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Review Article

Surgical Treatment of Perinatal Intracranial Haemorrhage

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Abstract

Perinatal intracranial haemorrhage is a serious complication during brain development resulting in different degree of psychomotor retardation. According to its origin, haemorrhage can be defined as traumatic and nontraumatic. Thanks to modern care in gynaecology and neonatology, traumatic injury is rare but intraventricular bleeding of premature infants remains crucial event in postnatal care, despite technological achievements in the last decades, there is no essential improvement in prognosis for such patients. The article describes types of traumatic haemorrhages and deals with the topic of intraventricular bleeding of premature infants and options for surgical treatment. This work also includes reviews of foreign authors and their experience with the treatment of intracranial haemorrhage from departments with enough cases for statistical analysis of treatment modalities.

Keywords: *Intracranial Haemorrhage; Hydrocephalus; Premature Infant; Germinal Matrix; VP Shunt*

Intracranial haemorrhage differentiation

Perinatal intracranial haemorrhage can be defined based on its location to intra-axial (intracerebral, intracerebellar, intraventricular) and extra-axial (epidural, subdural, subarachnoid) and based on its origin to traumatic and atraumatic. Traumatic haemorrhage often develops during a complicated delivery. Mode of origin is either excessive pressure or strain to neonate's head during prolonged, aborted or fast delivery, as well as during delivery of the hypertrophic foetus, or abnormal positioning [1]. Atraumatic bleeding occurs mostly in premature neonates. Origin of bleeding, in this case, is hypoxic-ischemic insult associated with circulatory instability and other display of high prematurity of foetus. Haemorrhage is found mostly in germinal matrix, or in ischemic necroses.

Imaging

Ultrasound, due to its non-invasiveness, the possibility of repeating and absence of radiation is mostly used and is the first choice during diagnosis and later check-ups. Sensitivity and specificity is > 91% [2]. Ultrasound picture of intraventricular haemorrhage is an echogenic-like pathological collection. Ventricular dilatation can be observed in time. After blood clots resorption, ventricles diameter can regress (in 75% cases with post-haemorrhagic ventriculomegaly resolve within 4 weeks), also can persist ("arrested hydrocephalus") or progress to post-hemorrhagic hydrocephalus. Cause of hydrocephalus is a blockage of cerebrospinal fluid circulation in the ventricles, extraventricular blockage or combined. Echogenicity of resorbing blood clot lessens in the centre with the hyperechogenic rim. Smaller clots can dilute, bigger clot keeps its shape in enlarged ventricle creating image of "ventricle in ventricle". Resorbing can take several weeks. Intraparenchymal/periventricular haemorrhage is depictured, like an intraventricular clot, with central loss of echogenicity and peripheral hyperechogenic rim.

Vascular blood flow is followed-up by transcranial Doppler ultrasound and intracranial hypertension can be detected even before any clinical signs. Peripheral vascular resistance correlates with intracranial pressure. Other parameters are pulsatility index, maximal blood flow in the systolic phase, mean blood flow and end-diastolic value. By pressing the fontanelle, an increase of basal values of the resistivity index could predict intracranial hypertension. These values regress after drainage operations [3-5].

Traumatic haemorrhage may occur on cortical surface as in subcortical layers and manifesting as subarachnoid and subdural bleeding. It is difficult to detect smaller subarachnoid haemorrhage on ultrasound but it can be described as an increase of echogenicity or highlight of cortical gyri with fading of its contours.

CT scan of subdural haemorrhage shows areas with high and low density. In the next 2 weeks, the volume is progressing, changing to isodense and secondary mass effect may occur. CT scan of subdural haemorrhage shows areas with high and low density. In 2 weeks time, the volume is progressing, changing to isodense and secondary mass effect may occur.

MRI is useful for distinguishing of subacute and chronic subdural haemorrhage, as well as for parenchymal lesions and venous thrombosis. Gradient echo (GRE) sequences are useful in the detection of acute hemorrhage (Figure 1). Transependymal oedema on T2 MRI helps distinguish acute hydrocephalus and ventriculomegaly. The disadvantage is that MRI is time-consuming, with the need for transport and sedation of the patient.

