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An Updated Guide to Meeting Yearly Stroke CME/CNE Requirements

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Module 2:
Pediatric Stroke
(2.0 credit hours)

Pediatric Stroke

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Pediatric strokes, defined as strokes occurring in patients 28 days to 18 years of age, are classified as ischemic or hemorrhagic cerebral events, and are seen in two to three per 100,000 children per year. They have the same incidence as pediatric brain tumors.[1] Early identification of stroke is paramount in patient outcomes, as therapy and subsequent recovery is often time dependent.

Treatment is driven by the underlying etiology of the event and type of stroke sustained by the patient. The post-stroke course and rehabilitation has extensive implications beyond the patient's medical needs, with financial and societal impacts for the patient and his or her family.[2]

Definition of the Problem

Stroke, a clinical syndrome of rapidly developing focal or global neurologic deficits lasting more than 24 hours, is diagnosed in more than 2000 children each year.[3,4] Pediatric strokes, defined as strokes that occur in individuals 28 days to 18 years, are classified as ischemic or hemorrhagic cerebral events. In 2013, the CDC's Web-based Injury Statistics Query and Reporting System (WISQARS™) reported that for children younger than 1 year and between 5-14 years of age, cerebrovascular accidents ranked in the 10 leading causes of death. Other adverse outcomes include persistent neurologic deficit, seizures, stroke recurrence, and psychosocial implications. Emergency physicians who care for pediatric patient populations should include stroke in the differential diagnosis when patients present with neurologic complaints, signs, or symptoms; however, a high index of suspicion is needed given the varied presentation depending on the location of the stroke and the patient's age. Due to the potentially devastating consequences of strokes and the time-sensitive nature of interventions, early identification of a stroke presenting in the emergency department (ED) is paramount for mobilizing resources and initiating treatment.[5]

Epidemiology

Pediatric strokes affect children of all ages, from birth through teenage years. While the incidence of childhood stroke is relatively rare, affecting two to three per 100,000 children per year, the diagnosis is still made as commonly as the diagnosis of childhood brain tumor.[1] The incidence of an arterial ischemic stroke (AIS) is 7.8 per 100,000 children and the incidence of hemorrhagic stroke is 2.9 per 100,000.[6] About one-third of all strokes are diagnosed in children younger than 1 year of age.[3] In the teenage population, subarachnoid hemorrhage (SAH) is the most common cause of stroke.[7]

Stroke mortality in children is high, and risk of death during the acute phase is predicted by level of consciousness on admission.[3] The total mortality of AIS, SAH, and intraparenchymal hemorrhage (IPH) is 5-7%.[4] The mortality of cerebral sinovenous thrombosis (CSVT) is 3-12%.[8,9] This risk increases for children who suffer repeat strokes.[3] More than half of all survivors have persistent neurologic, cognitive, or psychiatric deficits. Nearly one-third of all survivors develop epilepsy. Universally, strokes are associated with significant financial costs to families and society.[2]

Etiology

Unlike adult strokes, pediatric strokes are associated with a myriad of conditions. One-half of children who experience a stroke have at least one premorbid illness.[10,11] Ischemic strokes commonly arise from medical conditions, whereas hemorrhagic strokes are more likely to occur from structural anomalies or severe head trauma.[5,12] The etiologies of AIS are shown in Table 1. The etiologies of hemorrhagic stroke are listed in Table 2.

In children with predisposing risk factors, a stroke may also be "triggered" by certain conditions. For example, head trauma may trigger arterial strokes, while dehydration may trigger venous strokes.[3] Common infectious processes such as otitis media, varicella, meningitis, and tonsillitis can also trigger strokes.[13] Notably, hypertension is not a common trigger for hemorrhagic stroke in children, although it is a common cause of IPH in adults.[3]

Table 1: Etiologies of Arterial Ischemic Strokes in Children

- Sickle cell disease
- Cardioembolic
- Moyamoya syndromes
- Cervical arterial dissection
- Steno-occlusive cerebral arteriopathy
- Other determined etiology
- Multiple probable/possible etiologies*
- Undetermined etiology

* Cerebral angiitis, fibromuscular dysplasia, cerebral involvement in systemic vasculitis, bacterial meningitis, hypertension, prothrombotic disorders, clinical chicken pox, and hyperhomocysteinemia.

