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# Pediatric Stroke: Diagnosis and Management in the Emergency Department

November 2019
Volume 16, Number 11

## Abstract

Although pediatric stroke is rare, it is a leading cause of morbidity and mortality in children. The diagnosis of stroke is often delayed in children, which can contribute to death and disability. Management of pediatric stroke is challenging because there are few data to support the efficacy of interventions, and management is based on society guidelines and expert opinion, as well as extrapolation from adult stroke management. This issue reviews the most common causes of pediatric stroke, provides guidance for distinguishing stroke from stroke mimics, discusses the indications for laboratory studies and imaging modalities, and offers evidence-based recommendations for treatment.

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**This issue is eligible for 4 Stroke CME credits and 0.25 Pharmacology CME credits.**

## Case Presentations

*A 7-year-old boy is brought in by ambulance after a witnessed generalized seizure lasting 2 minutes at home. He has no history of prior seizures. Upon arrival to the ED, he appears postictal and is moving all of his extremities. His blood glucose is 110 mg/dL. His vital signs are: temperature, 36.9°C (98.5°F); heart rate, 60 beats/min; blood pressure, 110/70 mm Hg; respiratory rate, 14 breaths/min; and oxygen saturation, 98% on room air. The boy vomits while the nurse is trying to obtain IV access. Per the mother, the boy has been receiving chemotherapy for lymphoma and was complaining of a headache earlier in the day. He has no history of intrathecal chemotherapy. The mother does not think he had any head trauma recently. You know that the child needs brain imaging, but you are uncertain which imaging would be most useful…*

*In the next room, you see a 5-year-old boy with sickle cell disease who was brought to the ED by his father. The father states that 1 hour prior to arrival, the boy started stumbling while walking. The father says he didn't think much of it until he noticed the child's speech was slurred. The father also says he thinks his son's face looks different on 1 side, though you cannot appreciate facial asymmetry on examination. The boy has 3 out of 5 strength of the left arm and leg, as well as dysarthria. He is alert and denies headache or visual changes. The rest of the neurological examination seems normal. The boy's vital signs are unremarkable except for mild elevation of blood pressure. You are concerned about a stroke and begin to think about what tests to order as well as which specialists to consult before initiating treatment...*

*You then see a 2-year-old girl who was brought to the ED by her parents after she fell forward with a toothbrush in her mouth. The mother removed the toothbrush from the unconscious child's mouth and noted blood on the toothbrush as well as in the child's mouth. Although the child was unresponsive for 30 seconds after the event, no seizure-like activity was noted. On presentation, the patient is alert with normal mental status and normal vital signs. She has no obvious intraoral trauma, abnormal voice, or stridor, and she has a normal neurological examination for her age. Given the loss of consciousness and the report of blood on the toothbrush despite no oral laceration seen, you decide to obtain a CT angiogram of the neck. The CT angiogram shows a dissection of the left internal carotid artery and subcutaneous air in the area. You consider what treatments to initiate, which specialist to consult, whether further imaging is needed, and what should be the disposition of this child...*

## Introduction

Stroke is typically thought of as a disease that occurs in older adults with risk factors for atherosclerosis. Stroke also occurs in the pediatric population, but the etiologies, risk factors, and presentation of stroke differ from those of adults. Stroke is more common in neonates than in children, and will be discussed separately, as the risk factors, treatment, and outcomes differ from those of older infants and children (see the "Neonates" section on page 13.).[1,2]

Annually, stroke affects 1 to 2 children per 100,000 children,[1,3] and it is among the top 10 causes of pediatric mortality, with a mortality rate of up to 10% for arterial ischemic stroke (AIS) and 25% for hemorrhagic stroke.[4,5] Despite potential neuroplasticity, two-thirds of children will have persistent neurological deficits after a stroke.[1]

There is usually an excessive delay in the diagnosis of pediatric stroke, which may contribute to morbidity and mortality. A retrospective study of children with AIS in an urban center found a median of 22.7 hours from symptom onset to diagnosis of stroke and 12.7 hours from hospital presentation to the time of diagnosis. On initial assessment, the diagnosis was suspected in only 38% of children.[6] Another study found that physicians documented a suspicion of stroke in only 26% of children with AIS.[7] Multiple studies have found that children with acute-onset neurological symptoms are most often brought to the emergency department (ED) by private vehicle rather than by ambulance.[6,8] The delay in diagnosis is likely multifactorial, in part due to clinicians' unfamiliarity with pediatric stroke and a bias for diagnosing more common stroke mimics. A clinician who does not know the different etiologies of stroke in children may not identify the risk factors. Children also present differently from adults with stroke. Children are more likely to have seizure and altered mental status with stroke, which generates a large list of differential diagnoses.[1,6]

Management of pediatric stroke is challenging because there are few data to support the efficacy of interventions, and management is based on society guidelines and expert opinion (with the exception of children with sickle cell disease). Management of stroke in children is also extrapolated from adult stroke management even though the pathophysiology and etiologies of stroke in children differ significantly from adults.

This issue of *Pediatric Emergency Medicine Practice* reviews common causes of pediatric stroke, offers guidance on how to distinguish stroke from its mimics, discusses the indications for imaging modalities, and provides evidence-based treatment recommendations.

## Critical Appraisal of the Literature

A literature search was performed in MEDLINE® and the Cochrane Database of Systematic Reviews using the search terms *pediatric stroke*, *pediatric stroke management*, and *hemorrhagic stroke pediatric presentation management*. Results were limited to studies involving children aged 0 to 18 years, those with full

text in English, and those involving human subjects. References within the articles were also reviewed to identify additional articles for inclusion. Titles and abstracts were reviewed for relevance to the topic, and 70 articles were chosen for inclusion.

Several pediatric stroke registries, prospective cohorts, and retrospective cohorts are reported in the literature.[1,6,8-18] Until about 10 years ago, there were only case reports of medical interventions for pediatric stroke. Evidence for surgical interventions and mechanical thrombectomy is still based mainly on case reports.[19-22] There are no completed prospective controlled trials of anticoagulation, antiplatelet medication, or thrombolysis for AIS in children, though society guidelines support the use of anticoagulation and antiplatelets, based on the observed safety of these interventions in cohort studies.[3,23]

## Etiology and Pathophysiology

There are many different causes of pediatric stroke, each with its own pathophysiology. Although there is some crossover in the etiology of ischemic and hemorrhagic stroke, they are generally discussed separately in the literature. Sickle cell disease is the most common cause of pediatric stroke in some populations,[24] and is discussed separately due to its great importance and the differences in management from other causes of stroke (see the "Sickle Cell Disease" section on page 9).

