Transfontanellar ultrasound in preterm infants - a survival guide for the young radiologist on call

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Learning objectives

After studying this electronic presentation, the reader should be able to:

- Reflect the technical considerations and implement them into scanning practice;
- Understand the location of the standardized imaging planes and to know the main anatomical landmarks;
- Become familiar with the different sonographic aspects of the developing human brain;
- Know the normal variants;
- Recognize the most frequent, important and clinically relevant pathologies;
- Transfer the practical hints from the different sections of the poster into the daily routine.

Background

General considerations:

In experienced hands, the ultrasonographic examination is an invaluable tool for neonatal brain assessment, especially in preterm babies because it can provide a reliable and early diagnosis.

Additionally, cranial ultrasound has many advantages: safety (lack of ionizing radiation, no need for sedation), the fact that it is dynamic and adaptable right to the needs of the moment and that it can be repeated as often as required.

Although the young radiologist might not be quite familiar with head ultrasound in preterm babies (due to a lack of exposure and practice), he or she nevertheless has to know the normal ultrasound anatomy, the variants and the important pathological findings of the immature brain according to gestational age [1].

Preterm infants are especially at risk for brain lesions which may often be silent, but may have a serious impact on further neurological development.

In order not to miss pathologies which may be of prognostic value, screening protocols should be well established in each neonatal care unit and should include four or five brain scans [2] in routine diagnostics of an otherwise healthy preterm. In the literature however there are various recommendations regarding the timing and number of the scans, with a range of between 4 and 15 scans, depending on authors and different institutions. Below,
we list the scanning recommendation used in our institution, and in other parts of Europe, adapted after G. van Wezel-Meijler (2007).

<table>
<thead>
<tr>
<th>NICU and/or &lt; 32 weeks GA and/or birth weight &lt;1,500 g</th>
<th>High care and ≥ 32 weeks GA and ≥ 1,500 g</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 24 h after birth</td>
<td>3rd day</td>
</tr>
<tr>
<td>3rd day</td>
<td>3rd day</td>
</tr>
<tr>
<td>Twice a week until 2nd week</td>
<td>Weekly until discharge</td>
</tr>
<tr>
<td>Weekly until discharge</td>
<td>Weekly until discharge</td>
</tr>
<tr>
<td>Around term</td>
<td>When needed in case of suspected anomalies</td>
</tr>
<tr>
<td>When needed in case of suspected anomalies</td>
<td>When needed in case of suspected anomalies</td>
</tr>
</tbody>
</table>

**Table 1**: Cranial ultrasound screening programme in preterms

*References*: adapted after Wezel - Meijler, 2007

**Findings and procedure details**

A good technique helps to unmask findings, which would otherwise be missed. In order to obtain a good image set you can influence some factors:

*Technical considerations:*

1. **Probe/Transducer**

The choice of an adequate transducer is crucial in order to obtain a good and reliable image. The transducer type and frequency must be adapted to the size of the head and to the width of the fontanelle. Usage of both, a sector/convex and a linear transducer is recommended, depending on the structures we need to analyze.

2. **Scanning parameters**

   - **Frequency** - Must be adapted to the structure that has to be evaluated [3]; For an optimal 'in depth' scanning and for a good overview over the brain parenchyma the frequency of the sector/convex transducer is usually from
7.5-10 MHz. For an excellent resolution, the linear probes are preferred, with a frequency from 9 to 18 MHz.

- **Depth** - Before beginning the coronal scan, you should ensure the proper depth by a short midline sagittal overview to establish the caudal limit of occipital bone (Fig. 1). For the main image set, keep the depth constant to maintain the proportions;

![Fig. 1: An example of an inadequate (Fig.1 A) and adequate (Fig.1 B) depth adaptation.](image)

**References**: Bern University Hospital, Inselspital, Department of Diagnostic, Interventional and Pediatric Radiology, University of Bern, Switzerland.

- **Gain** - An adequate adjustment of gain helps not to miss important findings (for example focal hyperechogenicity of the periventricular white matter) or to misdiagnose normal findings as pathology (for example periventricular white matter 'blush' that will be discussed later.

- **TGC (time-gain compensation curve)** - A common mistake made by inexperienced operators is the inadequate setting of time gain compensation curve (TGC) which may lead to unproportionally 'bright' aspects of certain parts of the brain, which may be mistaken as brain edema [1]. A good
adjustment of the TGC curve ensures a homogeneous and equilibrated image. (Fig. 2)

Fig. 2: A: Inappropriate gain and TGC curve adaptation (inhomogeneity of the image with black appearance in the area next to the probe and too bright appearance of the deeper structures). B: Appropriate gain and TGC adaptation.

References: Bern University Hospital, Inselspital, Department of Diagnostic, Interventional and Pediatric Radiology, University of Bern, Switzerland.

- **Focus** - the focus indicator should always be located in the area of interest and it should be adapted during the scan, accordingly. In most occasions the focus will be on the bottom of the image.

3. Important teaching points:

- Try to obtain a symmetric, centered and perpendicular image - this is essential for an optimal assessment (Fig. 3);
Fig. 3: A: An asymmetric scan does not allow immediate right - left comparison of the anatomical structures and of the subependymal bleeding on the right side. B: A symmetric and centered scan; red arrow (subependymal hemorrhage).

References: Bern University Hospital, Inselspital, Department of Diagnostic, Interventional and Pediatric Radiology, University of Bern, Switzerland.

- Analyze the images by comparing right to left;
- Avoid applying too much pressure on the fontanelle with the probe during scanning (Fig. 4);
Fig. 4: Inappropriate high pressure on the anterior fontanelle leads to an impression of the superior walls of the lateral ventricles and of the cavum septi pellucidi (upper images, red arrows). A more careful positioning of the probe on the fontanelle of the same patient can be seen in the lower images (white arrows). Please note the subependymal bleeding on the right side with cystic transformation over time (coronal sections).

References: Bern University Hospital, Inselspital, Department of Diagnostic, Interventional and Pediatric Radiology, University of Bern, Switzerland.