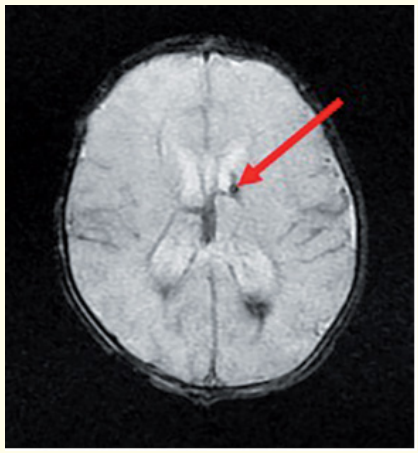

Figure 1: *MRI scan of subependymal bleeding, GRE sequence.*

Traumatic haemorrhage

From the view of the traumatic aetiology, for intracranial haemorrhage development is quite hazardous even vaginal delivery. Traumatic haemorrhage can be divided into intracerebral, intracerebellar, acute or chronic subdural, epidural and subarachnoid. In full-term neonates, the most common finding is firstly subarachnoid, secondly subdural haemorrhage. Least common findings are epidural or intracerebral haemorrhage.

Intracerebral haemorrhage

Frequent location of this traumatic haemorrhage is cerebellum and upper part of the vermis or is associated with acute subdural haematoma in the posterior fossa. Mode of origin is applied pressure to back of baby's head transferred to the cerebellum, against tentorium, or pressure to the skull causing tentorial damage and damage of adjacent venous sinuses. Another location of traumatic

haemorrhage in full-term neonates are ventricles, with the pathogenesis of increased venous pressure. Indication criteria for surgical treatment of posterior fossa bleeding must be well-grounded as it poses substantial risks and possible coagulopathy must be addressed. Severe asphyxiation can result in intracerebral bleeding (e.g. thalamic) in full-term neonates as well [6]. Risks of surgery is that of blood loss, which, even in small amounts might have severe consequences to child haemodynamics. Considering the fine vascular architecture of the neonatal brain and high levels of parenchymal water, usage of suction and coagulation in an effort to stop bleeding might progress the ischaemia and destruction [6-8].

Acute subdural haematoma

Acute subdural haematoma incidence is associated with a vacuum extractor or forceps usage, or in breech delivery, mostly in full-term neonates. Progression of intracranial pressure presents with excessive crying, vomiting or lethargy. Convulsions might be induced by subarachnoid haemorrhage. Massive haematoma manifests with ipsilateral bulbar deviation, ipsilateral n. oculomotor paresis and contralateral hemiparesis. Infratentorial bleeding presents by opisthotonos, the pressure to the brainstem induces bradycardia, ventilation disorders and loss of consciousness [9].

Considering its high risks most of these bleedings do not require surgical treatment. Smaller haematomas resolve spontaneously or regress to the chronic stage when evacuation with repeated punctures is possible. Massive haematomas, mainly those with direct pressure to the brainstem, are very often fatal. In the case of sizable collections, with significant midline shift and compression of the brain, evacuation with craniotomy is a possibility, with great attention to sinus flow and handling of the source of the bleed. Massive haematoma can cause ischemia of hemisphere with subsequent oedema [6,7].

Chronic subdural haematoma

Chronic subdural haematoma (SDH) is more often found in toddlers than in neonates, mainly from 6 to 12 month and develop from acute SDH after 2 - 3 weeks. Authors Green., *et al*. published MRI findings of bilateral subdural haematoma found intrauterine [10]. Very often it occurs bilaterally. Small haematoma can be asymptomatic, bigger might progress in volume with time and cause signs of intracranial hypertension - hyperirritability, intolerance of food, and progression of head circumference. Brain atrophy formation in chronic hygroma (decoloured blood) may lead to microcephaly and development retardation. In the case of asymptomatic progress with negative signs of intracranial hypertension (fontanelle niveau), subsequent observation of intracranial findings with the revisory sonographic examination is possible. Within the next 2-3 months, gradual absorption of liquid residue and re-expansion of the brain is also possible [11]. Evacuation of chronic SDH consists of repeated punctures of the subdural collection (needle 19-21G) in local anesthetization, with the aspiration of liquid residue, repetition is possible every 2 - 3 weeks. Another possibility is evacuation with external drainage with the possibility of subdural space flushing or insertion of a subdural-peritoneal shunt in cases with persistent chronic collections. Even bilateral collection can be resolved with unilateral shunt insertion with subsequent extraction [6,7]. There can be problems with septated collections drainage as well as the risk of infection. Evacuation from burr hole presents the possibility of active flushing from subdural space and keeping the drainage in, a procedure must be done with general anaesthesia. With persistent septated collections, mini-craniotomy is sometimes necessary, with the chance to fenestration or resection of nanomembranes. The disadvantage is the level of invasivity, subdural space is exposed enough for the treatment [12].