*Ischemic stroke* encompasses AIS and cerebral sinus venous thrombosis (CSVT), in which there is concomitant ischemia or hemorrhage. For the purposes of this discussion, *AIS* is defined as an acute neurological deficit with an acute infarct in a corresponding arterial territory on brain imaging.[1] *CSVT* is the state of abnormal clot formation in the deep and dural venous sinuses of the brain. The resulting increased venous pressure can lead to impaired arterial inflow and ischemia.[3] *Hemorrhagic stroke* is defined as any nontraumatic intracerebral hemorrhage, subarachnoid hemorrhage, or intraventricular hemorrhage (excluding those related to prematurity). While the majority of adult stroke is ischemic, in children, the proportion of ischemic strokes and hemorrhagic strokes is equal.[4]

### Ischemic Stroke

Prospective cohorts have identified the most common causes of pediatric AIS, which can be categorized as: (1) arteriopathies, (2) cardiac etiologies, (3) prothrombotic states, and (4) systemic disorders (eg, sickle cell disease and bacterial sepsis).[1,9]

#### Arteriopathies

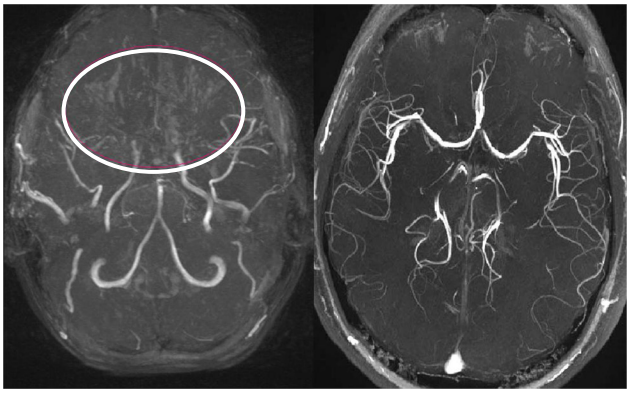
Arteriopathy is a structural abnormality of a cervical or intracranial artery that is typically diagnosed on vascular imaging (or on autopsy). This includes stenosis, aneurysm, dissection, or occlusion not due to an embolus. Arteriopathies cause approximately 50% of AIS. Children with arteriopathy have a 66% chance of stroke over 5 years.[11,25]

Focal cerebral arteriopathy is a subset of arteriopathy defined as a focal area of stenosis. This idiopathic entity is the most common arteriopathy. While the cause of focal cerebral arteriopathy is not well understood, one study found an association between arteriopathy and recent upper respiratory infections in children aged 5 to 9 years.[11] Vasculitis is a much less common arteriopathy, but it is also associated with recent infection, particularly of the central nervous system and parapharyngeal spaces.[26]

Moyamoya is the next most common arteriopathy, although it is very uncommon in the population at large.[27] Moyamoya (Japanese for "puff of smoke," a description of the angiography image of collateral circulation) is caused by gradual stenosis of the proximal branches of the intracranial internal carotid arteries and development of collateral vessels. **(See Figure 1.)** In the United States, moyamoya is most prevalent among children of Asian decent, with a peak incidence in children aged approximately 5 years. When the etiology is idiopathic, it is referred to as *moyamoya disease*; when it occurs secondary to another condition such as sickle cell disease, it is called *moyamoya syndrome*. Moyamoya is associated with other conditions, such as neurofibromatosis type 1 and Down syndrome. It may cause ischemic or hemorrhagic stroke, but ischemic stroke is much more common in children.[27]

Dissection of the head or neck vessels also can cause stroke in children. Cervicocephalic arterial dissection is most common among boys aged 6 to 10

**Figure 1. Moyamoya Syndrome on Magnetic Resonance Angiogram**



Left image: Evidence of moyamoya
Right image: Normal brain
Source: https://en.wikipedia.org/wiki/Moyamoya_disease#/media/File:MRA_Moya-moya-disease.JPG
Author: commons:User:MBq, commons:User:SBarnes

years. The underlying cause is often unknown, but a systematic review of dissection in children found that 50% of these children had some trauma in the preceding week. Most children presented with hemiparesis, regardless of whether the dissection was in the anterior or posterior circulation. Pain is not a reliable indicator of dissection in children. Headache was present in about 50% of children on presentation, whereas neck pain was present in only 1% to 11% of children.[28]

### Cardiac Etiologies

Cardiac disorders cause approximately 30% of pediatric strokes.[1,9] This is most commonly due to thromboemboli related to congenital heart disease, acquired valvular disease, cardiomyopathy, or arrhythmias. Atrial septal defects or ventricular septal defects with right-to-left shunts may also cause stroke.[3] Many strokes related to cardiac disease occur during surgery or catheterization procedures.[1]

### Prothrombotic States

Prothrombotic states are also associated with pediatric stroke. Hypercoagulation disorders may not cause stroke without the presence of other risk factors, but they should be identified because they are potentially modifiable risk factors.[3] **Table 1** lists some prothrombotic conditions that have been associated with pediatric AIS.[1,29]

### Systemic Disorders

Systemic causes of pediatric stroke include sepsis, intrathecal methotrexate use, mitochondrial disorders, and genetic disorders.[1,3,30] MELAS (mitochondrial encephalopathy with lactic acidosis and stroke-like episodes) can present with stroke symptoms in a child who was otherwise healthy in early childhood. CADASIL (cerebral autosomal dominant arteriopathy with subcortical infarcts and leukoencephalopathy) is a genetic mutation that leads to multiple deep matter infarctions. Treatment of stroke in these cases is focused on the underlying condition and is often limited.[3]

**Table 1. Hypercoagulable States Associated With Pediatric Arterial Ischemic Stroke**

- Elevated lipoprotein(a)
- Protein C deficiency
- Protein S deficiency
- Factor V Leiden mutation
- Antithrombin III deficiency
- Activated protein C resistance
- Antiphospholipid antibody syndrome
- Elevated homocysteine
- Elevated factor VIII



### Cerebral Sinus Venous Thrombosis

CSVT is a rare but important cause of stroke in children. It can have associated ischemia or hemorrhagic transformation. Ischemia from CSVT may not follow an arterial pattern. CSVT has been associated with recent surgery, focal infection, prothrombotic conditions, use of prothrombotic medications (eg, oral contraceptives or PEG-asparaginase), and dehydration. CSVT presents with focal neurological symptoms as well as the signs and symptoms of increased intracranial pressure: headache, papilledema, cranial nerve VI palsy, and encephalopathy.[31] Management of CSVT is to treat the underlying cause (mastoiditis, hematologic disorder, etc) and anticoagulate. Even when hemorrhage is present, anticoagulation for CSVT is thought to be beneficial, based on adult and limited pediatric data.[3,23,31]

### Hemorrhagic Stroke

In children, hemorrhagic stroke is equally as common as ischemic stroke, but it has a higher mortality. Arteriovenous malformations are the most common cause of hemorrhagic stroke.[12,25] Other causes include cavernous malformations, aneurysms, and tumors. Isolated spontaneous subarachnoid hemorrhages are most likely to occur as a result of an aneurysm.[4] Spontaneous subarachnoid hemorrhage is, overall, less common in children than in adults because aneurysms in children are often idiopathic rather than from long-standing hypertension. Childhood aneurysms are caused by rare congenital anomalies, connective tissue disorders, and rheumatologic conditions.[32]

Bleeding disorders may also cause pediatric hemorrhagic stroke. In one retrospective review, thrombocytopenia was the most common hematologic cause of intraparenchymal hemorrhage.[33] Intracranial hemorrhage from idiopathic thrombocytopenic purpura typically occurs when the platelet level is < 20,000/mL. Hemophilia, liver failure, disseminated intravascular coagulation, and iatrogenic coagulopathies also cause hemorrhagic stroke in children.[4]

## Differential Diagnosis

The differential diagnosis of stroke in children is broad and includes other neurologic disorders, infections, metabolic disorders, toxins, nonaccidental trauma, and psychogenic causes.[34] **(See Table 2, page 5.)** The most common stroke mimics (acute-onset neurologic changes) are migraines, seizures, Bell palsy, conversion disorder, and syncope.[35] Although these more benign diagnoses are common, several studies have found that other neurological emergencies are also common in children for whom there is concern for stroke.[17,36] Such emergencies include meningitis, encephalitis, brain tumors, and