Adapted from: Gumer LB, Del Vecchio M, Aronoff S. Strokes in children: A systematic review. *Pediatr Emerg Care* 2014;30:660-664.

Table 2: Etiologies of Hemorrhagic Strokes in Children

- Vascular malformations
  - Arteriovenous malformation
  - Cavernous hemangioma
  - Aneurysm
  - Subarachnoid hemorrhage
  - Venous malformation
- Brain tumors
- Trauma/dissection
- Underlying medical disorder
- Undetermined

Adapted from: Gumer LB, Del Vecchio M, Aronoff S. Strokes in children: A systematic review. *Pediatr Emerg Care* 2014;30:660-664.

Arterial Ischemic Stroke

The most common cause of non-traumatic childhood stroke is a cardioembolic event from congenital or acquired heart disease.[14] In fact, cardiac disease is present in 27% of children in the United States who are hospitalized for a stroke.[15] Hematologic disorders are also important risk factors for both ischemic and hemorrhagic strokes. The link between sickle cell disease (SCD) and AIS is significant: SCD is the most common cause of stroke in African American children, and 11% of patients with SCD will experience a first stroke before the age of 20. If left untreated, two-thirds of these patients may experience recurrence.[15,16] Red blood cell transfusions for strokes in patients with SCD is the only well-studied recommended treatment of any type of childhood stroke.[17] Anemia is present in more than 25% of children with AIS.[13] Prothrombotic disorders have also been associated with AIS.[18] Additionally, thrombocytopenia and coagulation disorders increase risk for IPH.[3]

Vascular disorders increase the risk for both ischemic and hemorrhagic strokes. Non-traumatic arterial dissection of the anterior circulation, which tends to occur intracranially in older children and adolescents (compared to extracranially in adults), accounts for 20% of AIS.[13,19] Though rare, children may also experience posterior circulation strokes, which are commonly due to vertebral artery dissections.[20] Children with autoimmune or inflammatory vasculopathies are at slightly increased risk of both ischemic and hemorrhagic stroke compared to the general population.[2]

Moyamoya vasculopathy, which is a radiologic term, is characterized by bilateral stenosis of the terminal internal carotid arteries (*see Figure 1a*) with resultant collateralization that gives a pathognomonic "moyamoya" (Japanese for "puff of smoke") appearance on angiography (*see Figure 1b*).[15] It is present in up to 20% of children with AIS. Although the radiologic finding was first described in Japan, the term "moyamoya" is often loosely used to describe any terminal internal carotid artery disease. Moyamoya disease is idiopathic; moyamoya syndrome describes a moyamoya appearance on angiography that is secondary to other conditions, such as Down syndrome, neurofibromatosis type 1, or head trauma.[19,21]

Hemorrhagic Stroke

Traumatic brain injury (TBI) is an importantly preventable cause of hemorrhagic stroke. More than 40,000 children are treated in the ED for TBI each year, of which 2% are classified as moderate or severe.[22] Approximately one-half of all severe TBI patients require surgical hematoma evacuation.[23] Campaigns and provider-initiated instructions to promote the use of bicycle helmets and appropriate automobile restraints are worthwhile preventive tools to address this public health concern.

Children with vascular anomalies, including arteriovenous malformations (AVM), cavernous hemangiomas, and aneurysms, are at increased risk for hemorrhagic strokes. Any mass lesion, such as a brain tumor, also increases the risk for hemorrhagic stroke.[3]

Cerebral Sinovenous Thrombosis

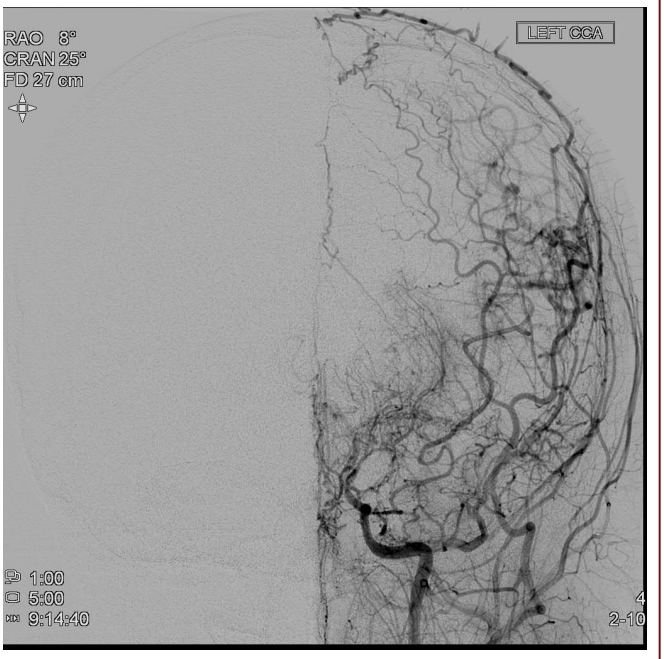
CSVT can cause secondary ischemic or hemor-