Epidural hematoma

Epidural hematoma (Figure 2) is a very rare occurrence and most commonly does not require surgery. Medial meningeal artery in the neonate is not located in bone crease yet, hence it is not prone to damage as in adulthood. Bleeding usually occurs from epidural veins and is associated with a bone fracture. Blood collection is located on both sides of bone and part of the haematoma is released during skin incision. After the revision of epidural space, handling the source of bleeding and dura stitching to the borders of craniotomy is performed, also it is possible to insert subgaleal drainage. Infratentorial bleeding is very rare, occurs mainly in older children [7].

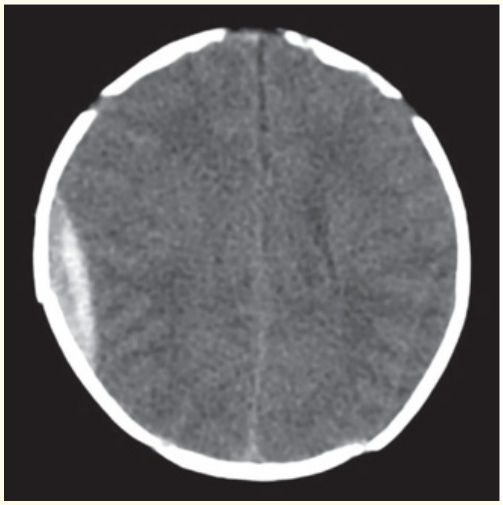

Figure 2: *CT scan of epidural bleeding of the neonate.*

Atraumatic haemorrhage

Atraumatic haemorrhage in full-term neonates is rare. Pathogenesis is an ischemic attack - artery embolus, venous thrombosis or arterial thrombosis/vasospasm. This can result in thalamic bleeding which may progress to intraventricular [13]. Another source are vascular malformations or coagulation deficit. Possible, but rare are tumour bleedings (teratoma, astrocytoma, medulloblastoma, plexus papilloma) [14]. The most common type is germinal matrix bleeding, mainly in immature neonates.

Germinal matrix bleeding

The germinal matrix is highly vascularized tissue with a size of average 2,3 mm and subependymal location. It is developed around 7 gestational week, with maximum size reached in 20 - 26 week. At the end of 2nd and beginning of 3rd trimester, this tissue is differentiated to neural and glial cells, which migrate out, where further white and grey matter develops. During the next intrauterine growth, the germinal matrix is eliminated and after 34 week nearly disappears. In early period is fully vascularized by thin wall arteries (recurrent artery of Heubner, thalamostriate artery and anterior choroidal artery) [2,11,15,16]. During 3rd trimester, synaptic connections are developed. Therefore, even small local bleeding could result in a disastrous effect on brain development.

Factors of perinatal and postnatal atraumatic haemorrhage are respiratory distress, asphyxia, dehydration, resuscitation with excessive fluid load and rapid changes of brain arterial and venous pressure values [17,18].

Incidence of intraventricular bleeding in infants under 1500g is 30 - 50% [18,19] and is growing with prematurity. Until 28th gestational week, bleeding occurs in 60 - 80%, until 30th week is around 40% and further decrease to 15 - 20%. 85% of bleedings occur until 3rd day after delivery and only 10 - 15% in 2nd week and later. The incidence in full-term neonates isn't more as 5%. Haemorrhage in first 12 hours after delivery is the most dangerous because of the risk of secondary intracerebral haemorrhage, developmental abnormalities and infant death [17].

Effects of intraventricular bleeding are germinal matrix destruction, periventricular hemorrhagic infarction (on average 15% accompanied intraventricular bleedings) [17], post-hemorrhagic hydrocephalus and porencephaly.

