Pediatric Neuro Issues: Caring for the Child's Brain

I. Introduction

A. The brain is the most essential organ of all! The ultimate goal of all our treatment is to preserve the intellect, unique personality, talents, and emotions of the person in our care. With children, neurological care is even more crucial because continuing growth and development are essential for the pediatric brain.

B. The following is not an exhaustive neurologist's approach but rather an abbreviated focus on the essentials which should be part of prehospital stabilization and transport care.

II. Overall responsiveness/activity

A. Apparent awareness and baseline activity can be noted from a distance

1. Is the child looking at you or interacting with a parent?
2. What is his position?
3. Is he vocalizing?
4. The child who appears to be sleeping may in fact just be doing so, but failure to arouse to an ambulance which has arrived with lights and siren is concerning!
5. Are there movements suggestive of seizure?

B. Normal pediatric behavior varies with age: most 4 month olds don't sit up and most 4 year olds do. Thus behavior must always be evaluated in context of the child's age.

1. Caregivers who are also parents have a potential experiential reference, at least when their children are older than the child in question.
2. The Denver Developmental scale has been used by pediatricians for evaluation of verbal, gross, and fine motor skills but it is far too complicated for use in acute care. However, medical caregivers should have some baseline knowledge of the major milestones such as walking, using words, and speaking in sentences.
3. Never hesitate to use the **true** experts, the child's parents or caregivers! They know him well and can certainly report changes from his normal state. Remember that the urgent acute question is not, "Is this child normal for age?", but rather, "Is he different from usual?" If he is a developmentally-delayed child who never speaks, lack of verbal response is not concerning, while failure to speak may be an ominous sign in a child who is usually articulate.
4. If the child is obviously awake, alert, and developmentally appropriate (e. g., a 2 year old whose primary communication is, "No!!"), an elaborate neurological evaluation is not nearly as important as it is in a child who appears to be neurologically abnormal.
5. The Glasgow Coma Score (see appendix) is the primary assessment tool used in patients with apparent alteration of mental status, and although it was originally designed for adults, it can be used for children if the verbal component is appropriately modified.
   a. Note that many components of the GCS are findings that an alert caregiver might notice in the course of routine care. Thus response to voice, touch, or pain are likely to be obvious in the course of basic hands-on care, since we inevitably speak to, touch, and (regrettably) hurt our patients.
   b. Glasgow Coma Score should be assigned serially so that trends in the child's condition become apparent
   c. "Under 8, intubate!" is a reasonable axiom, so long as there is no reversible cause such as hypoglycemia and the EMS crew is equipped to intubate.

C. Multiple possible etiologies of encephalopathy or coma; can be divided into two subgroups:
    1. Diffuse, metabolic: less likely to produce focal findings such as a blown pupil
        a. Hypoglycemia, diabetic ketoacidosis
        b. Meningitis, encephalitis
        c. Cerebral hypoxia/ischemia
        d. Cerebral edema
        e. Intoxication/drug overdose
        f. Major derangements of serum sodium, hyperosmolar states
        g. Reye syndrome
        h. Hepatic or uremic encephalopathy
        i. Post-ictal state
        j. Inborn errors of metabolism
        k. Hypertensive encephalopathy
        l. Severe hypothermia or hyperthermia
    2. Structural, anatomic: may result in focal findings reflecting site of the lesion
        a. Intracranial hemorrhage/contusion (consider child abuse!)
        b. Brain tumor
        c. Cerebral infarction
        d. Brain abscess
        e. Hydrocephalus
D. Note that **there is usually a continuum of decreasing level of consciousness before a patient becomes fully comatose.** *Altered mental status in a child is usually obvious to parents before it is apparent to a stranger*, and when a parent states, "My child just isn't himself!", the prudent caregiver will take the observation very seriously.

III. The eyes

A. Eye examination is an essential part of a routine neurological evaluation. (However, note that seeing even one pupil - never mind both simultaneously - may be extremely difficult in a child who is determined to keep his eyes shut. However, such a responsive child probably doesn't have serious CNS pathology, so assessing one eye at a time may be acceptable.)
B. Pupils should be:
    1. Round, not irregular or oval
    2. Equal (note that some normal individuals always have mild anisocoria; however, a markedly enlarged, sluggish or non-reactive pupil is likely to be a result of an acute neurological emergency).
    3. Reactive to light
    4. Consensually reactive, i.e., reactive when a light is applied to the other eye
C. Pupil size may be significant. In particular, though numerous forms of pathology result in enlarged pupils, pinpoint pupils are uncommon and the examiner's first thought should be of opiate exposure - even in a non-ambulatory infant.
D. The eyes should move in parallel and freely in all directions.
    1. Loss of lateral gaze reflects a 6th cranial nerve (abducens) palsy and may result from increasing intracranial pressure.
    2. Downward eye deviation (sunsetting) results from midbrain pressure and is typical of hydrocephalus with acute shunt malfunction (a neurosurgical emergency!)
    3. Other gaze abnormalities may reflect a variety of neurological problems

E. Doll's eye movements may be seen in a comatose individual whose brainstem centers for parallel gaze are still intact but who is not conscious enough to focus his gaze.