Figure 1a: Moyamoya Disease

Magnetic resonance angiography demonstrates multiple areas of stenosis in the internal carotid arteries, typical of moyamoya disease. This patient suffered multiple watershed region infarcts.

Figure 1b: Moyamoya Disease

Cerebral angiography of the same patient demonstrates 75% stenosis of the supraclinoid left internal carotid artery with moyamoya type collaterals, which result in a pathognomonic "puff of smoke" appearance.



rhagic events.[9] Risk factors for CSVT include chronic health disorders (50%), most notably congenital heart disease, inflammatory bowel disease, genetic disorders, hematologic disorders, prothrombotic states, and malignancies. They also occur in healthy children with acute systemic illness or head and neck infections (41%). Iron deficiency and leukemia were reported in 10% of cases. Sickle cell anemia is not a reported risk factor for CSVT.[24]

Pathophysiology

For the most part, the presumed mechanism of ischemic stroke is a cardioembolic event, especially if the patient has an underlying cardiac disease. However, because cardiac lesions can cause chronic hypoxia and polycythemia, thrombotic diseases may also factor into stroke mechanism. In patients with conditions that allow right-to-left shunting, such as septal defect, patent foramen ovale, or single ventricle, venous blood may enter the systemic circulation and cause a paradoxical embolus. Stroke may also be a complication of cardiac catheterization or cardiac surgery.[25]

In traumatic strokes, the mechanism of stroke is from stretching or tearing of the vertebral or carotid arteries from extreme hyperextension, contralateral head rotation, or direct insult to the neck or orbit. These injuries cause dissection, arteriovenous fistula, or pseudoaneurysm formation, and ultimately disrupt blood flow directly or by causing artery-to-artery thromboembolisms.[26] Occlusion following trauma may also be related to preexisting risk factors, such as infection, that cause the cerebral anatomy to be vulnerable. When faced with even subtle shear or stretch, intimal lesions and thrombosis may result.[27] In children who experience AIS from vertebral artery dissection after trauma, the pathophysiology of the dissection may be related to anatomic variations caused by forceful accidents, such as atlanto-axial subluxation, bony lesions, or fibrous soft tissue disruption, which may compress the vertebral artery during head rotation.[2] Figure 2 illustrates findings typical of strokes related to traumatic vertebral artery dissection.

For children with sickle cell anemia, strokes result from development of cerebral arteriopathy. Large vessels, such as the distal internal carotid artery or the proximal segment of the middle or anterior cerebral arteries become stenotic, which then become a nidus for thrombus formation and artery-to-artery emboli. Additionally, these stenotic segments can cause decreased cerebral perfusion with resultant watershed ischemia.[2] Later in

Table 3: Diagnostic Studies for Evaluation of Pediatric Stroke	
Imaging options	■ Computed tomography (CT) without contrast ■ Computer tomography angiography (CTA) ■ Computer tomography venography (CTV) ■ Magnetic resonance imaging (MRI) ■ Magnetic resonance angiography (MRA) ■ Magnetic resonance venography (MRV) ■ Transcranial ultrasound with Doppler flow in neonates and infants
Laboratory analysis (serum, urine)	■ Bedside glucose ■ Complete blood count (CBC) with differential ■ Comprehensive metabolic panel ■ Coagulation panel (PT/INR, PTT) ■ Blood, urine cultures ■ Consider inflammatory markers (erythrocyte sedimentation rate, C-reactive protein), antinuclear antibody test, HIV, syphilis, plasma amino acids, urine amino acids, toxicology screen, fasting lipid panel
Laboratory analysis (cerebrospinal fluid)	■ Cell count with differential ■ Protein ■ Glucose ■ Gram stain ■ Culture ■ Xanthochromia ■ Consider additional tests if infectious etiology is suspected
Additional testing	■ Electrocardiogram (ECG) ■ Transthoracic echocardiogram (TTE)

ing a good history of present illness in children who are unable to or too young to communicate is challenging. The differential diagnosis for neurologic symptoms and findings is broad. Twenty-one percent of children presenting with suspicion of stroke had a different disease, and 60% of children with neurologic deficits had another non-benign etiology.