Germinal matrix haemorrhage is affected by pneumothorax, seizures, cardiopulmonary resuscitation, excessive fluid income, hypoxia and other factors which influence on brain circulation [19]. Neonates with congenital cardiac defects can be retarded in development as long as 4 weeks after correct gestation age. Involution of the germinal matrix is, therefore, delayed and its presence carries the risk of bleeding [20].

According to Papile haemorrhage classification based on ultrasound exam, there are 4 grades [21]:

- Grade I: Subependymal and germinal matrix bleeding (Figure 3).
- Grade II: Intraventricular extension without ventricular dilatation (Figure 4).
- Grade III: Intraventricular extension with ventricular dilatation (Figure 5).
- Grade IV: Intraparenchymal bleeding, blood could/could not be in ventricles (Figure 6).

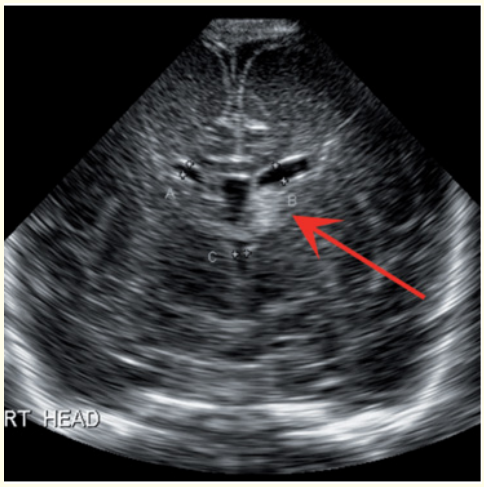

Figure 3: *Grade I, Papile classification.*

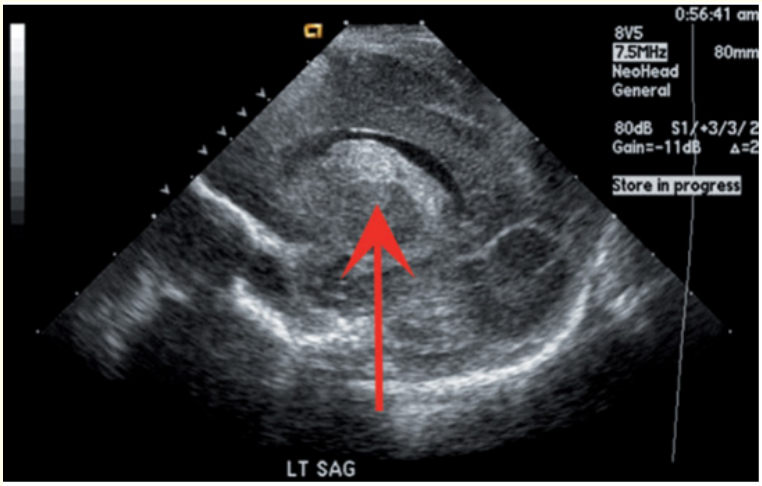

Figure 4: *Grade II, Papile classification.*

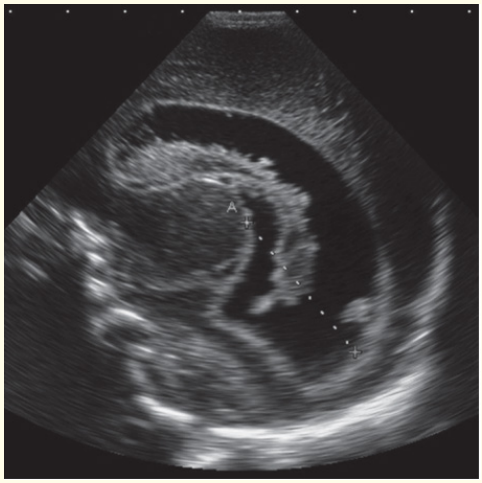

Figure 5: *Grade III, Papile classification.*

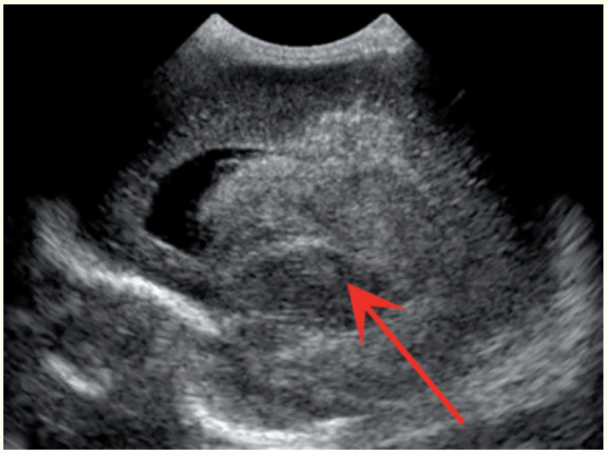

Figure 6: *Grade IV, Papile classification.*

Post-hemorrhagic hydrocephalus and surgical treatment

Origin of post-hemorrhagic hydrocephalus is usually caused by intraventricular bleeding from the germinal matrix with subsequent progressive dilatation of the ventricular system and with signs of elevated intracranial pressure. Changes in brain blood flow regulations result in its hypoperfusion and secondary damage. With hydrocephalus diagnosis besides imaging examination (USG, CT, MRI), there is also a need for overall clinical examination and ophthalmologic examination of fundus oculi [3,4]. Ventriculomegaly is most commonly developed 1 - 3 weeks after intraventricular bleeding. In its next development, intraventricular bleeding can progress asymptomatically (up to 68%) [17], in cases with progression of signs there can be growth of head circumference (1,5 - 2 cm/week or 2 mm/day), ophthalmoplegia, fontanel tension, diastasis of cranial sutures, irritability, intolerance of food and vomiting [2,17,22]. Implantation of the shunt without former derivation of hemorrhagic liquor, especially in premature neonates is associated with wound complication,

infection and obstruction of the shunt system. SCF parameters before implantation differ from department to department or preferred drainage systems. Advised pre-surgery weight of a child is 2000g [2,23-25].

Lumbal and ventricular puncture

Repeated lumbal and ventricular punctures are considered as outdated procedures due to their low effectivity and associated risks. They are still used when there is a need for liquor sample examination [26]. Lumbar puncture is executed on lateral position with the extraction of 10 - 20 ml of liquor. Repeated lumbar punctures increase risk of infection, does not stop the progression of hydrocephalus a does not decrease the need of subsequent VP shunt implantation. Lumbar puncture is contraindicated in cases of obstructive hydrocephalus [2,27,28]. A similar effect is with a ventricular tap via fontanel. It is used when the lumbar puncture is contraindicated. The risk of the procedure is the intracranial infection and intracerebral haemorrhage with subsequent porencephaly [2].