## Table 2. Differential Diagnosis for Pediatric Stroke

| Category | Differential Diagnosis | Distinguishing Features |
|---|---|---|
| Metabolic conditions | Hypoglycemia, hyperglycemia | Point-of-care glucose level |
| | Inborn errors of metabolism | Other signs or symptoms in the newborn period (eg, vomiting, tachypnea, altered mental status) |
| | Mitochondrial disease | Family history of mitochondrial disease, hearing deficits, short stature/growth problems, cardiac conduction defects |
| Toxin exposure | Lead ingestion | Gastrointestinal symptoms, blue line along the gums (chronic toxicity) |
| | Carbon monoxide exposure | Other members (and pets) of the household affected |
| | Cyanide exposure | Tachypnea, elevated lactic acid level |
| | Alcohol ingestion | "Drunkenness," elevated ethanol level, osmolar gap |
| | Drugs of abuse | Sympathomimetic toxidrome |
| | Intrathecal methotrexate administration | Magnetic resonance imaging findings, clinical history |
| | Inhalant use | Skin changes around the nose and mouth, chemical odor on the patient |
| | Anticholinergic agent exposure | Mydriasis, tachycardia, no focal neurological deficit |
| Infection | Meningitis/encephalitis | Fever |
| Trauma | Occult trauma | Recent head or neck injury, including posterior oropharyngeal trauma |
| | Nonaccidental trauma | Conflicting history or additional unexplained injuries |
| Peripheral lesions | Botulism | Constipation, poor feeding |
| | Myasthenia gravis | Weakness worse with repeated muscle use or improves with applying ice |
| | Bell palsy | Isolated unilateral weakness of the face involving the forehead and lower face |
| | Peripheral neuropathy | Follows the distribution of one or several nerves |
| | Guillain-Barré syndrome | Bilateral progressive weakness, decreased reflexes |
| Spinal cord lesions | Transverse myelitis | Bilateral sensory deficit corresponding to a spinal level |
| | Spinal cord infarct | Symptoms correspond to anterior or posterior spinal artery territory |
| | Acute disseminated encephalomyelitis (ADEM) | Multifocal neurological deficits that can localize to cranial nerves, brain, and spinal cord<br>Concomitant encephalopathy |
| | Epidural abscess or hematoma | Risk factors, focal pain, fever |
| | Acute flaccid myelitis | Acute-onset weakness decreased reflexes, sensation preserved |
| Other central nervous system lesions | Postinfectious cerebellitis | Cerebellar symptoms with a history of recent viral/bacterial infection |
| | Tumor | Symptoms referable to involved location |
| | Idiopathic intracranial hypertension | Papilledema<br>Cranial nerve VI palsy |
| | Reversible posterior leukoencephalopathy syndrome | Encephalopathy and elevated blood pressure |
| Seizure | Todd paralysis | Quickly resolving hemiplegia |
| Migraine | Complex migraine | Numbness rather than weakness, vision changes |
| Channelopathies | Alternating hemiplegia of childhood | Hemiplegia, quadriplegia, abnormal eye movements in an infant |
| Psychogenic | Conversion disorder | Constantly changing neurologic examination, nonanatomic distributions, and give-way weakness |

traumatic brain injury.[36] Therefore, it is important to maintain a sense of urgency and have a low threshold for obtaining imaging.

Migraine is a common stroke mimic in children and can be a clinical challenge to differentiate from stroke. The presence of headache cannot differentiate between migraine and stroke. Studies report that 25% to 50% of children with AIS had headache at the time of presentation in the ED.[1,37] Nonetheless, there are some features that can help differentiate AIS from migraine. Migraines are frequently associated with visual symptoms and vomiting. The neurologic deficit in a complex migraine is most commonly focal numbness. Neurologic symptoms of migraine commonly resolve within 30 minutes. In contrast, children with AIS present with sudden-onset focal weakness (more often than numbness), speech or language changes, ataxia, and/or seizures. In one study, the median age of children with migraine was 13.4 years, whereas the median age for AIS was 5 years ($P < .001$).[37] To summarize the literature on differentiating stroke from migraine, sudden-onset focal weakness or speech or language changes in a young child that do not resolve within 30 minutes are clinically concerning for stroke.[37]

## Prehospital Care

Prehospital care of stroke should emphasize care for the airway, breathing, and circulation as well as rapid transport to the ED. If possible, the patient's glucose level should be checked to rule out a rapidly reversible cause of stroke-like symptoms. Correcting hypoglycemia, hypoxia, and hypotension will prevent secondary insult to the brain. A brief history regarding the time of onset and past medical history should be obtained, especially if caregivers are not transported with the child.

## Emergency Department Evaluation

### History

History-taking should focus on the time of onset, stroke risk factors, and narrowing the differential. Although children rarely receive thrombolysis or thrombectomy, knowing the time of onset of stroke is important to minimize harm to the patient if a consultant recommends these interventions. Knowing how long the child has had symptoms will help predict whether the child's clinical course may continue to worsen.

Many children with AIS have an identifiable risk factor, though it may be as subtle and common as a recent viral illness. Obvious risk factors obtained in past medical history include sickle cell disease, congenital heart disease, and prothrombotic conditions.[9] Other risk factors to consider are head, neck, or respiratory tract infections within the preceding 3 days.[9,25,38] Head or neck trauma in the preceding 3 months may increase the risk of AIS, especially more recent and more severe trauma.[39] Acute systemic illness such as sepsis, shock, and dehydration also increase the risk of stroke.[9] Patients with chronic conditions such as trisomy 21, Williams syndrome, neurofibromatosis type 1, PHACES syndrome, and Alagille syndrome have increased risk of cervical and cerebral arteriopathies.[40] Children with congenital heart disease who have undergone corrective surgery still have increased risk for stroke, even years later.[41]

Risk factors for hemorrhagic stroke may include use of antithrombotic medications, bleeding disorders, thrombocytopenia, cancer (particularly brain, but also leukemia), and a history of intracranial hemorrhage.[4,42] Sickle cell disease also increases the risk of hemorrhagic stroke.[4] Conditions associated with aneurysms in children include polycystic kidney disease, fibromuscular dysplasia, Ehlers-Danlos syndrome, Klippel-Trenaunay syndrome, tuberous sclerosis, hereditary hemorrhagic telangiectasia, pseudoxanthoma elasticum, and Marfan disease.[32]

The history should be used to narrow the differential as much as possible. A key feature of stroke is its sudden-onset presentation. Gradual-onset symptoms may point to other neurological conditions such as acute disseminated encephalomyelitis (ADEM) or migraine. Children may have presented previously with similar symptoms due to a prior transient ischemic attack. The emergency clinician should ask about potential exposures or ingestions, and any medications in the household. A recent history of trauma is important to evaluate for traumatic intracranial hemorrhage and possible arterial dissection. Recent history of headache or seizure does not help rule in or rule out stroke.[43] Children with dissection frequently do not report focal pain or headache.