• Do the scanning systematically and thoroughly with inspection to all relevant structures, such as the corpus callosum, the cerebellum, the 4th ventricle, the cisterna magna - in order not to miss important findings;

• When pressing the freeze-button / print-button with one hand, keep the other hand willfully motionless on the baby's head to avoid self-made reflexive moving artifacts which will lead to an unclear, fuzzy image.

4. Safety:

Although ultrasound is a safe imaging method, without proven harmful effects in routine diagnostic use nevertheless we should attempt to limit the time and intensity of sound wave exposure since the preterm baby is very fragile. Please keep in mind:
• Perform a head ultrasound only if indicated;
• Shorten the scan time to a reasonable minimum;
• Since the Doppler mode leads to a rise of the MI (mechanical index) and the
  TI (thermal index), use Doppler only with purpose and avoid to stay too long
  at a certain point with the probe (the soundwave energy could heat up the
  tissue;
• Do not apply too much pressure on the baby’s head [1,2,3].

**Standard planes in transfontanellar ultrasound**

The *anterior fontanelle* provides an excellent physiological window for scanning the
infant brain and represents the main approach. Scanning through the other, minor
fontanelles (posterior, sphenoid and mastoid) is not always performed, but highly
encouraged, because it may help to visualize pathologies that otherwise can be missed
(the posterior and mastoid fontanelles allow a more ‘in detailed’ analysis of the cerebellum
with a possible underlying hemorrhage). *(Fig. 5)*

![Diagram of skull showing fontanelles](image)

**Fig. 5:** Axial (left diagram) and sagittal (right diagram) overviews of the skull showing
the fontanelles. FB (frontal bone); PB (parietal bone); TB (temporal bone); OB (occipital
bone); AF (anterior fontanelle); PF (posterior fontanelle); SF (sphenoid fontanelle); MF
(mastoid fontanelle); yellow arrow (metopic suture); red arrow (coronal suture); black
arrow (lambdoid suture).

**References:** authors
We illustrate the intracranial structures in coronal and sagittal planes through the anterior fontanelle, emphasizing the most relevant anatomical structures.

**Coronal planes**

![Coronal planes diagram](image)

**Fig. 6**: Sagittal view of the six standard coronal planes.

**References**: authors

There are six standard sections to achieve and explore during coronal scanning through the anterior fontanelle while tilting the transducer from anterior to posterior in a sequential manner[4]. All the coronal images should be symmetrical, centered by the interhemispheric fissure in the midline.

1. **The first coronal section** is the most anterior. It depicts the frontal lobes and the superior orbital wall constitutes the caudal boundary. (Fig. 7)
Fig. 7: First standard coronal section through the frontal lobes. Left upper image (34 weeks premature; image obtained with a 10 MHz sector probe). Right lower image (28 weeks premature; image obtained with a 14 MHz linear probe). FL (frontal lobes); arrow (interhemispheric fissure); oval contour (corresponding to the area of the anterior cerebral arteries); red dotted line (orbital ridge).

References: Bern University Hospital, Inselspital, Department of Diagnostic, Interventional and Pediatric Radiology, University of Bern, Switzerland.

- Normal findings of this section
  - The symmetry of the gray and white matter and a straight interhemispheric fissure;
  - Gray matter tends to be hypoechoic and white matter hyperechoic;
  - Non apparent sulci in preterm babies under 28 weeks.
2. The second coronal section depicts the anterior horns of the lateral ventricles, the cerebral parenchyma, the cavum septi pellucidi when present and the middle cerebral artery. The arterial double contour and pulsation is a helpful landmark. (Fig. 8)

Fig. 8: Second coronal section through the frontal horns of lateral ventricles. Left upper image (34 weeks premature; image obtained with a 10 MHz sector probe). Right lower image (28 weeks premature; image obtained with a 14 MHz linear probe). LV (lateral ventricles); C (caudate nucleus); T (temporal lobes); * (cavum septi pellucidi); red arrows (corpus callosum); white dotted arrow (middle cerebral artery); red dotted line ( fissure).

References: Bern University Hospital, Inselspital, Department of Diagnostic, Interventional and Pediatric Radiology, University of Bern, Switzerland.

- Normal findings of this section
- Symmetry or mild asymmetry in ventricular size;
- Collapsed or narrowed ventricular cavities in the first 24 hours after birth [6];
- Prominent ventricular cavities after the 1st day of life, depending on gestational age (basic concept of development: the younger the child the wider the liquor spaces. Therefore, at the time of delivery there should be almost no CSF (cerebro spinal fluid) spaces. The neurocranium is completely filled with brain parenchyma).

3. The third coronal section is at the level of the third ventricle and depicts the body of the lateral ventricles, the 3rd ventricle, the deep gray matter and Sylvian fissure. (Fig. 9)

![Fig. 9: Third coronal section through the 3rd ventricle. Left upper image (34 weeks premature; image obtained with a 10 MHz sector probe). Right lower image (28 weeks premature; image obtained with a 14 MHz linear probe). LV (lateral ventricles); V3 (third ventricle); P (putamen); GP (globus pallidus); M (midbrain); red arrows (corpus callosum); red dotted line (fissure).](image)

**References:** Bern University Hospital, Inselspital, Department of Diagnostic, Interventional and Pediatric Radiology, University of Bern, Switzerland.

- Normal findings of this section
- The structures are almost symmetric, but symmetry does not exclude pathology (always pay attention to basal ganglia, especially thalami, which, when hyperechoic bilaterally can reveal oedema, ischaemia or haemorrhage)[9];

- The Sylvian fissures may be wider in premature babies (referred to as Sylvian cisterns).

4. The fourth coronal section is at the level of the cerebellum. It has the typical appearance of a "Christmas tree" and contains a part of the brainstem, the vermis and the cerebellar hemispheres, the tentorium cerebelli, the body of lateral ventricles, brain parenchyma and the cisterna magna. (Fig. 10)

Fig. 10: Fourth coronal section at the level of cerebellum (image obtained with a 10 MHz sector probe, in a 34 weeks premature): LV (lateral ventricles); FO (frontal operculum); TO (temporal operculum); C (cerebellum); white dots (fissure); red dots (hippocampal fissure); red dotted line (tentorium cerebelli).