The differential should include hypoglycemia, electrolyte disturbances (such as hyponatremia, hypo- or hypercalcemia, hypokalemia, or hypomagnesemia), infection (such as abscess, encephalitis, or meningitis), tumor, primary seizure disorder, autoimmune disorder, inborn errors of metabolism, and toxic exposure.[41]

Management

The time-sensitive goal in the management of any stroke is to rescue viable brain tissue, prevent complications, and minimize the risk of recurrent stroke by treating conditions that could cause recurrence.[42] There are comprehensive and specific, multi-specialty guidelines for the management of ischemic and hemorrhagic strokes in adults. Unfortunately, the only proven strategy for acute management of childhood AIS is exchange transfusion for children with sickle cell anemia.[43] Much of the recommendation for managing strokes in children is extrapolated from adult studies.[36]

Immediate Management of All Strokes

In the emergency setting, the first goal in management is to ensure patient stability. This includes adhering to principles of emergency resuscitation. Protect the patient's airway from aspiration by elevating the head of the bed. Ensure that the patient is properly oxygenating and ventilating via pulse oximetry monitoring and direct observation of the patient's mental status and respiratory drive, and intervene if necessary. Confirm cardiovascular stability using electrocardiographic monitoring and blood pressure measurement. If the patient presents with stroke symptoms following a traumatic incident, immobilize the patient's neck using a cervical collar. Seizures should be medically managed if they are present.

The emergency physician's target should be

CME Questions

MODULE 2: PEDIATRIC STROKE

1. **Hemorrhagic strokes in children are frequently caused by:**
   a. hypertension.
   b. severe head trauma.
   c. sickle cell disease.
   d. cardioembolic event from congenital or acquired heart disease.
2. **Which of the following is not a risk factor for cerebral sinovenous thrombosis?**
   a. Sickle cell disease
   b. Congenital heart disease
   c. Inflammatory bowel disease
   d. Hematologic disorders and malignancies
3. **Which of the following is the most common etiology of ischemic strokes in children?**
   a. Thrombotic disease
   b. Cardiac catheterization
   c. Congenital or acquired heart disease
   d. Sickle cell disease
4. **What is the most common presenting symptom of stroke in the pediatric patient older than 1 year of age?**
   a. Altered mental status
   b. Focal neurological deficit
   c. Lethargy
   d. Seizure
5. **A 12-year-old girl presents complaining of a "thunderclap" headache that began 16 hours ago. It was worst at onset. She has no focal neurologic deficits on exam. A head CT without contrast is obtained. What is the next best step in management?**
   a. Lumbar puncture
   b. MRV
   c. Ibuprofen and dismissal with one week neurology follow-up
   d. Antibiotic therapy
6. **Which of the following can present with focal neurological deficits?**
   a. Anemia
   b. Leukocytosis
   c. Hypokalemia
   d. Hypoglycemia
7. **When should a physician consider starting anticoagulation in pediatric stroke patients?**
   a. The etiology of the stroke is thought to be sickle cell disease.
   b. There is a confirmed cerebral sinovenous thrombosis.
   c. Intracranial dissections are identified.
   d. Endocarditis from a native valve is considered the etiology.
8. **When should thrombolytics in childhood strokes be given?**
   a. When a child presents with focal neurological deficits and no evidence of hemorrhage on imaging
   b. When a child is found minimally responsive with left sided hemiplegia
   c. To children with sickle cell disease and focal neurological complaints
   d. Never; there is no clear research showing benefit of recombinant tissue plasminogen activator or alteplase in the pediatric patient population

To earn credit for Module 2, log on to https://med-ed.ahcmedia.com/a/B182 to take the post-test.