Some of the most common manifestations of pediatric AIS include hemiparesis, altered speech or language, seizure, and altered level of consciousness.[1,7,43] Infants are more likely than older children to have nonfocal signs such as altered mental status and seizures.[43,44] Although seizures often suggest an alternative diagnosis in adults, this is not the case in children. Hemorrhagic stroke often presents with the expected findings of vomiting, altered level of consciousness, and headache.[43,45]

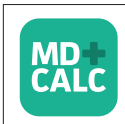
### Physical Examination

For adults, prehospital personnel or triage staff often use stroke screening tools to identify stroke. Unfortunately, a stroke screening tool is not frequently implemented for children.[46] To identify pediatric stroke early, the diagnosis should be considered with any neurologic complaint in a child.

It is important to maintain a standardized approach to evaluating children with possible stroke.

The patient's airway, breathing, and circulation should be evaluated first, followed by a complete neurological examination. For critically ill patients who need to be intubated with sedation and paralysis, establish a baseline neurological examination prior to intubation, if safe, by evaluating for movement of all 4 extremities and level of responsiveness.

Neurological examinations can be challenging in young children. There is a validated version of the United States National Institutes of Health Stroke Scale (NIHSS) that has been adapted for children aged 2 to 17 years, called the *PedNIHSS*. The PedNIHSS accounts for the developmental level of the child.[47] The numeric score is calculated similarly to the adult NIHSS, ie, a higher score indicates a more severe stroke. The PedNIHSS is summarized in **Table 3, page 8**. For a full description of the PedNIHSS, along with diagrams, see the article supplemental data by Ichord et al in the American Heart Association (AHA) online *Stroke* journal (www.ahajournals.org/doi/suppl/10.1161/STROKEAHA.110.607192).[48]




An MDCalc online tool for the PedNIHSS is available at: www.mdcalc.com/pediatric-nih-stroke-scale-nihss

A full head-to-toe examination should be completed to assess for other causes of the patient's presentation (eg, trauma and nonaccidental trauma). A toxidrome may be suggested by findings such as muscle rigidity, clonus, hyperthermia, nystagmus, dry or moist skin, or skin discoloration around the nose and mouth due to huffing.

## Diagnostic Studies

Laboratory evaluation for stroke should assess for stroke mimics and causes of stroke, including glucose level, electrolytes, renal function, complete blood cell count, prothrombin time/international normalized ratio, and partial thromboplastin time. Laboratory tests to evaluate for specific prothrombotic states may be ordered by the inpatient team or hematologist once a stroke is confirmed.

Initial imaging for stroke is with computed tomography (CT) and/or magnetic resonance imaging (MRI) of the brain. CT is often performed first, due to its wide availability and rapid ability to rule out hemorrhage. However, some institutions are adopting rapid MRI protocols that take about 20 minutes. MRI is more sensitive for acute ischemia than CT, can better evaluate the posterior fossa, and can more reliably exclude stroke mimics. The International Pediatric Stroke Study Neuroimaging Consortium recommends MRI as its first-line study because MRI can evaluate for bleeding and ischemia as well as diagnose other conditions better than CT.[49] However, even a 20-minute MRI may require sedation and/or removal of orthodontic hardware to complete, so the risks of sedation must be weighed against the need for the MRI. Each facility should have an organized stroke protocol to facilitate imaging and avoid diagnostic delay.

Vascular imaging should be obtained when ischemic or hemorrhagic stroke is identified or highly suspected. Arteriopathies are a common cause of stroke, even among children with known cardiac disease.[11] Identification of an arteriopathy can also help predict the recurrence of stroke.[1] Options include magnetic resonance angiogram, CT angiography, and catheter angiography. Both CT venography and MRI susceptibility-weighted imaging are sensitive for detecting CSVT.[49] T1 MRI with contrast is also extremely sensitive and may be more accurate than magnetic resonance venography in some cases. Catheter angiography is the best choice for evaluating aneurysms, malformations, small distal branches, extracranial dissections, and the posterior circulation, but this is likely to be done after initial stabilization and imaging.

For patients without known complex congenital heart disease, echocardiogram with a bubble study is frequently performed nonemergently during the evaluation for stroke etiology.

## Treatment

Initial treatment of stroke patients in the ED should focus on stabilizing the airway, breathing, and circulation and correcting hypoxemia, hypoglycemia, dehydration, anemia, and fever. In the absence of seizures, there is no evidence to support empiric administration of anticonvulsant medications.[23]

### Ischemic Stroke

Treatment of ischemic stroke in children is based on few data and is extrapolated from practices in adults, except in the case of children with sickle cell disease, for whom there are data to guide management. There are no studies showing the superiority of one medical treatment over another, and there are no studies on the safety or efficacy of thrombolytics in children[5,47,50] Therefore, it is important to be aware of expert guidelines and involve neurology consultants early on in the care of pediatric stroke patients.

#### Arterial Ischemic Stroke

Accepted medical therapies for AIS in children include antiplatelet medications (eg, aspirin) and anticoagulants (eg, unfractionated heparin [UFH] or low-molecular-weight heparin [LMWH]). **(See Table 4, page 9.)** The AHA acknowledges the lack of clinical trial data to support use of one class of medication over another for treating pediatric AIS.

## Table 3. Pediatric National Institutes of Health Stroke Scale (PedNIHSS)[48]

| Examination | Examination Tips |
|---|---|
| **Level of consciousness**<br>0 = Fully alert<br>1 = Responds if stimulated<br>2 = Responds only to repeated stimulation or painful stimulus, obtunded<br>3 = Only reflexes present or no response | • Observe patient's appearance and activity<br>• Stimulate as needed<br>• Check for reflexes |
| **Answers questions**<br>0 = Both answers correct<br>1 = One answer correct<br>2 = Neither answer correct | • Ask the child how old they are<br>• If parent is in the room, ask "Where is mom/dad?"<br>• Using fingers to count or looking in the direction of the parent is considered a correct response |
| **Follows tasks**<br>0 = Performs both tasks<br>1 = Performs one task<br>2 = Performs neither task | • Ask the child to open and close their eyes<br>• Have them squeeze your hand or touch their nose |
| **Gaze**<br>0 = Normal gaze<br>1 = Partial gaze palsy<br>2 = Total gaze paresis, not overcome by oculocephalic maneuver | • Test gaze with interesting object/toy or video<br>• In total gaze paresis, the eyes still do not move with the "doll's eye" test |
| **Visual fields**<br>0 = Normal<br>1 = Partial hemianopia (1 specific quadrant)<br>2 = Complete hemianopia (half the visual field)<br>3 = Bilateral hemianopia (blind in both eyes) | • Children aged > 6 years can be asked to count fingers<br>• Children aged ≤ 6 should blink to threat |
| **Facial palsy**<br>0 = Normal<br>1 = Minor paralysis (mild asymmetry)<br>2 = Partial paralysis (no movement lower face)<br>3 = Complete paralysis (no movement upper and lower face) | • Encourage the child to smile, close eyes, raise eyebrows, show teeth<br>• Pantomime and perform motions with child |
| **Motor: arm and leg**<br>0 = No drift, holds against gravity for 10 sec<br>1 = Some drift, cannot hold for 10 sec<br>2 = Some brief effort against gravity<br>3 = No effort against gravity<br>4 = No movement<br>5 = Amputation or joint fusion, unable to examine | • Score each extremity separately<br>• Test movement against gravity<br>• Ask child to copy you<br>• If the child is unable to follow instructions, watch for spontaneous movements like reaching out for a toy |
| **Limb ataxia**<br>0 = Absent<br>1 = Present in 1 extremity<br>2 = Present in both extremities | • For older, cooperative children, have them perform the finger-to-nose and heel-to-shin tests<br>• For children aged < 5 years, have them reach for a toy, then try to kick the toy |
| **Sensory**<br>0 = Normal response<br>1 = Mild to moderate sensory loss (feels touch but not pain, or sensation is decreased in areas)<br>2 = Total sensory loss | • Response to a noxious stimulus like a pin-prick |
| **Best language**<br>0 = No aphasia<br>1 = Mild to moderate aphasia<br>2 = Severe aphasia<br>3 = Mute, global aphasia | • Ask older children (aged > 6 years) to name objects or look at a picture and describe it<br>• Observe how younger children speak and comprehend during the rest of the examination |
| **Dysarthria**<br>0 = Normal<br>1 = Mild to moderate (slurred speech)<br>2 = Severe (unable to understand their speech)<br>9 = Intubated | • Ask family members if speech is abnormal from baseline, particularly in young children |
| **Extinction and inattention**<br>0 = No abnormality<br>1 = Inattention or extinction to a sensory modality (auditory, tactile, spatial, etc.)<br>2 = Profound hemi-inattention | • Observe the child's interactions throughout the examination |

