NEUROSURGICAL MANAGEMENT OF PEDIATRIC PATIENTS WITH NONTRAUMATIC BRAIN HEMORRHAGE

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Abstract

Nontraumatic intracranial hemorrhage (ICH) in pediatric patients is an uncommon but critical neurological emergency associated with significant morbidity and mortality. Unlike adults, pediatric ICH is most commonly caused by vascular malformations, hematological disorders, and neoplasms rather than hypertension or amyloid angiopathy. Management requires rapid diagnosis, careful neurological assessment, and a multidisciplinary approach integrating neurosurgical, neurocritical care, and hematological expertise. This article provides an expanded review of the etiology, pathophysiology, clinical features, diagnostic strategies, and current neurosurgical management options for pediatric nontraumatic brain hemorrhage, with emphasis on individualized treatment and outcomes.

Keywords: pediatric intracranial hemorrhage, neurosurgery, AVM, hydrocephalus, hematoma evacuation, neurocritical care

BOLALARDA NOTRAVMATIK MIYA QON QUYILISHI BILAN OG‘RIGAN BEMORLARNI NEYROXIRURGIK BOSHQARUVI

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[2]Respublika Shoshilinch Tibbiy Yordam Ilmiy Markazi Namangan filiali

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Annotatsiya

Bolalarda notravmatik intrakranial qon quyilishi (ICH) kam uchraydigan, ammo hayot uchun xavfli nevrologik holat bo‘lib, yuqori darajadagi nogironlik va o‘lim bilan bog‘liq. Kattalardan farqli ravishda, bolalarda ICH ko‘pincha arterial gipertenziya yoki amiloid angiopatiya bilan emas, balki qon tomir malformatsiyalari, gematologik kasalliklar va o‘smalar bilan bog‘liq bo‘ladi. Bunday bemorlarni boshqarish tezkor tashxis qo‘yish, puxta nevrologik baholash va neyroxirurgiya, neyroreanimatsiya hamda gematologiya mutaxassislarini o‘z ichiga olgan multidissiplinar yondashuvni talab qiladi. Ushbu maqolada bolalarda notravmatik miya qon quyilishining etiologiyasi, patofiziologiyasi, klinik belgilari,

diagnostik usullari va zamonaviy neyroxirurgik davolash usullari keng yoritilib, individual yondashuv va davolash natijalariga alohida e'tibor qaratilgan.

Kalit so'zlar: bolalarda intrakranial qon quyilishi, neyroxirurgiya, AVM, gidrotsefaliya, gematoma evakuatsiyasi, neyroreanimatsiya

НЕЙРОХИРУРГИЧЕСКОЕ ВЕДЕНИЕ ДЕТЕЙ С НЕТРАВМАТИЧЕСКИМ ВНУТРИМОЗГОВЫМ КРОВОИЗЛИЯНИЕМ

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Аннотация

Нетравматическое внутримозговое кровоизлияние (ВМК) у детей является редким, но крайне тяжелым неврологическим состоянием, сопровождающимся высокой заболеваемостью и смертностью. В отличие от взрослых, у детей ВМК чаще связано не с артериальной гипертензией или амилоидной ангиопатией, а с сосудистыми мальформациями, гематологическими нарушениями и опухолями. Ведение таких пациентов требует быстрой диагностики, тщательной неврологической оценки и

мультидисциплинарного подхода с участием нейрохирургов, специалистов интенсивной терапии и гематологов. В данной статье представлен расширенный обзор этиологии, патофизиологии, клинических проявлений, методов диагностики и современных нейрохирургических подходов к лечению нетравматических внутричерепных кровоизлияний у детей с акцентом на индивидуализацию терапии и исходы лечения.

Ключевые слова: внутричерепное кровоизлияние у детей, нейрохирургия, АВМ, гидроцефалия, эвакуация гематомы, нейрореанимация

Introduction

Intracranial hemorrhage in children accounts for approximately 1–3 cases per 100,000 annually but represents a disproportionate cause of pediatric stroke and neurological disability. The developing brain exhibits unique anatomical and physiological characteristics, including increased plasticity and different cerebrovascular autoregulation, which influence both presentation and recovery. Early recognition and timely neurosurgical intervention are essential to prevent secondary brain injury caused by mass effect, elevated intracranial pressure (ICP), and ischemia.

Etiology and Risk Factors

The causes of nontraumatic brain hemorrhage in pediatric populations are diverse and age-dependent:

- **Vascular malformations**
  - Arteriovenous malformations (AVMs)
  - Cavernous malformations

- Developmental venous anomalies

- **Hematologic disorders**
  - Hemophilia
  - Thrombocytopenia
  - Vitamin K deficiency (especially in neonates)
- **Neoplasms**
  - High-grade gliomas
  - Medulloblastomas
  - Choroid plexus tumors
- **Cerebral venous sinus thrombosis (CVST)**
- **Infections and vasculitis**
- **Idiopathic cases**

AVMs remain the leading identifiable cause, accounting for a large proportion of spontaneous hemorrhages in older children.