References: Bern University Hospital, Inselspital, Department of Diagnostic, Interventional and Pediatric Radiology, University of Bern, Switzerland.
- Normal findings of this section

- Symmetry/slight asymmetry of the ventricular cavities, choroid plexuses and brain parenchyma echogenicity;

- Cerebellum has hyperechoic appearance due to the tentorium cerebelli, thus in order to exclude a haemorrhage at this level, scan through the posterior or mastoid fontanelles.

5. The fifth coronal section is through the ventricular trigone with the choroid plexuses which dominate this image [1]. The ventricular cavities diverge laterally. Additionally, periventricular white matter is visible, and in some cases a cavum Vergae can be recognized between the lateral ventricles. (Fig. 11)

Fig. 11: Fifth coronal section through the ventricular trigone. Left upper image (34 weeks premature; image obtained with a 10 MHz sector probe). Right lower image (28 weeks premature; image obtained with a 14 MHz linear probe). LV (lateral ventricles);
C (cerebellum); red dotted line (central sulcus); white dotted line (fissure); white dotted arrow (parieto-occipital sulcus).

**References:** Bern University Hospital, Inselspital, Department of Diagnostic, Interventional and Pediatric Radiology, University of Bern, Switzerland.

- **Normal findings of this section**

  - Symmetry of the white periventricular matter (peritriginal "blush") and choroid plexuses echogenicity;

  - Although the white matter has a symmetric appearance, it should be less echogenic than the choroid plexus. Otherwise, a periventricular leukomalacia or other white matter pathology has to be considered.

  - Divergent appearance of the lateral ventricles; if parallel, look in first place for corpus callosum dysgenesis.

6. **The sixth coronal section** is through the occipital lobes and depicts the periventricular white matter and cortical gray matter, with the interhemispheric fissure in the midline. *(Fig. 12)*
**Fig. 12:** Sixth coronal section through the occipital lobes. Left upper image (34 weeks premature; image obtained with a 10 MHz sector probe). Right lower image (28 weeks premature; image obtained with a 14 MHz linear probe). FL (frontal lobes); OL (occipital lobes); white dotted arrow (parieto-occipital sulcus); red dotted arrow (central sulcus); oval shape (posterior periventricular white matter).

**References:** Bern University Hospital, Inselspital, Department of Diagnostic, Interventional and Pediatric Radiology, University of Bern, Switzerland.

- **Normal findings of this section**

- Symmetry of sulcation (if present) and periventricular white matter.

**Sagittal planes**
Fig. 13: Coronal view of the main sagittal planes (one median and two parasagittal on each side).

References: authors

The standard images corresponding to this plane are obtained by tilting the transducer from medially to laterally, in a sequential manner. There are five main sections:
1. The midline sagittal section - this image depicts many anatomical structures and gives a lot of information. (Fig. 14)

Fig. 14: Midline sagittal section. Left upper image (34 weeks premature; image obtained with a 10 MHz sector probe). Right lower image (28 weeks premature; image obtained with a 14 MHz linear probe). CL (clivus); CG (cingulate gyrus); Th (Thalamus); OL (occipital lobe); CM (cisterna magna); V3 (third ventricle); V4 (fourth ventricle); white dotted line (cingulate sulcus); red arrows (corpus callosum).

References: Bern University Hospital, Inselspital, Department of Diagnostic, Interventional and Pediatric Radiology, University of Bern, Switzerland.

- Normal findings of this section
- Non apparent sulci (depending on GA);
- Corpus callosum should be entirely visible;
- Pseudo-lesional appearance of occipital lobes in very preterm babies (see 'Variants' section for further details).
2. The parasagittal right and left sections are dominated by the presence of the lateral ventricle (C - shape), the choroid plexus and the periventricular white matter. (Fig. 15)

Fig. 15: Parasagittal section. Left upper image (34 weeks premature; image obtained with a 10 MHz sector probe). Right lower image (28 weeks premature; image obtained with a 14 MHz linear probe). C (caudate nucleus); T (thalamus); TL (temporal lobe); PL (parietal lobe); OL (occipital lobe); OH (lateral ventricle, occipital horn); white dotted line (caudo-thalamic groove).

References: Bern University Hospital, Inselspital, Department of Diagnostic, Interventional and Pediatric Radiology, University of Bern, Switzerland.

- Normal findings of this section

- The choroid plexus of the lateral ventricles often extends anteriorly and insinuates into the caudo-thalamic groove, between the thalamus and the caudate nucleus (on the floor of the lateral ventricle) and appears as a white spot (Pitfall: not to be confused with a small haemorrhage into the germinal matrix) [1].
3. The tangential parasagittal right and left sections are carried out laterally and superficially to the lateral ventricles and depict the white periventricular matter, different sulci (depending on age) and Sylvian fissure. (Fig. 16)

**Fig. 16**: Tangential parasagittal section. Left upper image (34 weeks premature; image obtained with a 10 MHz sector probe). Right lower image (28 weeks premature; image obtained with a 14 MHz linear probe). FL (frontal lobe); PL (parietal lobe); TL (temporal lobe); red dotted line (Sylvian fissure); white dotted line (parieto-occipital sulcus).

**References**: Bern University Hospital, Inselspital, Department of Diagnostic, Interventional and Pediatric Radiology, University of Bern, Switzerland.

- Normal findings of this section
  - Homogeneity of the white matter and normal hypoechoic gray matter;
  - Adequate sulcation according to gestational age;
  - The Sylvian fissure.
Section through the mastoid fontanelle (Fig. 17)

Fig. 17: Axial section obtained with a 10 MHz sector probe through the mastoid fontanelle, in a 24 weeks premature. TL (temporal lobe); c (cerebellar hemispheres); V (vermis cerebelli); white arrow (lateral ventricle, temporal horn); red arrow (cisterna magna).

References: Bern University Hospital, Inselspital, Department of Diagnostic, Interventional and Pediatric Radiology, University of Bern, Switzerland.