AHA guidelines recommend that it is reasonable to start either aspirin or anticoagulation in the acute period until therapy can be directed toward a more specific etiology.[3] These medications have been used safely in children with AIS.[51] Aspirin is the typical maintenance therapy in other cases of AIS. Anticoagulation may be used in a child with AIS due to cardioembolism or prothrombotic disorders. The decision of which medication to use should be made in consultation with a multidisciplinary team that is familiar with managing pediatric stroke. The AHA notes that there is an increased risk of recurrent stroke in pediatric AIS cases not treated with either anticoagulation or antiplatelet medications.[3] The American College of Chest Physicians guidelines recommend aspirin unless the cause is known to be dissection or cardioembolism, in which case UFH/LMWH is recommended.[23] Actual practice is consistent with these guidelines, in which most children receive either antiplatelets or anticoagulants.[1]

Heparin/LMWH is the recommended therapy for CSVT, in addition to treating the underlying cause and/or associated infection. The American College of Chest Physicians guidelines recommend anticoagulation for children with CSVT even in the presence of hemorrhage. Alternatively, anticoagulation can be withheld in these patients, unless the clot is found to be larger 5 to 7 days later.[23] Anticoagulation remains controversial in neonates.[23] Moyamoya is slightly different and is treated primarily with revascularization.[3] Pharmacologic therapy should be discussed with the consulting pediatric specialists, especially in situations where hemorrhage exists with ischemic stroke.

**Table 4. Medications for Ischemic Stroke[5,23,52]**

| Medication | Dose |
|---|---|
| Low-molecular-weight heparin (enoxaparin) | Children: 1 mg/kg SQ every 12 hr<br>Neonates: 1.5 mg/kg SQ every 12 hr |
| Unfractionated heparin | Loading dose: 75 units/kg IV over 10 min<br>Maintenance dose: for children aged ≤ 1 yr, 28 units/kg/hr IV; for children aged > 1 yr, 20 units/kg/hr IV, with a goal aPTT of 60-85 seconds |
| Aspirin | 3-5 mg/kg/day PO |
| Alteplase* | 0.9 mg/kg: first 10% as an IV bolus, remaining 90% given IV over 1 hr |

*Not typically recommended in the treatment of pediatric stroke, particularly in children aged ≤ 12 years. The efficacy, safety, and dosing in children has not been established.

Abbreviations: aPTT, activated partial thromboplastin time; IV, intravenous; PO, oral; SQ, subcutaneous.

**Thrombolytics**

In contrast to adult stroke care, thrombolytics are not yet the standard of care in the hyperacute period of pediatric stroke. The AHA and American College of Chest Physicians acknowledge the lack of data on the safety and efficacy of thrombolytic use in children.[3,23] Nonetheless, thrombolytics are used in certain cases under the guidance of specialized pediatric stroke care teams.[3] Recent observational studies report few adverse outcomes from use of tissue plasminogen activator (tPA) for AIS in children.[20,53] One cohort study of children who received tPA demonstrated 4 out of 15 children developed intracranial hemorrhage, but the overall number of children who received tPA was small and some of them were treated outside of the time window used in adults.[54] The observational studies of tPA use in childhood AIS were not designed to evaluate neurological outcome after tPA, so the efficacy of tPA in children is unknown.[54,55]

**Mechanical Thrombectomy**

Mechanical thrombectomy is an option for pediatric AIS, and has been performed in children as young as 2 years old.[56] Although subject to publication bias, there are several case reports of mechanical thrombectomy in children with stroke that demonstrated good outcomes.[22,57,58] Due to limited data, the American College of Chest Physicians guidelines recommend against routine use of mechanical thrombectomy in pediatric stroke patients, although in some circumstances, many experts will consider thrombectomy.[3,23]

**Sickle Cell Disease**

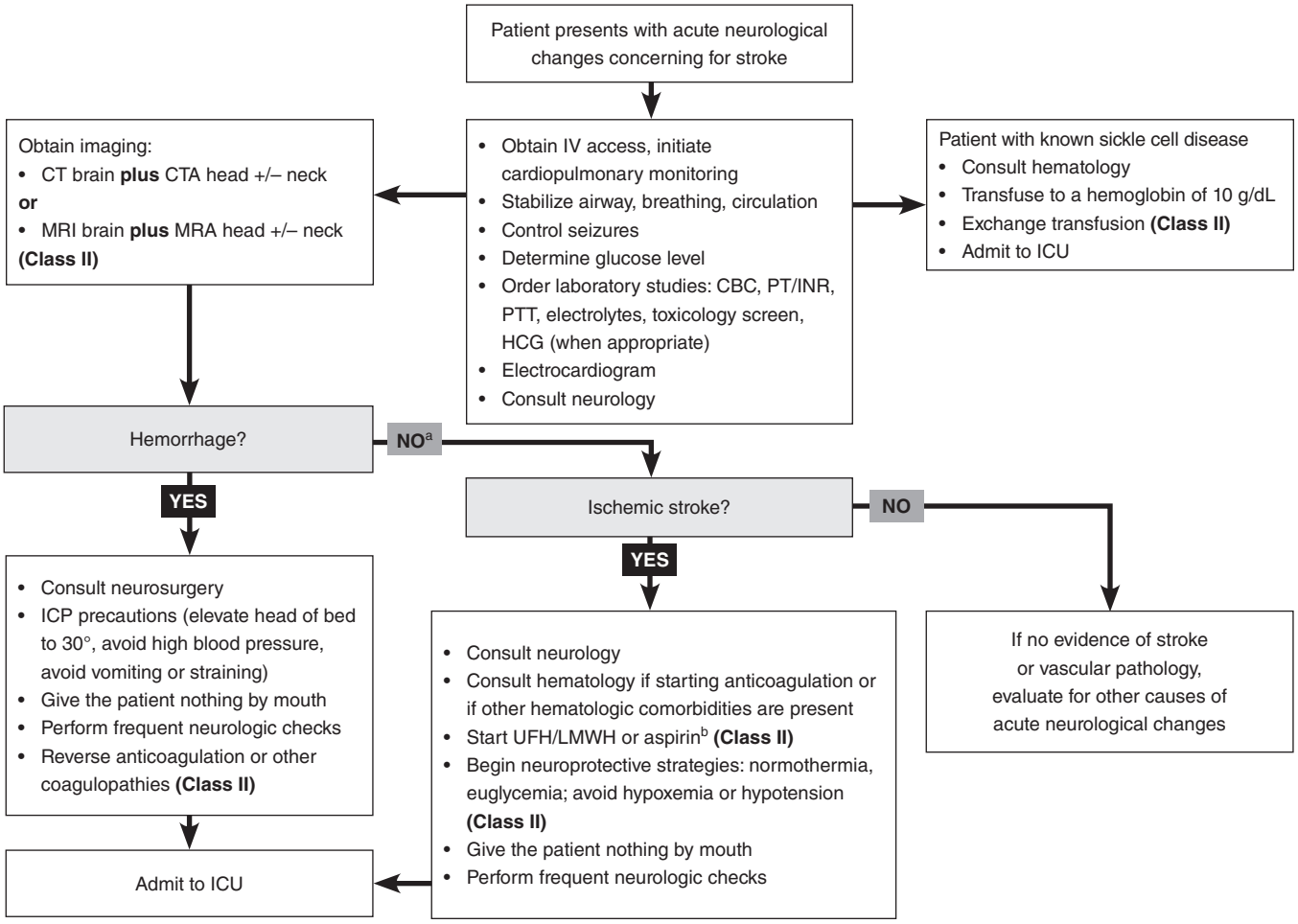
Patients with sickle cell disease are treated differently because of their unique pathophysiology. Though aspirin is also given, the primary goal of treatment of pediatric stroke due to sickle cell disease is to decrease the amount of hemoglobin S. Transfusion of red blood cells or exchange transfusion is performed to reduce hemoglobin S to < 30% of the total hemoglobin, or to reach a total hemoglobin level of 10 to 11 g/dL.[3,59] Transfusion alone is inadequate to lower the hemoglobin S percentage sufficiently without concomitant hyperviscosity or volume overload. Exchange transfusion is the ideal method, but simple transfusion may be used initially in children with hemoglobin concentrations of < 9 g/dL while resources are mobilized to perform the more effective exchange transfusion.[3]