External ventricular drainage

Implantation of external ventricular drainage (EVD) is usually performed in general anaesthesia, with the introduction of the catheter through the lateral part of fontanel and its advantage is continuous CSF drainage and regular examination. Adjustment of drainage system height is done to prevent over drainage or underdrainage of ventricles.

EVD presents alternative in children with thin skin, where implantation of the subcutaneous reservoir with repeated punctures threatens its perforation. There is also a possibility of intraventricular injection of fibrinolysis (streptokinase) [29]. Favourable is the usage of thin catheters implanted from minimal approach [24,30]. Some risks of this type of drainage are obstruction, dislocation of the catheter and infectious complications - up to 50% after 3 weeks of continuous usage [2]. Certain prevention is to let catheter out subcutaneously, distally to implantation site [17]. Over drainage carries a risk of subdural collections formation [28]. Another disadvantage of EVD, as well as of lumbar and ventricular punctures is the loss of liquids a possibility of electrolytes and proteins depletion. The need for subsequent VP shunt implantation after EVD extraction is up to 64 - 78% of cases [23].

Ventriculosubgaleal shunt

Compared to ventricular reservoirs, these shunts are rare, even though has advantages like constant drainage and reduction of taps for cerebrospinal fluid (CSF) derivation [27]. The intraventricular part is introduced through fontanelle, or via a borehole and distal part is located in subgaleal space. The aim is to use the absorptive capacity of subgaleal preformed space. It is advised, prevention of head position on the fluid collection site so cerebrospinal fluid can fill subgaleal space [23]. The shunt is temporary until reaching the desired weight of the child and after correction of CSF parameters for definitive shunt implantation. There are only 10 - 20% cases, in which another shunt operation is unnecessary. Subgaleal space has reservoir function with absorptive capacity and reduces intracranial pulsations which are increased because of hydrocephalus [24]. Taps of collections are performed in case of intracranial hypertension or progressive ventricular dilatation. Opposite to the ventricular reservoir or external ventricular drainage, there is no loss of fluids and minerals with subgaleal shunts [24,31]. Complications count staphylococcus infection [24,28], shunt obstruction or dislocation. As a reason for infections is assumed skin barrier weakening after fluid collection arise. Another reason may be fluid stasis with an increased risk of germ colonisation. After adhesions development in subgaleal space, absorptive capacity is reduced and another surgical intervention is needed. Problem is also cosmetic result and pseudo-meningocele development after implantation.