Colour Doppler and spectral assessment

For screening of vascular structures, we usually assess:

- Arterial circle of Willis with RI (resistance index) and PI (pulsatility index) at the level of the anterior cerebral artery and the aspect of the spectral curve; (Table 2)
• Check if the superior sagittal sinus and the vein of Galen (in sagittal view) are open [9]. (Table 3)

<table>
<thead>
<tr>
<th>Anatomical structure</th>
<th>RI</th>
<th>PI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior cerebral artery</td>
<td>0,73±0,08</td>
<td>2,7±0,9</td>
</tr>
<tr>
<td>Basilar artery</td>
<td>0,72±0,09</td>
<td>2,7±0,7</td>
</tr>
<tr>
<td>Internal carotid artery</td>
<td>0,77±0,08</td>
<td>3,0±0,8</td>
</tr>
</tbody>
</table>

Table 2: Approximative values of RI and PI. Note: RI(resistance index) and PI(pulsatility index)

References: adapted after Deeg and colleagues [18]

<table>
<thead>
<tr>
<th>Anatomical structure</th>
<th>Medium value of velocity (cm/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Superior sagittal sinus</td>
<td>9,2 ± 1,1</td>
</tr>
<tr>
<td>Inferior sagittal sinus</td>
<td>3,5 ± 0,3</td>
</tr>
<tr>
<td>Internal cerebral veins (right/left)</td>
<td>3,4 ± 0,2 / 3,2 ± 0,3</td>
</tr>
<tr>
<td>Galen vein</td>
<td>4,3 ± 0,7</td>
</tr>
</tbody>
</table>

Table 3: Normal velocities in the main cerebral veins.

References: Adapted after Deeg [18]

The immature brain - normal anatomy according to age

Between the 24\textsuperscript{th} and the 40\textsuperscript{th} week of gestation, the brain parenchyma undergoes major developmental changes. The most important "mile stones" for preterms are described below.

In extremely preterm babies (23-24 weeks of gestation) the brain has a smooth, featureless surface. We list below the ultrasonographic visible structures according different gestational ages.

• 22 weeks
  - Interhemispheric fissure;
  - Parieto-occipital fissure +/- anterior part of cingulate sulcus;
  - Widely open Sylvian fissure with prominent insula (so called Sylvian cistern).
• 24 weeks (Fig. 18)

- Entirely visible corpus callosum.

Fig. 18: 24 weeks GA preterm, 1ST day of life. A. Coronal section at the level of third ventricle. B. Midsagittal section. C. Tangential parasagittal section (illustrating the wide Sylvian fissure and the exposed insula).

References: Bern University Hospital, Inselspital, Department of Diagnostic, Interventional and Pediatric Radiology, University of Bern, Switzerland.

• 26 weeks (Fig. 19)

- The cingulate sulcus appears in the anterior segment in the parasagittal view;
- Central sulcus indents the brain surface;
- Prominent germinal matrix.
Fig. 19: 26 weeks GA preterm, 2nd day of life. A. Coronal section at the level of third ventricle. B. Midsagittal section. C. Tangential parasagittal section (the Sylvian fissure remains wide).

References: Bern University Hospital, Inselspital, Department of Diagnostic, Interventional and Pediatric Radiology, University of Bern, Switzerland.

- 28 weeks (Fig. 20)
- Partially covered insula, more prominent Sylvian fissure;
- Complete cingulate gyrus;
- Central sulcus well visible.
Fig. 20: 28 weeks GA preterm, 1st day of life. A. Coronal section at the level of third ventricle. B. Midsagittal section. C. Tangential parasagittal section.

References: Bern University Hospital, Inselspital, Department of Diagnostic, Interventional and Pediatric Radiology, University of Bern, Switzerland.

- 30 weeks (Fig. 21)

- Deeper Sylvian fissure;
- Marginal sulcus;
- Superior temporal sulcus.
Fig. 21: 30 weeks GA preterm, 1st day of life. A. Coronal section at the level of third ventricle. B. Midsagittal section. C. Tangential parasagittal section

References: Bern University Hospital, Inselspital, Department of Diagnostic, Interventional and Pediatric Radiology, University of Bern, Switzerland.

- 32 weeks (Fig. 22)

- All primary sulci can be visible at this age to a variable degree depending on individual development.
**Fig. 22:** 32 weeks GA preterm, 4th day of life. A. Coronal section at the level of third ventricle. B. Midsagittal section. C. Tangential parasagittal section.

**References:** Bern University Hospital, Inselspital, Department of Diagnostic, Interventional and Pediatric Radiology, University of Bern, Switzerland.

- 34 weeks (Fig. 23)
  - Increasing complexity of gyri and sulci with secondary sulci being visible
**Fig. 23**: 34 weeks GA preterm, 1st day of life. A. Coronal section at the level of third ventricle. B. Midsagittal section. C. Tangential parasagittal section.

**References**: Bern University Hospital, Inselspital, Department of Diagnostic, Interventional and Pediatric Radiology, University of Bern, Switzerland.

- **36 weeks (Fig. 24)**

- Tertiary sulci are visible.
**Fig. 24:** 36 weeks GA preterm, 7th day of life. A. Coronal section at the level of third ventricle. B. Midsagittal section. C. Tangential parasagittal section.

**References:** Bern University Hospital, Inselspital, Department of Diagnostic, Interventional and Pediatric Radiology, University of Bern, Switzerland.

**Variants and pitfalls:**

**VENTRICLES AND CEREBRO SPINAL FLUID (CSF) SPACES**

**Asymmetric lateral ventricles (Fig. 25)**

A mild asymmetry of the lateral ventricles may sometimes be present, especially among preterm babies with an incidence of 40% [5], the left ventricle being more prominent than the right one. Moreover, head position can slightly modify the ventricular size, *the less dependent ventricle being larger than the more dependent one* [10]. A 'benign' unilateral enlarged ventricle is often associated with an enlarged ipsilateral choroid plexus [11].
Fig. 25: Coronal section through the 3rd ventricle in a 30 weeks preterm baby illustrating the ventricular asymmetry with the left side more prominent, as a normal variant. White arrows (radial glial guides/fibers representing the pathways of neuronal migration). 14 MHz linear probe.

References: Bern University Hospital, Inselspital, Department of Diagnostic, Interventional and Pediatric Radiology, University of Bern, Switzerland.