**Summary**

Pediatric AIS management remains somewhat controversial, and there are no guiding randomized controlled trials for children except for those with sickle cell disease. For most AIS patients, the initial medical therapy is either anticoagulation (with UFH or LMWH) or antiplatelet therapy and should be

# Clinical Pathway for Management of Pediatric Stroke




Abbreviations: CBC, complete blood cell count; CT, computed tomography; CTA, computed tomography angiography; CSVT, cerebral sinus venous thrombosis; HCG, human chorionic gonadotropin; ICP, intracranial pressure; ICU, intensive care unit; INR, international normalized ratio; IV, intravenous; LMWH, low-molecular-weight heparin; MRA, magnetic resonance angiogram; MRI, magnetic resonance imaging; PT, prothrombin time; PTT, partial thromboplastin time; UFH, unfractionated heparin.

[a]Arterial ischemic stroke can have a component of hemorrhage. In this case, discuss with the consultant what treatment strategy to pursue.

[b]Medication choice should be made in consultation with a specialist:

UFH/LMWH:
- Dissection
- Cardiac disease
- CSVT
- Hypercoagulable states

Aspirin:
- Moyamoya
- Sickle cell disease

## Class of Evidence Definitions

Each action in the clinical pathways section of *Pediatric Emergency Medicine Practice* receives a score based on the following definitions.

**Class I**
- Always acceptable, safe
- Definitely useful
- Proven in both efficacy and effectiveness

*Level of Evidence:*
- One or more large prospective studies are present (with rare exceptions)
- High-quality meta-analyses
- Study results consistently positive and compelling

**Class II**
- Safe, acceptable
- Probably useful

*Level of Evidence:*
- Generally higher levels of evidence
- Nonrandomized or retrospective studies: historic, cohort, or case control studies
- Less robust randomized controlled trials
- Results consistently positive

**Class III**
- May be acceptable
- Possibly useful
- Considered optional or alternative treatments

*Level of Evidence:*
- Generally lower or intermediate levels of evidence
- Case series, animal studies, consensus panels
- Occasionally positive results

**Indeterminate**
- Continuing area of research
- No recommendations until further research

*Level of Evidence:*
- Evidence not available
- Higher studies in progress
- Results inconsistent, contradictory
- Results not compelling

started in discussion with pediatric neurology. Definitive evidence-based recommendations are lacking. The benefit of anticoagulation with heparin is its short half-life and ease of reversibility. The stroke etiologies that may benefit the most from anticoagulation include congenital cardiac disease, dissection, and major hypercoagulable states. Ultimately, therapy should be based on the hospital protocol and/or in consultation with neurology and hematology specialists. Thrombolytic therapy and advanced therapy, such as mechanical thrombectomy, may be beneficial in certain cases of pediatric AIS, but there is not sufficient evidence to support routine use.

### Hemorrhagic Stroke

Management of hemorrhagic stroke in children is also extrapolated from adult management. There are even fewer prospective data on pediatric hemorrhagic stroke management than AIS.[4] Nonetheless, general neuroprotective strategies used in adults probably apply to children as well; for example, preventing and/or treating hypotension (but avoiding hypertension), hypoxemia, and hypoglycemia. Intracranial pressure should be kept from rising by keeping the head of the bed elevated to 30° and keeping the patient calm or sedated as needed. Hyperosmotic agents such as mannitol and hypertonic saline solutions can be used to temporarily lower intracranial pressure, and hypotonic fluids should be avoided.[60] Neurosurgical intervention may be required with clinical evidence of brain herniation.

Further bleeding should be prevented, when possible. If the child has a low platelet level, hemophilia, or an otherwise high international normalized ratio (INR) that predisposes the patient to bleeding, this can be corrected with transfusion of platelets, clotting factor, or fresh-frozen plasma (also vitamin K), respectively. Reversal of antithrombotic medications should be considered while weighing the risks and benefits. **Table 5** lists some of the recognized reversal agents for antithrombotic medications.[60]

Surgical craniotomy is an option when decompression is needed. For cerebellar hemorrhage, any sign of hydrocephalus, brainstem compression, or bleeds > 3 cm may warrant decompression.[5,60] Embolization and/or resection may be considered for arteriovenous malformations or aneurysms, which is another reason why vessel imaging is important to obtain early on.[15]

It is not known whether oral nimodipine reduces subsequent vasospasm in children after subarachnoid hemorrhage due to an aneurysm.[60] While nimodipine improves outcomes in adults and is likely to be beneficial in children, the ideal dose for children has not been established. A dose of 1 mg/kg every 4 hours in children has been reported to cause significant hypotensive events.[61]

## Special Populations

### Patients With Sickle Cell Disease

The epidemiology, pathophysiology, and treatment of stroke in patients with sickle cell disease varies from other pediatric stroke populations. The incidence of stroke in patients with sickle cell disease is as high as 285 cases per 100,000 children per year.[24] Sickle cell disease increases the risk of arteriopathies as well as small vessel strokes and moyamoya-like disease.[11,24] While ischemic stroke is most common, sickle cell disease also increases the risk of hemorrhagic stroke.[4,24] As mentioned previously, treatment consists of exchange transfusion to reduce the amount of hemoglobin S.

For more information on the management of sickle cell disease in pediatric patients, see the November 2016 issue of *Pediatric Emergency Medicine Practice*, "Managing Acute Complications of Sickle Cell Disease in Pediatric Patients," available at: www.ebmedicine.net/SCD.

