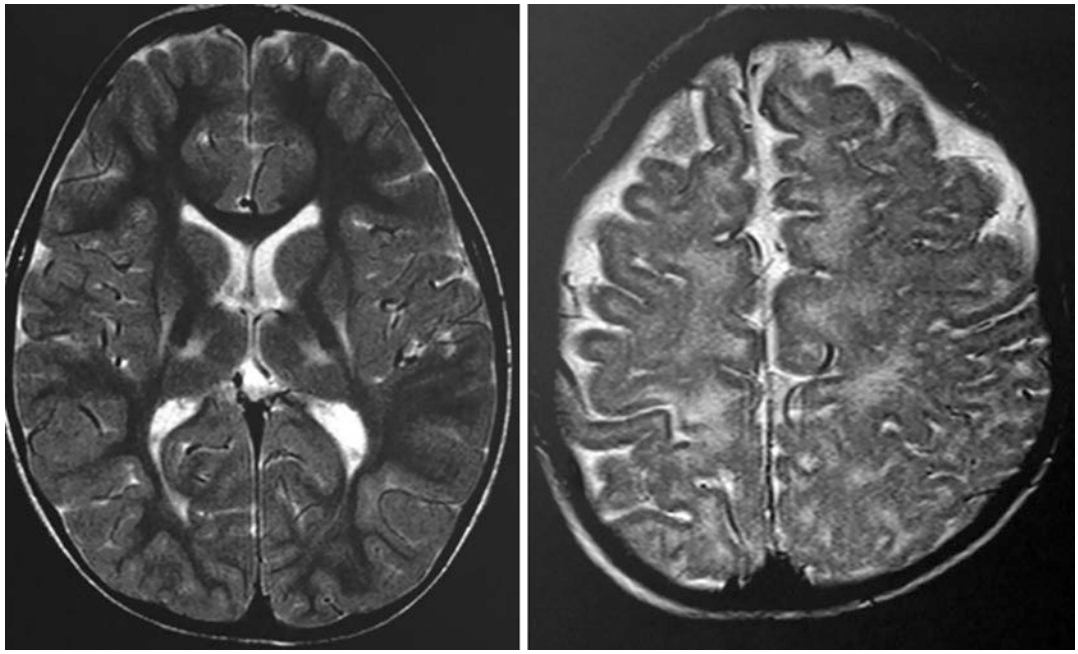

Fig. 14 Previous perinatal hypoxic ischemic injury. Bilateral volume loss with gliosis involving the antero-lateral thalamus and the posteromedial lentiform nucleus with gliosis in the perirolandic subcortical white mater

- Obstructive hydrocephalus, which is also referred to as non-communicating hydrocephalus, describes a collection of diseases with a differing pathophysiological mechanism, but the same end result of dilated CSF spaces. As the name suggests, an obstructive or compressive mass causes occlusion of the draining CSF pathway and therefore dilation of the proximal chambers. Congenital hydrocephalus may arise from aqueductal stenosis, or from various posterior fossa malformations. The spectrum of Arnold-Chiari malformations and Dandy-Walker malformations are especially relevant in the paediatric setting. An obstructive tumour or a colloid cyst is another cause of relevance in the child/young adult.

Although rare, a choroid plexus tumour is an important differential to exclude in the paediatric setting (Jaiswal et al. 2009). A choroid plexus tumour is an overgrowth of the CSF producing tissues, as such it causes hydrocephalus because it excessively produces CSF, at a rate beyond which it can be excreted.

Choroid plexus tumours are the most common brain tumour in a child under 1 year of age. On imaging, they appear as a lobulated mass in the ventricle (most commonly the lateral ventricle).

Dilatation of the subarachnoid spaces may be a normal finding in the neonate. The underlying physiology is not well-understood; however, the widely accepted theory is that the developing drainage pathways cannot promptly divert the CSF during the first year of life, leading to CSF accumulation in the subarachnoid space. This is an incidental and self-limiting finding, for which no treatment is necessary.

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