F. In a patient whose neck cannot be moved (note that doll's eye testing requires turning the head from side to side), cold caloric testing can compel the eyes to move if the brainstem is functioning; if the eyes move, this test thus rules out brain death.

G. Funduscopic exam should be undertaken in the ED in any child with altered mental status, even if it is inconvenient and even if the child's pupils are not dilated.

1. Note that retinal hemorrhages **almost always mean non-accidental trauma** in any child who does not have a clear-cut coagulopathy, major known trauma, or a recent vaginal birth. Most abused children have multiple hemorrhages, some of which are centrally-enough located to see even without dilating the pupil.
2. Papilledema should raise concerns about increased ICP, and a baseline assessment of the disk of any child at risk for developing intracranial hypertension will facilitate recognition of subsequent changes.

IV. Increased intracranial pressure

A. Increased ICP may result from an increase in any of the usual intracranial components, i.e., blood, brain, or CSF, or it may be caused by an abnormal mass such as tumor, abscess, or hematoma.

B. Dangerously increased ICP may result in death or permanent injury as a result of a herniation syndrome or as a result of cerebral ischemia (cerebral blood flow diminishes as ICP rises to the level of arterial pressure). Thus critically increased ICP is a neurological emergency.

C. Signs and symptoms of increased ICP

1. Headache (if the child is old enough and conscious enough to complain of one)
2. Irritability/fussiness in an infant (a completely non-specific finding)
3. Bulging anterior fontanel if the child is young enough to have one: the anterior fontanel offers a window on the infant brain!
4. Vomiting (but this can result from many other causes)
5. Decreasing LOC as the ICP elevation worsens
6. Eye findings, including 6th nerve palsy, a "blown" pupil, sunset eyes (especially in a child with hypdrocephalus), papilledema on funduscopic exam
7. Seizures
8. Posturing (flexor or extensor)
9. Cardiopulmonary changes are unpredictable: the classic Cushing triad of bradycardia, hypertension, and respiratory abnormalities is not reliably present in children, but if it does appear, it should be taken seriously

V. Movements

A. If the child is moving spontaneously, weakness or asymmetry should be noted. Paresis or paralysis may become more obvious with painful procedures: does the child withdraw the limb in which blood has been drawn or IV placement undertaken?

B. Recall that horizontal cutoffs reflect spinal cord pathology while vertical asymmetry reflects brain abnormality.

1. A child who has been restrained by only a lap belt in a crashing vehicle and who has leg weakness or paralysis afterwards has probably suffered a lumbar spine and cord injury - and may well have serious intra-abdominal injuries as well!

2. A child who has weakness or paralysis of one side of his face or body often has brain pathology (a variety of types are possible), though the finding may result from a more benign condition such as a transient Todd's paralysis or a Bell's palsy.

C. Note that unusual or repetitive movements may result from motor activity of a seizure.

VI. Seizures

A. Seizures are a common presenting complaint in children requiring a 911 response or acute emergency care.

B. The commonest pediatric seizures are febrile convulsions, which are benign and self-limited.

1. Occur in 2-5% of otherwise normal children
2. Limited to younger ages (usually under 5 years but not common under 5 months)
3. Associated with illnesses producing fever, especially respiratory or ear infections
4. Features of febrile convulsions
    a. Generalized tonic-clonic, <u>not</u> focal seizures
    b. Relatively short duration of <15 minute (usually <5 minutes)
    c. Usually <u>not</u> associated with prolonged or severe post-ictal depression
    d. Tendency to recur, either during the same or a subsequent febrile illness
    e. Benign: <u>not</u> associated with chronic neurological sequelae

C. Unfortunately, children with other causes of seizures may also present with seizure in association with fever; other causes must always be considered!