**Table 5: Antithrombotic Medication Reversal Agents[23,52,62]**

| Medication | Reversal Agents |
|---|---|
| Aspirin or clopidogrel | • Platelets (5-10 mL/kg if the child weighs < 20 kg; 1 apheresis pack if the child weighs > 20 kg)*<br>• Desmopressin (0.3 mcg/kg IV) |
| Warfarin | • Vitamin K (0.03 mg/kg IV over 20 min)<br>• Fresh-frozen plasma (20 mL/kg IV)<br>• Prothrombin complex concentrate:<br>◦ INR 2 to < 4, 25 units/kg<br>◦ INR 4 to 6, 35 units/kg<br>◦ INR > 6, 50 units/kg |
| Unfractionated heparin | • Protamine sulfate (1 mg IV/100 units of heparin), if heparin was given within 30 min |
| Low-molecular-weight heparin | • 1 mg IV protamine for every 1 mg of enoxaparin (if enoxaparin administered within 8 hr)<br>• 0.5 IV mg protamine for every 1 mg of enoxaparin (if enoxaparin administered within 8-12 hr) |
| Direct thrombin and factor Xa inhibitors | • Prothrombin complex concentrate (adult dosing: 50 units/kg IV; pediatric dosing not established)<br>• Idarucizumab may reverse dabigatran, but pediatric dosing is not established |

*Controversial: platelet use in adults with intracerebral hemorrhage who are on aspirin is associated with worse outcomes and is not recommended.

Abbreviation: INR, international normalized ratio; IV, intravenous

## Risk Management Pitfalls in the Management of Pediatric Stroke

1. **"Stroke is an adult disease! This child was previously healthy, he can't be having a stroke."**
Though stroke is uncommon in children, it does occur. Even previously healthy young children can experience stroke. A recent upper respiratory infection can increase the risk of stroke in an otherwise healthy child.

2. **"I obtained a CT scan instead of an MRI because it's too difficult to obtain an MRI in the ED, and it won't give me management-changing information."**
Though CT scan may yield important diagnostic information, MRI is the preferred modality for pediatric stroke. MRI can better detail AIS and CSVT in addition to common stroke mimics. Delaying MRI delays definitive diagnosis, treatment, and possible prevention of future stroke.

3. **"This child's hemiparesis was likely Todd paralysis because he had a seizure prior to arrival."**
Children with stroke can present with seizure. New-onset focal seizures, prolonged paralysis, other neurological deficits, or stroke risk factors should prompt evaluation for stroke.

4. **"The child presented with altered mental status, but there were no focal neurologic signs, so stroke was not on my differential diagnosis."**
In the case of ischemic stroke, children are more likely than adults to present with nonfocal signs and symptoms (eg, altered mental status), making the diagnosis especially challenging. A high level of suspicion for stroke must be maintained.

5. **"This patient was last well 2 hours ago, and he has a PedNIHSS score of 10. The CT scan showed no hemorrhage, so I don't need to involve neurology prior to giving tPA."**
While some specialists may recommend thrombolytics in pediatric AIS, emergency clinicians should never make this decision on their own. tPA may be reasonable in some situations under the guidance of a neurologist with experience treating pediatric stroke. Vascular imaging that demonstrates complete or partial occlusion of the vessel is required, in addition to other radiologic, laboratory, and clinical criteria. The safety and efficacy of thrombolytics in children have not been studied adequately.

6. **"The patient was not moving his left arm as well as his right. He was complaining of a headache, so I thought he probably had a complex migraine."**
The presence of a headache does not rule out stroke in a child. Complex migraines in children are more commonly associated with visual and sensory changes rather than weakness, and migraine should be a diagnosis of exclusion.

7. **"The patient had just came back from a CT scan when the lab called to report a critical glucose value of 20 g/dL."**
It is important to check the point-of-care glucose level in any child with stroke-like symptoms, because hypoglycemia can cause focal neurological changes and is an easily reversible stroke mimic. Checking the glucose level before sending the child for a CT scan may save them from unnecessary radiation.

8. **"My patient with sickle cell disease had evidence of an ischemic stroke. Her hemoglobin was 8 g/dL, so I didn't think she needed a blood transfusion."**
The treatment goal for AIS in patients with sickle cell disease is to increase the hemoglobin level to 10 to 11 g/dL via exchange transfusion. If the hemoglobin level is < 10 g/dL and exchange transfusion is not readily available, simple transfusion of red blood cells to a level of 10 g/dL is usually recommended.

9. **"I highly suspected stroke in my patient. I thought an MRI brain scan should be sufficient imaging."**
Much of pediatric AIS is due to an arteriopathy. Obtaining vascular imaging with the initial imaging is helpful to immediately identify the cause of the patient's AIS and to inform treatment and prevention of future stroke. This is especially important if the patient is going to be sedated for the MRI, so the patient does not have to be sedated more than once.

10. **"I was concerned the patient had intracerebral hemorrhage, so I rushed him to the CT scanner before wasting time with IV placement or other resuscitation."**
While it is important to rapidly diagnose and contact neurosurgery in the case of a hemorrhagic stroke, it is also important to prevent secondary brain injury from causes such as hypoxia or hypotension/hypertension. Interventions such as IV placement and supplemental oxygen or intubation should be performed to stabilize the patient prior to obtaining imaging.

### Neonates

Neonatal patients are another subset of pediatric patients at risk for stroke, because neonates can experience arterial ischemic and/or hemorrhagic stroke as a consequence of their in-utero environment, delivery, and congenital risk factors.[2] Congenital heart disease is a major risk factor;[63] coagulopathies and cerebral vascular abnormalities are less common causes.[64] The incidence of neonatal stroke is approximately 10 cases per 100,000 live births.[1] Many neonates with stroke present with seizure within the first week of life.[2,63,65] Other reported findings include a full fontanelle, lethargy, vomiting, increasing head circumference, and hemiparesis.[2,63,65] Stroke should be in the differential when a neonate presents with any of these findings.

## Controversies and Cutting Edge

### Therapies for Pediatric Stroke

More data are needed to support future therapies for pediatric stroke. Research on thrombolysis in children is lagging behind adult stroke research. Unfortunately, the first prospective trial of Thrombolysis in Pediatric Stroke (TIPS trial) was discontinued in 2013 due to difficulty in enrolling enough subjects.[66] Intra-arterial interventions are an emerging successful therapy in adult AIS, but more research is needed in children.

### Pediatric Stroke Protocols

One step toward improving pediatric stroke care is initiating pediatric acute stroke protocols in hospital and prehospital settings. Such protocols involve a stroke screening tool that, when positive, triggers actions that could improve the timeliness of diagnosis and stroke care. For example, a code stroke may page the pediatric neurologist, radiologist, anesthesiologist, and critical care teams. In one study, institution of a pediatric stroke protocol such as this led to greater use of MRI as the first diagnostic study, more rapid diagnosis of mild strokes, and a trend toward reduction in time to diagnosis of outpatient stroke.[67] Another study showed significantly decreased time to MRI from ED presentation after implementation of a stroke pathway.[68]

## Disposition

Any child with stroke will likely be admitted to the intensive care unit.[69] The exception is a child who presents several days to weeks after onset of symptoms, has a stable course, and is admitted for further evaluation of etiology and risk factors. In the acute period of stroke, children are at risk for continuing ischemia, hemorrhage, edema, increased intracranial pressure, herniation, and seizures, so intensive-level care is necessary.