Connatal cysts / Coarctation of the lateral ventricles (Fig. 26)

In the literature there are still debates regarding the physiopathology of connatal cysts. Some authors state that the connatal cysts are due to a preexisting event and differentiate connatal cysts from ventricular coarctation [13], whereas others [17] suggest that connatal cysts and ventricular coarctations are the same entity as normal isolated variant, without precursory event. In both circumstances, there is no impact on the clinical outcome.
What remains important is that these two entities should not be confused with other cystic structures as germinal matrix cysts, subependymal cysts due to perinatal infection or with cystic periventricular leukomalacia [14]. The position of the cysts in relation to the external angle of the lateral ventricles can help to differentiate these entities (Fig. 27); in case of connatal cysts/coarctations, the cyst is located in continuation to the external angle of the lateral ventricles, whereas cysts originating from the germinal matrix are located below the lateral ventricle, and the post PVL cysts appear above the lateral ventricles [11].

Fig. 26: Coronal section through the 3rd ventricle (left upper image) and left tangential parasagittal section (right lower image) illustrating bilateral connatal cyst/ventricular coarctation, in a 27 weeks premature (14 MHz linear probe).

References: Bern University Hospital, Inselspital, Department of Diagnostic, Interventional and Pediatric Radiology, University of Bern, Switzerland.
Fig. 27: Coronal diagram through the 3rd and lateral ventricles illustrating the typical location of the different types of periventricular cysts: red oval shape (germinal matrix post-hemorrhage cysts); yellow circle (connatal cysts/ventricular coarctation); blue circle (typical location for cysts secondary to PVL); red dotted line (external angle of the lateral ventricle).

References: authors

Cavum septi pellucidi et vergae (Fig. 28)
The septa pellucida (two paired translucent leaflets) are related to corpus callosum development, and begin to form at about the 12th week of gestational age. Although these two membranes form only one single fluid filled cavity lined by glia (not ependymal cells) [13] two different names are used: anterior to the foramen Monro is called cavum septi pellucidi (CSP) and posterior to it, cavum Vergae [15].

The presence of a cavum septi pellucidi (with Vergae) is physiological in preterms and in some term babies. The closure of the cavity begins at about 6 months of GA and progresses from posterior to anterior. By term, posterior closure is almost complete (97%) and 85% of CSP disappear until the age of 2 months [1,15].

Keep in mind that the cavum septi pellucidi et Vergae is located between the two lateral ventricles and not below (this is the main feature that differentiate cavum septi pellucidi from the 3rd ventricle).

Absence of the CSP (due to the absence of the septum pellucidum itself) can occur in various cerebral anomalies, especially in malformations that affect the corpus callosum (e.g., agenesis of the corpus callosum) due to the tight developmental connection of the two structures. Among other anomalies associated with the absence of a CSP, Winter et al. [15] describes: Aicardi syndrome, holoprosencephaly (alobar, semilobar or lobar), septo-optic dysplasia and schizencephaly.
**Fig. 28:** Coronal and midsagittal sections in a 28 weeks preterm baby illustrating the presence of cavum septi pellucidi (pink star) and cavum Vergae (white star), as normal variant (14 MHz linear probe).

**References:** Bern University Hospital, Inselspital, Department of Diagnostic, Interventional and Pediatric Radiology, University of Bern, Switzerland.

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**Cavum veli - interpositi (CVI) (Fig.29)**

A CVI represents an anatomic variation with cystic appearance located in the pineal region. Typically, it lies beneath the fornices of the corpus callosum and above the internal cerebral veins.

It is important to differentiate a CVI from a pineal cyst (which usually has a round appearance and may have a mass effect over the internal cerebral veins). An aneurism or a malformation of the Galen vein may be identified by using a Doppler interrogation or an MRI study.
Fig. 29: Coronal and midline sagittal section in a term baby showing the cavum veli interpositi (white arrow), as a normal variant. 9 MHz sector probe.  

References: Bern University Hospital, Inselspital, Department of Diagnostic, Interventional and Pediatric Radiology, University of Bern, Switzerland.

Megacisterna magna (Fig. 30)

The cisterna magna is referred to as megacisterna magna if the cranio-caudal diameter exceeds 8 mm, and it is considered a normal variant if it is an isolated finding. It should be distinguished from an arachnoid cyst or Blake’s pouch cyst (by the absence of mass effect) and from a Dandy-Walker malformation (by the presence of cerebellar vermis) [10].
**Fig. 30:** Midline sagittal section illustrating megacisterna magna in a 35 weeks preterm. 10 MHz sector probe.

**References:** Bern University Hospital, Inselspital, Department of Diagnostic, Interventional and Pediatric Radiology, University of Bern, Switzerland.

**CHOROID PLEXUS**

*Choroid plexus cysts (Fig. 31)*

The small plexus cyst (smaller than 10 mm), are usually unilateral and not associated with CNS or genetic abnormalities, thus representing an incidental, clinically non-significant finding [7]. **Note:** Large cysts (> than 10 mm) or bilateral cysts are reported to be associated with chromosomal abnormalities such as trisomy 9, 18 or 19 [6,14].
Fig. 31: Choroid plexus cyst (white arrows) in a 33 weeks premature baby (14 MHz linear probe). Left upper image (coronal section through the ventricular trigone). Right lower image (left parasagittal section illustrating the body of the left lateral ventricle).

References: Bern University Hospital, Inselspital, Department of Diagnostic, Interventional and Pediatric Radiology, University of Bern, Switzerland.

Lobulated, truncated or split choroid plexus are rare findings

A truncated choroid plexus has a flat aspect at the lower portion and has the appearance of a fluid-solid level and a split choroid plexus has a cleft which leads to a 'double plexus' appearance [11].

BRAIN PARENCHYMA

Peritrigonal echogenic "blush" (Fig. 32)
A peritrigonal echogenic "blush" is an increased echogenicity of the white posterior periventricular matter (seen most frequently in the sagittal or parasagittal plane) and extends from anterior to posterior in parallel to the ventricular walls. It can be a normal finding especially among preterm infants and disappears or fades in the coronal sections, since the respective fibers are cut in a different manner. Moreover, it is a symmetric finding in coronal sections.

The differential diagnoses include cerebral haemorrhage or periventricular leukomalacia (PVL). Both of them can be suspected in case of asymmetrically dense spots or heterogeneous and abnormally dense periventricular halo [4].