1. The cause of the fever AND the seizure may be a serious CNS infection such as meningitis
2. Fever lowers the seizure threshold; many children who will eventually prove to have true seizure disorders have their first seizure in conjunction with a febrile illness

D. Causes of seizures in childhood

1. Febrile convulsions
2. CNS infections: meningitis, encephalitis, brain abscess
3. Trauma: consider non-accidental trauma in a young patient with unexplained seizures!
4. Metabolic
    a. Hypoxic/ischemic encephalopathy
    b. Hypoglycemia
    c. Acute hyponatremia (may be suggested by history)
    d. Drugs or toxins
    e. Severe hyperthermia
    f. Hypocalcemia (not detectable by most paramedics)
5. Idiopathic seizure disorder (previously termed epilepsy)
    a. A common pediatric problem
    b. Possible causes of failure of anticonvulsant therapy in a child with a seizure disorder
        1). Febrile illness: fever increases likelihood of seizures in a child with an underlying seizure disorder
        2). Non-compliance with prescribed regimen (failure to take the drug, emesis)
        3). Growth without dose adjustment to maintain therapeutic levels
        4). Refractory seizure disorder
6. Brain tumor
7. Stroke from any cause
8. Other (congenital metabolic disorders, etc.)

E. Clinical appearance of a child with seizures
    1. Usually unconscious and unarousable
    2. Motor findings may consist of generalized or unilateral jerking of extremities, facial twitching or lip smacking, deviation of the eyes, or no motor abnormalities at all.
    3. *May be subtle in infants*, consisting of nothing but blinking, repetitive sucking movements, "bicycling" movements of the lower extremities, frequent Moro responses, or simple apneic or cyanotic spells
    4. Respirations may be rapid and shallow, unusually deep, erratic, or absent.
    5. Patient may appear pale, ruddy, or cyanotic.
    6. Heart rate and blood pressure may be elevated unless child has developed significant hypoxia or acidosis, in which case they will fall.

F. **Seizures are not necessarily benign**: they may in fact be associated with permanent neurological consequences or death, particularly if the seizure activity persists for an extended period.
    1. Underlying cause of the seizures (trauma, hypoglycemia, meningitis, etc.) may itself be damaging, and prolonged seizures can exacerbate the injury.
    2. Prolonged electrical status can produce CNS injury by means of increased local neuronal metabolic rate which may exceed substrate availability and result in local acidosis. This is exacerbated by fever, which is common with severe seizures. **Note that CNS injury from local hypoxia/acidosis will not be prevented even if the motor activity of the seizure is ablated by paralytic administration.**
    3. Apnea with resultant asphyxia, vomiting and aspiration, trauma resulting from seizure activity, lactic acidosis or rhabdomyolysis resulting from prolonged muscle activity, severe hyperthermia, and other complications may have long-term sequelae.

VII. Other

A. Meningeal signs often result from serious CNS infection.
    1. Recall that neck flexion is contraindicated in the case of possible C-spine injury; Kernig testing is not likely to be undertaken by EMS personnel but should be done in the hospital.
    2. Young infants usually do not have a clinically stiff neck, even in the face of fullblown meningitis.
    3. If the child is old enough to elicit meningeal signs and they are apparent to the EMS team, the child should be assumed to have meningitis until proven otherwise. This requires that EMS personnel wear masks and assume possible increase in the child's ICP. (Hospital caregivers should, of course, undertake appropriate work-up for infection and administer antimicrobials ASAP).

B. Skin findings may be significant: rashes may reflect serious infection with possible CNS involvement, while unusual bruises may result from abuse.

C. Breath odor may be clinically significant in a child with diabetic ketoacidosis or poisoning with certain agents (as well as rare congenital metabolic disorders).

D. Assess body temperature accurately in any child who may be profoundly hypothermic or a victim of heat stroke.

VIDEOS

VIII. Prehospital management

A. ABCs

1. Airway

a. May be compromised in a patient with altered mental status, and if there is no quick fix to improve the child's LOC, intubation will eventually be necessary to avoid aspiration as well as to assure continued airway patency.

b. Whether intubation should be attempted in the field depends on multiple variables, including rescuer skills, equipment/medications available to the EMS team, likely duration of transport, and condition of the child at baseline. If manual airway opening is successful and the EMS crew do not have optimal medications for intubation of a child who may have increased ICP, deferral of intubation to the ED staff may be preferable.

2. Oxygenation/ventilation

a. **High-flow oxygen should always be administered.**

b. Respiratory drive may be unstable in a child with decreased LOC, and these patients are often at risk from hypercarbia. (Note that a high pCO_2 is often well-tolerated by otherwise healthy individuals, but that in patients with increased ICP of severe metabolic acidosis, hypercarbia can be dangerous. The preferred pCO_2 for a patient with increased ICP is about 35, unless he is on the threshold of herniation, in which case it needs to be still lower.)

c. If any sort of pCO_2 monitoring is available to the EMS team, this is a group of patients in whom it may prove extremely valuable.

d. If the monitor reading suggests a pCO_2 >35 or the unmonitored child has periodic breathing or bradypnea, attempts should be made to assure ventilation. This can often be accomplished initially with BVM or bag/LMA or other airway adjunct, but if all non-invasive efforts fail, more invasive procedures such as intubation may be necessary.

e. Once ventilatory support has been accomplished, attempts should be made to identify a reversible cause of altered mental status such as hypoglycemia or narcotic toxicity. (See below).