Ventricular reservoir

Aim of the reservoir is the possibility of repeated taps with SCF drainage and antibiotics administration. Similar to subgaleal shunt, the reservoir is a temporary solution. Ventricular catheter is placed via fontanelle insertion or borehole. The catheter is connected to the reservoir (Rickham/Ommaya type) and placed in subcutaneous space. Day after surgery punctures can be started. The daily amount of derived fluid is 10 ml/kg with speed 1 ml per minute, with dripping, avoiding aspiration [2,22,25]. After connection of the shunt valve

and peritoneal/atrial catheter, VP or VA shunt is completed. Amount of fluid and frequencies of taps may be corrected according to sonographic and Doppler examination and fontanel tension [26]. Risk is wound dehiscence, catheter obstruction and infection (8 - 12%), also its ventricular dislocation.

Ventriculoperitoneal shunt

The most commonly used type of shunt is ventriculoperitoneal shunt with CSF drainage into the peritoneal cavity. Much less used is ventriculoatrial shunt with CSF drainage into the right atrium, and other drainage systems (e.g. ventriculopleural shunt). Shunt usually consists of proximal and distal catheter and valve. Most commonly catheters are silicone. Antisiphon unit can be also incorporated into the shunt. Another part is the reservoir for the possibility of CSF sampling. To verify the utility of the shunt without the need for reservoir tap there is the possibility of active CSF drainage with the pumping chamber. The shunt valve serves as liquor drainage regulation. The antisiphon unit function is over drainage prevention, drainage of the liquor is blocked, when pressure on the outlet of the valve drops to zero (verticalization of the patient). The shunt system implantation depends on results of biochemical and microbiological CSF parameters, usually, the levels of proteins must be below 2g, with minimal levels of blood elements and repeatedly negative culture findings [26,32]. The disadvantage of the shunt is a relatively high risk of complications. The most common are infections (*Staphylococcus epidermidis, Staphylococcus aureus*, gram-negative bacteria) and catheter obstruction [26]. Others include disruptions/interruptions and dislocations of the catheter, skin erosions, over drainage of ventricular system or complications associated with the distal catheter (intestinal perforation, ileus). Infectious complications decrease gradually with age, the highest incidence is in premature infants (30%) due to the immature immune system. Because of the higher protein content in cerebrospinal fluid after intraventricular haemorrhage, the risk of shunt obstruction also increases, in the first year after implantation it is around 40% [33]. Surgical revisions are therefore most common in this group of patients (20 - 50%). With the revisions, the risk of infection and overall adverse outcome continues to increase. With the long-term effect of the shunt, there is also an increasing addiction to it.

Conclusion

Intracranial haemorrhage of newborns presents a serious medical and economic problem in neonatology as well as in further pediatric care with a high risk of developing neurological deficit and later disorders. Traumatic bleeding is present rare, but in obstetrics is a serious complication due to the risk of irreversible damage to newborns and also for adverse forensic consequences. The most common type of intracranial bleeding is the non-traumatic germinal matrix bleeding, which occurs mainly in premature newborns. Partial prevention of this haemorrhage is the prevention of preterm birth. Despite proved effectiveness, surgical procedures are risky and could cause permanent damage to a varying extent. Indication criteria for neurosurgical intervention must, therefore, be carefully considered and performed as necessary range. Ventriculosubgaleal shunt has been known for over 100 years, but ventricular reservoirs are more commonly used in the treatment of post-hemorrhagic hydrocephalus. Lumbar, eventually ventricular punctures are obsolete due to significant risk of complications and their benefit is not sufficient. In recent decades and with the development of prenatal care and diagnosis, there has been a decline in premature births as well as intracranial haemorrhages.

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