**Fig. 32:** Right parasagittal section (left image) and coronal sections through the ventricular trigone (right images) in a 29 weeks preterm, illustrating the peritrigonal "blush" (red arrows). Please note that the focal echogenicity of the periventricular white matter seen on the parasagittal image, disappear on the coronal section. The immediate periventricular white matter has a symmetric relatively hypoechoic appearance. 10 MHz sector probe.

**References:** Bern University Hospital, Inselspital, Department of Diagnostic, Interventional and Pediatric Radiology, University of Bern, Switzerland.
**Occipital pseudolesion** (Fig. 33)

In extreme preterm babies (< 34 weeks of GA), the smooth surfaced occipital lobes appear hypoechoic and are delineated by the parieto-occipital fissure (cranially) and tentorium cerebelli (caudally), both of them appearing hyperechoic and producing a mass-like effect (do not misdiagnose this normal finding as a tumor) [11].

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**Fig. 33**: Midline sagittal section illustrating the occipital pseudo-lesion aspect in a 29 weeks premature baby. Parieto-occipital fissure (white arrow); OL (occipital lobe); red dotted arrow (tentorium cerebelli). 14 MHz linear probe.

**References**: Bern University Hospital, Inselspital, Department of Diagnostic, Interventional and Pediatric Radiology, University of Bern, Switzerland.

**Lenticulostriate vasculopathy** (Fig. 34)
Represents a non-specific finding without a specific known cause; it has been also described in association with some conditions, as TORCH infections, chromosomal anomalies or malformations and it is occasionally seen on ultrasound as uni- or bilateral finding.

Although the short term outcome of these patients is good, there is no clear data in the literature regarding long term sequelae.

**Fig. 34**: Coronal section through the 3rd ventricle (left upper image) and right parasagittal sections with colour Doppler, illustrating lenticulostriate vasculopathy (red arrows) in a 26 weeks preterm baby with neonatal infection (10MHz sector transducer, except right upper image - 14 MHz linear transducer).

**References**: Bern University Hospital, Inselspital, Department of Diagnostic, Interventional and Pediatric Radiology, University of Bern, Switzerland.

**Optic radiations** (Fig. 35)
Optic radiations appear as an ellipsoid hyperechoic area which is bilateral and hyperechoic, in the immediate proximity of lateral ventricles, best seen on the coronal section through the ventricular trigone. This aspect is seen almost invariably among preterm babies with a gestational age between 26 and 31 weeks especially when using a high-frequency linear transducer [13].

**Fig. 35**: Coronal section through the ventricular trigone illustrating the optic radiations (red arrows) in 28 weeks preterm infant. 14 MHz linear probe.

**References**: Bern University Hospital, Inselspital, Department of Diagnostic, Interventional and Pediatric Radiology, University of Bern, Switzerland.

**Wide extraaxial fluid spaces - normal**

In preterms, wide subarachnoid space may be observed and it should be interpreted in the clinical context (head circumference, age, family history).
Pathology:

There is a wide spectrum of pathologies in preterm babies, from congenital to acquired conditions (vascular, infectious, neoplastic). Since the aim of this poster is to support the young resident on call, we will focus on the most frequent and most urgent conditions.

Remember: Preterm babies with abnormal cranial ultrasound findings are often asymptomatic unless a massive change is present [2].

Frequent pathologies:

1. Intracranial bleeding (Fig. 36, 37, 38, 39, 40)

Due to the fragility of the germinal matrix and an underdeveloped homeostatic balance, the intracranial bleeding is the most frequent finding in preterm babies, especially among those who are born before 32 weeks of gestation. After prolonged scientific debates on the pathogenesis, the bleeding into the germinal matrix is thought to be of venous origin [2].

Major risk factors for ICH are: < 32 weeks of GA and/or birth weight <1,500 g [8].

The neurological outcome of these patients depends of the haemorrhage grade, extension and the presence of complications.

Regarding the terminology and classification, in the past, 'periventricular haemorrhage' was used as a generic term, including germinal matrix haemorrhage (GMH), intraventricular haemorrhage (IVH) and also intraparenchymal haemorrhage [1]. Papile and Volpe's classifications were used until recently, but Deeg and coworkers [12] proposed in 1999 a new, more ultrasound-based classification, which is broadly recognized and used in our institution by paediatric radiologists and by the neonatal care unit (DEGUM classification).
<table>
<thead>
<tr>
<th>Severity</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade I</td>
<td>Subependymal haemorrhage</td>
</tr>
<tr>
<td>Grade II</td>
<td>Intraventricular haemorrhage occupying less than 50% of the ventricular volume</td>
</tr>
<tr>
<td>Grade III</td>
<td>Intraventricular haemorrhage occupying more than 50% of the ventricular volume</td>
</tr>
<tr>
<td>Intraparenchymal haemorrhage</td>
<td>Side of the haemorrhage (left/right)</td>
</tr>
<tr>
<td>(former grade IV after Papile)</td>
<td>Location (frontal/parietal/occipital)</td>
</tr>
<tr>
<td></td>
<td>Size (small &lt; 1cm, medium 1-2 cm, large &gt; 2 cm)</td>
</tr>
<tr>
<td>Haemorrhage in other cerebral structures</td>
<td>Basal ganglia, cerebellum, brain stem</td>
</tr>
<tr>
<td>Post-haemorrhagic ventricular enlargement</td>
<td>Side of the ventricular enlargement (uni-/bilateral, 3rd or 4th ventricle)</td>
</tr>
</tbody>
</table>

**Table 4**: Classification of intracranial hemorrhage.

**References**: Adapted after "Classification of intracranial Hemorrhage in premature infants" - Deeg and co-workers. [12]
**Fig. 36**: Coronal section through the 3rd ventricle (upper image) and parasagittal sections (lower images) illustrating a grade I haemorrhage in the germinal matrix (red arrows) in a 24 weeks premature (2nd day of life). 14 MHz linear probe.

