Multifocal subpial hemorrhages in the neonate - Ultrasound-MRI correlation and an up to date review of the literature.

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Purpose

To highlight the pathophysiology of neonatal subpial hemorrhages (NSH) and describe their imaging features, both on ultrasound and MRI via case examples.

Introduction

Subpial hemorrhage is a rare type of intracranial hemorrhage and should be considered in the differential diagnosis in neonates when peripherally located hemorrhages are seen. They can occur both in term and preterm infants.

The pathophysiology of NSH is incompletely understood and has been proposed to be due to disruption of the glial limitans end-feet or glial precursors, leading to disruption of the basement membrane, tearing of subpial vessels and the subsequent pooling of blood within the subpial space (Barreto, 2021). Other theories include medullary venous compression or injury, arterial occlusion with hemorrhagic infarction and hemorrhagic venous infarction, cortical contusion related to parturitional trauma, or traumatic venous injury (Huang, 2004 and Dabrowski, 2021). Clinical risk factors for development of NSH include birth trauma, neurosurgical intervention, cardiorespiratory failure, hypoxic-ischemic encephalopathy, intraventricular hemorrhage and ischemic stroke (Dabrowski, 2021). Nonaccidental trauma has also been a previously reported association.

Distinct findings on US and MRI provide clues to the diagnosis of NSH on imaging. Data on developmental outcomes in NSH also remains incomplete with conflicting evidence in the literature with varying degrees of development delay reported by different case series. Temporal lobe is the most common location for NSH. The extension or recurrence of NSH is rare.

Neurosonography is a well-established imaging modality in both term and preterm infants to detect abnormalities ranging from hemorrhage to ischemia. It is an easy bedside tool in contrast to MRI. Imaging of the brain can be performed via different fontanelle of the skull including the anterior, posterior and the mastoid fontanelles. NSH are can be readily delineated if visible through the above skull windows. Oftentimes US is a helpful modality to follow the evolution of NSH.

MRI offers superior evaluation of not only the hemorrhage but also changes in the underlying parenchyma and is the modality of choice when confirming NSH. In addition to NSH, MRI can detect additional concurrent pathologies if present. There is strong correlation of findings between US and MRI.

Multifocality in Subpial Hemorrhages

- Dabrowski et al in 2021 found that 45% of subpial hemorrhages were multifocal in their cohort of 31 patients. Similarly, a retrospective review of cases at our institution found 33% of NSH cases were multifocal.
- The frequency of multifocality in subpial hemorrhages suggests an etiology that causes widespread disruption of the glia limitans and subpial vessels (Barreto, 2021).
- We present a case example of multifocal NSH in a preterm neonate in the setting of maternal COVID-19.

Anatomy of the Subpial Space

The subpial space is the region between the pia mater and brain, spinal cord, and nerve roots and contains blood vessels with varying amount of collagen. Pial arteries run parallel to the surface of the cerebral cortex and are surrounded by a single layer of pia. They are separated from the glia limitans on the surface of the cortex by the subpial space.

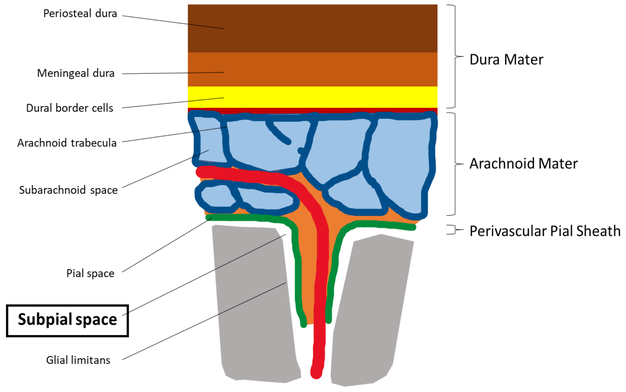

Fig 1. A diagram demonstrating the subpial space. The subpial space is a potential space between the glial limitans and pia meter. Typically closely opposed, it fills with blood products in the setting of NSH.

Key Ultrasound Imaging Characteristics

On neonatal head ultrasound, subpial hemorrhages can be identified when collections are seen closely tracking along the underlying brain parenchyma. The echogenicity of subpial hemorrhages is variable depending on the chronicity of the hemorrhage. There is usually underlying cerebral edema as well, seen initially as a focal increase in echogenicity and swelling of the subjacent cortex. Mass effect on the cortex beneath the hemorrhage is often seen.

Over time, the echogenicity of the underlying cortex decreases. The size of the collection decreases as well.

The advantages of ultrasound when compared to MRI include the cost, ease of acquisition, and exquisite detail for peripheral/superficial pathology including subpial hemorrhages.

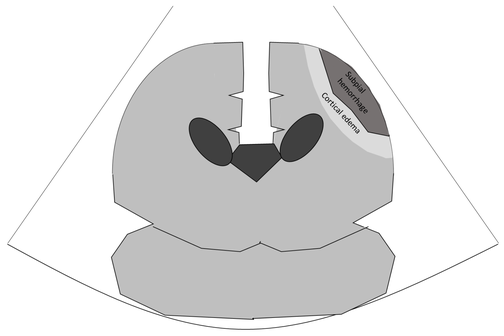

Fig 2. A diagram demonstrating the typical ultrasound appearance of a subpial hemorrhage. Often seen is a hypoechoic or mildly echogenic collection demonstrating mass effect on the subjacent rind of hyperechoic cortex.