3. Circulation

a. Note that heart rate and rhythm may be primarily affected by some of the underlying causes of seizures or coma (e. g., tricyclic overdose or severe hypothermia).

b. Tachycardia and hypertension are common with many disorders which result in a stress response. Hypertension plus relative **bradycardia** may reflect the ominous Cushing triad, though a relatively low heart rate may also simply result from traumatic brain injury or some poisons.

c. Though sorting out the true cause of circulatory abnormalities may not be possible in the prehospital setting, the primary underlying concern for EMS teams should remain to assure adequate brain perfusion. This will involve not only attempting to assure a stable rate and rhythm but also promoting a blood pressure sufficient to perfuse the CNS even if ICP is elevated.

B. **D = disability**

1. Once the essentials are being addressed, attention should be directed to the brain.
2. Physical exam should be undertaken as outlined above.
3. Essential labs include:
    a. Pulse oximetry to assure adequate saturation
    b. Blood glucose determination (this can also be measured in bone marrow!)
    c. Other labs are currently not available to most EMS providers, but if other bedside labs ARE possible, serum electrolytes, calcium, and blood gases would be extremely useful in some patients.
    d. In the ED, multiple additional tests should be considered, depending on the child's presentation.
        1). Work-up for infection (which may include an LP as well as blood work and other cultures)
        2). Additional chemistries, including renal and liver function tests, and (in some patients), serum osmolality, serum ammonia, serum for drug levels, or a carboxyhemoglobin level
        3). Urine tox screen
        4). Evaluation for trauma including a head CT, and, if indicated, a skeletal survey
        5). EEG
        6). Evaluation for intussusception
4. "Quick fixes" should be tried if possible. Interventions which may be available to EMS teams include:
    a. Restoration of brain oxygenation/perfusion
    b. Treatment of hypoglycemia
    c. Use of naloxone or flumazenil if narcotic or benzodiazepine toxicity is possible and reversal is not contraindicated
    d. Control of seizures often requires anticonvulsants (but recall that hypoglycemia, hyponatremia, hypocalcemia, or other specific causes of seizures may require other therapy)
        1). Note that this can be accomplished with IM midazolam or lorazepam; IV/IO placement is not required. (Rectal and nasal benzodiazepine administration are also possible but are less reliable than parenteral anticonvulsant therapy).
        2). A second longer-acting agent such as fosphenytoin is also desirable but it not available to most EMS providers. This should be offered in the ED to a child with severe seizures.
        3). Recall that if a paralytic has been administered for intubation or control of ventilation, that it **does not** provide control of the electrical seizure activity, which may result in further CNS injury if left uncontrolled.
    e. Other interventions may rarely be possible (e.g., pumping a sluggish but still partly functional VP shunt...)

5. Prehospital management of suspected increased ICP
    a. Elevate the child's head
    b. Keep the head midline and avoid jugular compression with ET tube tape, etc.
    c. Assure adequate ventilation (and undertake more aggressive hyperventilation if impending herniation is suspected)
    d. Control seizures, pain, and fever
    e. Consider diuretic administration (furosemide or mannitol) if recommended by physician supervisor
6. Emergent transport is indicated for most CNS catastrophes, but if time and personnel permit, a quick survey of the child's environment may offer clues which are not available to ED staff:
    a. Are there clues to poisoning such as empty bottles in the bathroom or bedroom (or drug paraphernalia in sight)?
    b. Does the story of trauma match the physical site where it allegedly occurred?
    c. Is there a barbecue or other outside device in use for heating or cooking because the family has no electricity?
    d. Other (signs of neglect, unsafe environment, etc.)

IX. Summary

A. Neurological crises are among the most frightening presenting problems of pediatric patients, and immediate intervention may be required in the prehospital setting.

B. Careful advanced preparation and appropriate acute intervention may result in survival of a neurologically normal child for decades thereafter.

GLASGOW COMA SCALE

Activity	Score	Infants	Children, Adults
Eye opening	4	Spontaneous	Spontaneous
	3	To speech	To verbal stimuli
	2	To pain	To pain
	1	No response	No response
Verbal	5	Coos, babbles	Oriented
	4	Irritable cries	Confused
	3	Cries to pain	Inappropriate words
	2	Moans to pain	Incomprehensible sounds
	1	No response	No response
Motor	6	Normal movement	Obeys commands
	5	Withdraws to touch	Localizes pain
	4	Withdraws from pain	Withdraws from pain
	3	Abnormal flexion	Abnormal flexion
	2	Abnormal extension	Abnormal extension
	1	No response	No response

Total = 3-15