**References**: Bern University Hospital, Inselspital, Department of Diagnostic, Interventional and Pediatric Radiology, University of Bern, Switzerland.
Fig. 37: Coronal and parasagittal sections illustrating a grade II haemorrhage (red arrows) in a 26 weeks premature. Note: slightly echoic content of the right lateral ventricle, due to blood staining (take the content of the cavum septi pellucidi as reference for comparison, because it is an independent, non-CSF filled cavity). 14 MHz linear probe

References: Bern University Hospital, Inselspital, Department of Diagnostic, Interventional and Pediatric Radiology, University of Bern, Switzerland.
Fig. 38: Coronal and parasagittal sections illustrating a grade III haemorrhage with secondary ventricular enlargement in a 32 weeks premature. Note: dilatation of the temporal horns of the lateral ventricles (white arrow) and the thickening of the ependymal (red arrow). 14 MHz linear probe.

References: Bern University Hospital, Inselspital, Department of Diagnostic, Interventional and Pediatric Radiology, University of Bern, Switzerland.
Fig. 39: Coronal (left) and tangential parasagittal (right) sections illustrating an intraparenchymal haemorrhage with cystic transformation, in a 26 weeks preterm. 14 MHz linear probe.

References: Bern University Hospital, Inselspital, Department of Diagnostic, Interventional and Pediatric Radiology, University of Bern, Switzerland.
Fig. 40: Coronal (left), left parasagittal and tangential parasagittal (right) sections illustrating an intraparenchymal haemorrhage (red arrows) in evolution in a 33 weeks premature with prior thoracic surgery for severe aortic stenosis.

References: Bern University Hospital, Inselspital, Department of Diagnostic, Interventional and Pediatric Radiology, University of Bern, Switzerland.

2. Periventricular leukomalacia (PVL):

White matter lesions in preterm infants are considered to be the main factor responsible of subsequent adverse outcome.

In contrast to intracranial bleeding which occurs mostly in the first 48-72 hours after birth, leukomalacia can occur in preterm babies until term age [13].

PVL can occur:

1. As an isolated phenomenon;
2. Associated to GMH and/or IVH;
3. In the context of infectious and metabolic fetopathies, or sinus thrombosis [13].

PVL has 3 main underlying mechanisms:

- Ischaemia;
- Inflammation;
- Excitotoxicity and free radical attack [13].

PVL - cystic

- diffuse non-cystic white matter injury

De Vries and colleagues [13] proposed a classification for PVL in 1992, which has been widely recognized. (Table 5)

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Transient periventricular densities (&gt;7 days)</td>
</tr>
<tr>
<td>II</td>
<td>Localized cysts adjacent to external angle of the lateral ventricle</td>
</tr>
<tr>
<td>III</td>
<td>Extensive cysts in fronto-parietal and occipital periventricular white matter (cystic periventricular leukomalacia)</td>
</tr>
<tr>
<td>IV</td>
<td>Extensive cysts in subcortical white matter (cystic subcortical leukomalacia)</td>
</tr>
</tbody>
</table>

Table 5: Classification system for periventricular leukomalacia


How to differentiate a grade I PVL from peritrigonal "blush"?

As mentioned above, there are some hints that may help in case of unclear classification of white spots in the periventricular white matter (peritrigonal "blush" vs periventricular leukomalacia). In general, the peritrigonal "blush" is less echogenic than the choroid plexus, has a symmetric, homogenous appearance, fading borders and is less visible or disappears in coronal sections. Otherwise, consider it to be a grade I leukomalacia or a haemorrhage. Correlate the ultrasound study with the clinical state and perform a follow-up ultrasound scan.

Life threatening pathologies that may require urgent management:

1. Brain oedema (Fig. 41, 42, 43)
In preterm babies, cerebral oedema is not an uncommon finding since they are a high risk group and it is seen mostly in asphyxia. The sonographic appearance depends on the severity and duration of the episode of asphyxia.

**Ultrasound can reveal:**

- Focal or diffuse hyperechogenicity of the brain parenchyma;
- Loss of differentiation between gray and white matter
- Narrowed/compressed ventricular cavities and extra axial fluid spaces;
- Effacement of the sulci.

The RI must be interpreted together with absolute velocities (do not forget the angle correction) and the compression degree over the fontanelle.

<table>
<thead>
<tr>
<th>Severity</th>
<th>Doppler characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage I</td>
<td>Normal flow profile, velocities and RI</td>
</tr>
<tr>
<td>Stage II</td>
<td>Increased diastolic amplitude, increased PSV and end-diastolic velocity (EDV), decreased RI</td>
</tr>
<tr>
<td>Stage III</td>
<td>Decreased diastolic amplitude, decreased PSV and EDV, increased RI</td>
</tr>
</tbody>
</table>

**Table 6**: The Spectral Doppler (RI) changes according to stage of the brain oedema. Note: RI (resistance index); PSV (peak-systolic velocity); EDV (end-diastolic velocity)

**References**: Adapted after Deeg and coworkers [18]
**Fig. 41:** Coronal section and spectral Doppler analysis in a 35 weeks preterm illustrating a slight cerebral oedema. Note: diffuse hyperechogenicity of the white matter (red arrow), narrowed ventricular cavities, subarachnoid space and sulci. Normal RI.

**References:** Bern University Hospital, Inselspital, Department of Diagnostic, Interventional and Pediatric Radiology, University of Bern, Switzerland.
**Fig. 42**: Coronal B-mode section and spectral Doppler analysis of a 30 weeks premature who is the donor twin (pregnancy with feto-fetal transfusion syndrome), showing severe cerebral edema. Images achieved in the 3rd day of life. Note: diffuse hyperechoic white matter with lost differentiation between white and gray matter (slight tendency to white-gray matter echogenicity inversion - red arrow), collapsed ventricular spaces, decreased RI (0.59) and high end-diastolic flow.

**References**: Bern University Hospital, Inselspital, Department of Diagnostic, Interventional and Pediatric Radiology, University of Bern, Switzerland.
**Fig. 43:** Coronal sections and spectral Doppler analysis in the 3rd day of life of a 33 weeks preterm with anoxic-ischemic encephalopathy due to prolonged perinatal asphyxia. Note: obvious diffuse white matter hyperechogenicity with preservation of the grey matter (subcortical ischemia), collapsed CSF spaces and low resistance index (RI) with an increased end-diastolic velocity.

**References:** Bern University Hospital, Inselspital, Department of Diagnostic, Interventional and Pediatric Radiology, University of Bern, Switzerland.