Key MR Imaging Characteristics

On magnetic resonance images, the typical description is a peripheral, crescent or ovoid shaped collection that follows the cortical contour with increased T1 and decreased T2 and SWI signal. Additional characteristics that help distinguish subpial hemorrhages from other neonatal leptomeningeal hemorrhages include:

- Subpial hemorrhages may occur in any location, however there is a predilection towards the temporal lobe
- These hemorrhages demonstrate mass effect on and are associated with infarcts of the subjacent cortex
- There is local pooling of blood products rather than spreading along the convexity, as is typical in subarachnoid hemorrhage
- As described by Assis et al in 2020, T2 images may demonstrate a yin-yang sign where there is a focal T2 dark collection extending into the cerebral sulci and an area of underlying T2 bright compressed cortex and white matter.
- Enlarged medullary veins, denoting congestion and thrombosis. Concomitant intraventricular and intraparenchymal hemorrhages can be found, both of which are common hemorrhage locations in neonates with venous thrombosis
- MR angiograms and venograms are usually normal.

Case Images

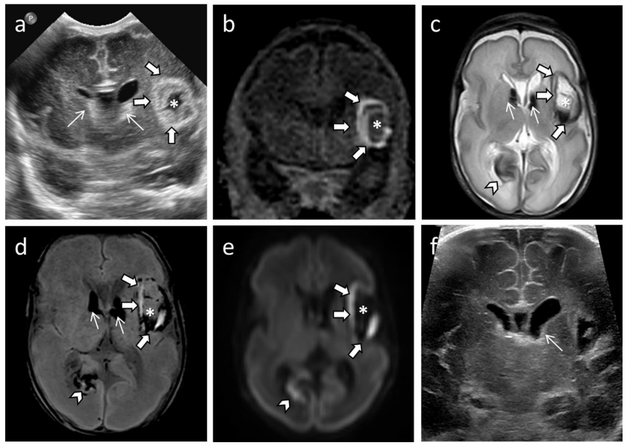

Fig 3. Baby girl born at 27 weeks in the setting of maternal preeclampsia complicated by SARS-COV-2 infection. Routine head ultrasound obtained at one month of life. Example of multifocal subpial hemorrhage.

Coronal (a) HUS images demonstrates a thick, donut-shaped echogenic rind surrounding a contained focal area of anechoic fluid with an echogenic rim (thick arrows). This is suggestive of cortical/subcortical hemorrhage/edema surrounding the subpial hemorrhage which typically occurs in the depth of the sulcus (asterisk). There is partial visualization of germinal matrix hemorrhage in bilateral caudothalamic grooves (thin arrows).

Coronal (b) T1 weighted image (T1WI) confirms the subacute hemorrhage in the insular cortex with a medial and peripheral rim of increased signal intensity consistent with parenchymal hemorrhage (thick arrows). There is a hypointense subpial collection (asterisk).

Axial T2 weighted images (T2WI) (c) and susceptibility weighted images (SWI) (d) demonstrate edema in the insular cortex (thick arrows) outlined by areas of parenchymal hemorrhage characterized by linear low signal intensity. The subpial collection has high signal intensity with a hypointense fluid-fluid level (asterisk). The bilateral germinal matrix hemorrhages are seen as low signal intensity in the caudothalamic grooves (thin arrows). Hypointensity on T2WI and SWI images related to parenchymal hemorrhage is also noted in the right medial occipital lobe (chevrons).

Axial DWI images (e) demonstrate hyperintensity corresponding to the area of underlying parenchymal edema and hemorrhage (thick arrow), subpial hemorrhage (asterisk), and occipital hemorrhage (chevron).

Coronal ultrasound images acquired approximately 2 months after (f) demonstrate gradual resolution of the hemorrhage with continued presence of the increased echogenicity in the underlying parenchyma and interval development of ex-vacuo dilatation of the frontal horn of the left lateral ventricle suggestive of encephalomalacia (thin arrow).

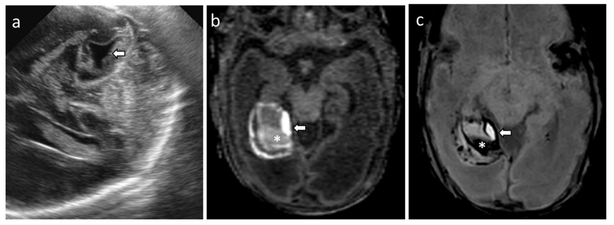

Fig 4. Right side up mastoid view (a) demonstrates an anechoic collection along the periphery of the sulci consistent with a subpial collection (thick arrow) with a rind of tissue suggestive of cortical edema in the periphery of the medial right occipital lobe. There is an echogenic medial rim surrounding the cortex and focal areas of increased cortical echogenicity suggestive of parenchymal hemorrhage.

Axial T1 weighted images (T1WI) (b) and susceptibility weighted images (SWI) (c) confirm focal edema of the cortex in the medial occipital lobe, with a focal areas of increased signal intensity on T1WI and decreased signal on SWI suggestive of parenchymal hemorrhage (asterisk). There is a medial rim of high signal intensity on T1WI and low signal intensity on SWI which is also consistent with hemorrhage. The focal peripheral area of increased signal intensity on T1 WI and SWI corresponds to blood in the subpial space (thick arrow).

Conclusion

Subpial hemorrhage is a rare type of intracranial hemorrhage, occurring in a wide variety of clinical scenarios affecting both preterm and term neonates. Multifocality is common, affecting 45% of cases in a recent case series. MRI and ultrasound are complementary to each other. On head ultrasound, subpial hemorrhages can be identified when localized collections are seen overlying a band of cortical echogenicity representing cerebral edema. Their evolution can be monitored serially on ultrasound. Confirmation of subpial hemorrhages is usually seen on MRI which can also detect additional concurrent abnormalities. Neurodevelopmental outcomes of NSH are not well understood with variable degrees of long-term neurological deficits reported in the literature, likely confounded by other concurrent injuries.

References

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