Pathophysiology

Primary brain injury results from the immediate mechanical effects of hemorrhage, including tissue disruption and hematoma formation. Secondary injury mechanisms include:

- Increased ICP and reduced cerebral perfusion pressure (CPP)
- Perihematomal edema
- Neuroinflammation
- Excitotoxicity and oxidative stress

In children, the brain's compliance may initially buffer small increases in volume, but rapid decompensation can occur.

Clinical Presentation

Clinical manifestations depend on hemorrhage location, size, and patient age:

- **General symptoms**
  - Acute headache
  - Nausea and vomiting
  - Altered level of consciousness
- **Focal deficits**
  - Hemiparesis
  - Cranial nerve deficits
  - Aphasia
- **Seizures**, particularly common in cortical hemorrhages
- **Infants**
  - Bulging fontanelle
  - Poor feeding
  - Irritability or lethargy

Diagnostic Evaluation

Neuroimaging

- **Non-contrast CT scan**: first-line modality for rapid detection
- **MRI brain**: superior for identifying underlying lesions and chronic changes
- **MR/CT angiography**: screening for vascular abnormalities
- **Digital subtraction angiography (DSA)**: gold standard for AVMs and aneurysms

Laboratory Studies

- Complete blood count
- Coagulation profile
- Screening for metabolic or genetic disorders when indicated

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Severity Assessment and Monitoring

Clinical severity may be assessed using pediatric adaptations of the Glasgow Coma Scale (GCS). Imaging-based scoring systems, such as hematoma volume estimation and presence of intraventricular hemorrhage, guide prognosis and intervention.

Continuous ICP monitoring is recommended in severe cases.

Indications for Neurosurgical Intervention

Surgical decision-making is individualized and based on:

- Hematoma size (>20–30 mL or significant relative volume)
- Mass effect or midline shift
- Neurological deterioration
- Hydrocephalus or intraventricular hemorrhage
- Identifiable surgical lesion (e.g., AVM, tumor)
- Refractory intracranial hypertension

Neurosurgical Management

1. Hematoma Evacuation

Open craniotomy remains the standard for accessible lobar hemorrhages with significant mass effect. Minimally invasive techniques, including endoscopic evacuation, are increasingly used to reduce surgical morbidity.

2. External Ventricular Drainage (EVD)

Indicated for intraventricular hemorrhage or acute obstructive hydrocephalus. It allows CSF diversion and ICP monitoring.

3. Decompressive Craniectomy

Used in life-threatening intracranial hypertension unresponsive to medical therapy. It reduces mortality but requires later cranioplasty and carries risk of complications.

4. Management of Underlying Vascular Lesions

- **Microsurgical resection**: definitive for accessible AVMs
- **Endovascular embolization**: adjunct or standalone therapy
- **Stereotactic radiosurgery**: for deep or inoperable lesions

Treatment strategies often involve multimodal approaches.

5. Tumor-Related Hemorrhage

Requires both hematoma evacuation and oncological management, including biopsy or tumor resection.

Neurocritical Care Management

Optimal outcomes depend on intensive postoperative care:

- ICP control (head elevation, osmotherapy)
- Maintenance of adequate CPP

- Seizure prophylaxis
- Ventilatory support
- Correction of coagulopathy
- Strict fluid and electrolyte balance

Complications

- Rebleeding
- Hydrocephalus
- Infection (meningitis, ventriculitis)
- Post-hemorrhagic epilepsy
- Long-term neurocognitive deficits

Outcomes and Prognosis

Prognosis depends on:

- Etiology (better in AVMs after definitive treatment)
- Initial neurological status (GCS)
- Hemorrhage volume and location
- Timeliness of intervention

Children often demonstrate better recovery due to neuroplasticity; however, significant disability may persist in severe cases.

Future Directions

Advances in minimally invasive neurosurgery, neuroimaging, and endovascular

techniques continue to improve outcomes. Ongoing research focuses on neuroprotection, biomarkers of secondary injury, and individualized treatment algorithms.

Conclusion

Pediatric nontraumatic brain hemorrhage requires rapid diagnosis and a multidisciplinary, patient-specific management approach. Neurosurgical intervention plays a pivotal role in selected cases, particularly in the presence of mass effect, hydrocephalus, or treatable underlying lesions. Continued advancements in surgical techniques and critical care are essential to improving survival and long-term neurological outcomes.

Keywords: pediatric intracranial hemorrhage, neurosurgery, AVM, hydrocephalus, hematoma evacuation, neurocritical care