2. **Venous sinus thrombosis (Fig. 44)**

Venous sinus thrombosis is not uncommon among preterm. About two thirds of the babies with venous sinus thrombosis are symptomatic (seizures), while some babies are asymptomatic. Thus, a vigilant sonographic screening in the neonatal care unit is essential in order to establish the correct diagnosis and the appropriate consecutive treatment.

In preterm infants, venous sinus thrombosis may lead to white matter lesions that are very similar to periventricular leukomalacia[13].
A linear, high-frequency transducer is most suitable to visualize the superior sagittal sinus (SSS), both in the coronal and in the sagittal planes. For evaluating the internal cerebral veins and the transverse sinus, a convex/sector transducer may be needed. A supplemental scan through the posterior fontanelle is recommended.

Although an acute thrombosis is usually hyperechogenic and leads to a widening of the lumen and to a bulging of the sinus wall, in some cases thrombosis cannot be detected by using the B mode only. Therefore, a Doppler scan is mandatory. According to Couture and Veyrac [19], two pitfalls must be avoided: a residual flow may persist within the proximal anterior part of the sinus; and despite complete total thrombosis, the anterior part of the sinus remains smaller than the posterior part. Thus, the posterior portion of the sinus should be always analyzed.

Fig. 44: Coronal and sagittal B-mode and colour Doppler sections in a 29 weeks preterm, illustrating a sagittal sinus thrombosis (white and red arrows). Note: ‘bulging’ appearance of the venous walls, hyperechoic lumen content and lack of venous flow while application of colour Doppler.

References: Bern University Hospital, Inselspital, Department of Diagnostic, Interventional and Pediatric Radiology, University of Bern, Switzerland.
3. Intracranial hypertension

A raise in intracranial pressure may be due to severe cerebral oedema (of vascular, metabolic/toxic or infectious origin, e.g.), intracranial haemorrhage (especially massive bleeding - Fig. 45), hydrocephalus (Fig. 46) and neoplasms.

Fig. 45: Coronal section through the 3rd ventricle in a 25 weeks preterm girl in her 10th day of life (left image) and one day later, after abdominal surgery for necrotizing enterocolitis (right image), illustrating a massive intracranial haemorrhage, with severe midline shift and associated midbrain compression. 9 MHz sector probe

References: Bern University Hospital, Inselspital, Department of Diagnostic, Interventional and Pediatric Radiology, University of Bern, Switzerland.
Fig. 46: Spectral Doppler assessment of the anterior cerebral artery in a 32 weeks preterm (21th day of life). The images illustrate ventricular enlargement (posthaemorrhagic hydrocephalus), narrowed extra-axial fluid spaces (subarachnoid space and cisterna magna) and an increased RI (0.92) with a decreased diastolic flow. These findings indicate intracranial hypertension. 10 MHz transducer.

References: Bern University Hospital, Inselspital, Department of Diagnostic, Interventional and Pediatric Radiology, University of Bern, Switzerland.

Intracranial hypertension acutely endangers the patient's life and may lead to death. The newborn may compensate an increased (intracranial) volume without increasing pressure by enlargement of the fontanelles, sutures and head circumference, still, when a rise in intracranial pressure occurs, it is sharper than in the adult because the CSF resorption spaces are smaller [19].

Although it is not possible to directly measure the intracranial pressure by ultrasound, indirect signs may be detected in Doppler sonography and B-mode, such as:

a. Elevated resistance index (RI).
The normal resistance index of the anterior cerebral artery is 0.73 ± 0.08. [20]

If the intracranial pressure increases, it may cause the diastolic blood flow to decrease, leading to an elevated RI. If the intracranial pressure exceeds the diastolic blood pressure, there is a diastolic retrograde flow and the RI increases to values > 1. In the newborn period, other causes of elevated RI values have to be taken into consideration as patent ductus arteriosus Botalli, dehydration or low arterial pCO₂ [18].

b. Fontanellar compression

The fontanellar compression test is an indirect assessment of the cerebral compliance and helps to estimate how much the blood flow will be impaired by a slight increase in the intracerebral volume. According to Couture and Veyrac [19], the compression of the anterior fontanelle requires accurate technique.

The pressure delivered to the fontanelle should be brief (no more than 5 s), enough to obtain a Doppler spectrum.

The compression should not be repeated, because there is a diminished response after repeated compressions.

A firm pressure is required, delivered by a trained operator.

c. Narrow external liquor spaces

d. Effacement of sulci

Examples of other pathologies that can be encountered in preterm: meninigits (Fig. 47), tuberous sclerosis (Fig. 48), septo-optic dysplasia (Fig. 49) and holoprosencephaly (Fig. 50).
**Fig. 47:** Coronal section focusing on the extra-axial spaces in a term baby, illustrating a dense echoic content of the subarachnoid space with a thick appearance of the pia mater (red arrow), compatible with a meningitis (blood cultures revealed E. coli infection). 14 MHz linear probe.

**References:** Bern University Hospital, Inselspital, Department of Diagnostic, Interventional and Pediatric Radiology, University of Bern, Switzerland.
Fig. 48: Coronal section through the 3rd ventricle (upper image) and right parasagittal section (lower image), in a 36 weeks baby illustrating subependymal nodules (red arrows) in the context of tuberous sclerosis. 10 MHz sector probe.

References: Bern University Hospital, Inselspital, Department of Diagnostic, Interventional and Pediatric Radiology, University of Bern, Switzerland.
**Fig. 49:** Coronal section through the 3rd ventricle, focused on the ventricular cavities, illustrating an absent septum pellucidum in a preterm with septo-optic dysplasia. 14 MHz linear probe.

**References:** Bern University Hospital, Inselspital, Department of Diagnostic, Interventional and Pediatric Radiology, University of Bern, Switzerland.
Fig. 50: Coronal section in a 33 weeks premature illustrating an alobar holoprosencephaly. 10 MHz sector probe

References: Bern University Hospital, Inselspital, Department of Diagnostic, Interventional and Pediatric Radiology, University of Bern, Switzerland.

Conclusion

The adequate performance and interpretation of cerebral ultrasound is essential in the healthcare of preterm infants. In order to support the less experienced radiologist on call, this poster comes with an overview of the appropriate technique, anatomy, variants and main pathologies in preterm babies.

Personal information
References