Pediatric AIS has a mortality rate between 4% and 10%, and hemorrhagic stroke has a mortality rate of up to 25%.[1,4,60,69,70] Most children with stroke survive, but with long-term neurological deficits.[1,4,60] In one study of a large Canadian stroke registry, 12% of children had recurrent ischemic stroke or transient ischemic attack.[1] Risk of hemorrhagic stroke recurrence is more difficult to estimate, but may be approximately 10%.[4] Therefore, children with stroke may require extensive care and medical follow-up beyond their initial hospitalization.

## Summary

Pediatric stroke is a rare—but important—diagnosis to make because of its high morbidity and mortality. It is a challenging diagnosis to make in a timely manner because of more common stroke mimics in children, clinicians' unfamiliarity with pediatric stroke, and the different ways in which children present with stroke. Hemorrhagic stroke and AIS occur with equal frequency among children, but are associated with different risk factors. Stroke is much more common in children with sickle cell disease than in the general population and is also managed differently, with exchange transfusion to lower the amount of hemoglobin S. Management of pediatric stroke that is not related to sickle cell disease is often extrapolated from adults, but there are some important differences. Experts recommend antiplatelet or anticoagulant medications for AIS, but there is insufficient evidence about the safety and efficacy of thrombolysis and thrombectomy in children. Once AIS is diagnosed, the specific medication choice should be ordered in consultation with the pediatric neurologist. Future studies should lead to more evidence-based management of pediatric stroke and stroke prevention.

## Time- and Cost-Effective Strategies

- **Imaging:** Obtain vascular imaging of the head and neck with the initial head imaging. Ask the radiologist whether there is a rapid MRI protocol for pediatric stroke. This will lead to faster diagnosis of the etiology of the stroke and prevent repeat sedation or contrast exposure.
- **Laboratory studies:** Initial laboratory studies should be comprehensive and include a CBC, PT, PTT, INR, electrolytes, renal function, and glucose level. A toxicology screen should be considered.
- **Other resources:** There is no need for administration of anticonvulsant medications in the absence of seizures unless there is an added neurosurgical reason to do so. IV fluids and supplemental oxygen are necessary only for maintaining normal volume status and oxygenation.

## Case Conclusions

*You were concerned about a CNS neoplasm in the 7 year-old boy, given his history of lymphoma with new neurologic changes. You were also concerned about intracerebral bleeding and infection that could result from his recent exposure to chemotherapy. His vomiting, low heart rate, and borderline elevated blood pressure were concerning for signs of increased intracranial pressure. As the nurse obtained IV access, you determined that the boy's mental status was not improving rapidly enough for a typical postictal course, and you were concerned about his airway, given his vomiting. You decided to intubate the boy, and you attempted to get a better neurological examination while the team was preparing for intubation. You also noted there were no signs of trauma. After successful intubation, a CT scan of the head was performed, and it showed intraparenchymal hemorrhage. While the child was on the CT table, you also obtained a CT angiogram of the head. A CBC panel showed a platelet level of 5000/mcL. You discussed the case with the neurosurgeon and hematologist, who recommended transfusing platelets to a level of > 100,000/mcL. Other neuroprotective strategies and ICP precautions were started and the child was admitted to the ICU.*

*You thought the 5-year-old boy with sickle cell disease in the next room was likely experiencing an AIS. You knew that tPA is not FDA-approved for use in children and may not be appropriate in a child with sickle cell disease, but the boy was in the treatment window for thrombolytics. A point-of-care glucose test was normal. You drew labs including a CBC, peripheral smear, reticulocyte count, PT/INR, PTT, and chemistry panel. You decided to consult neurology emergently before obtaining any imaging. The neurologist recommended that you call the child's hematologist. The child's hematologist reviewed the labs, which showed a hemoglobin level of 7 g/dL, and he recommended emergent exchange transfusion. While this was pending, transfusion of red blood cells was started. After evaluating the patient, the neurologist recommended a rapid stroke protocol MRI and MRA of the head and neck, which demonstrated cortical ischemia. The child was then admitted to the ICU and exchange transfusion was initiated.*

*In the case of the 2-year-old girl, you had already overcome the most challenging part of the case—making the diagnosis of left carotid artery dissection—due to your high level of suspicion after hearing the mechanism of injury and the patient's loss of consciousness. You consulted neurology and vascular surgery. They recommended obtaining imaging of the head, then starting heparin after baseline labs were performed. They also said that, if there was any change in the patient's neurological exam or clinical status, you were to obtain an emergent CT scan of the head to evaluate for bleeding. The patient was admitted to the ICU for frequent neurological checks and management of anticoagulation. After anticoagulating in the acute period, the medication was switched to aspirin for long-term prevention.*

## References

Evidence-based medicine requires a critical appraisal of the literature based upon study methodology and number of subjects. Not all references are equally robust. The findings of a large, prospective, randomized, and blinded trial should carry more weight than a case report.

To help the reader judge the strength of each reference, pertinent information about the study, such as the type of study and the number of patients in the study is included in bold type following the references, where available. The most informative references cited in this paper, as determined by the authors, are noted by an asterisk (*) next to the number of the reference.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## CME Questions


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**1. A previously healthy 5-year-old boy presents with left-sided hemiparesis for 3 hours. He had a cough and fever 1 week ago but has no significant past medical history or family history. Ischemic stroke is found on magnetic resonance imaging (MRI). Statistically speaking, what is the most likely cause of his stroke?**

a. Congenital heart disease
b. Hypertension
c. Arteriopathy
d. Elevated lipoprotein(a)

2. **A child presents with cranial nerve VI palsy and signs of increased intracranial pressure. She was recently treated for a sinus infection. What diagnosis should be highest on your differential?**
   a. Cerebral sinus venous thrombosis
   b. Arterial ischemic stroke
   c. Hemorrhagic stroke
   d. Cervical artery dissection

3. **A 14-year-old girl presents with a bilateral sensory deficit from the umbilicus down. This is most concerning for which of the following diagnoses?**
   a. Guillain-Barré syndrome
   b. Reversible posterior leukoencephalopathy syndrome
   c. Peripheral neuropathy
   d. Transverse myelitis

4. **A 9-year-old girl presents with 1 hour of headache and numbness of the right side of her face. She is well-appearing, with a normal neurological examination. She likely has what common stroke-mimic diagnosis?**
   a. Migraine
   b. Todd paralysis
   c. Bell palsy
   d. Brain tumor

5. **Which of the following features in a child with a neurological complaint is LESS consistent with stroke?**
   a. Altered mental status
   b. Gradual onset
   c. Generalized seizures
   d. Neurological deficit in a child with no chronic medical problems

6. **A 13-year-old boy presents with right facial droop and right arm weakness that started 5 hours ago. If readily available, the ideal initial diagnostic imaging study in this case is:**
   a. Computed tomography (CT) brain without contrast
   b. MRI brain and magnetic resonance angiogram (MRA) head and neck
   c. Cerebral angiography
   d. CT angiography of the neck

7. **A 6-year-old girl is found on MRI to have an arterial ischemic stroke, with symptom onset 2 hours ago. MRA shows a focal cerebral arteriopathy. She has a PedNIHSS score of 5. What is the recommended medical therapy in this case?**
   a. Tissue plasminogen activator given before 3.5 hours from symptom onset
   b. Mechanical thrombectomy
   c. Surgical revascularization
   d. Aspirin or anticoagulation with heparin/low-molecular-weight heparin

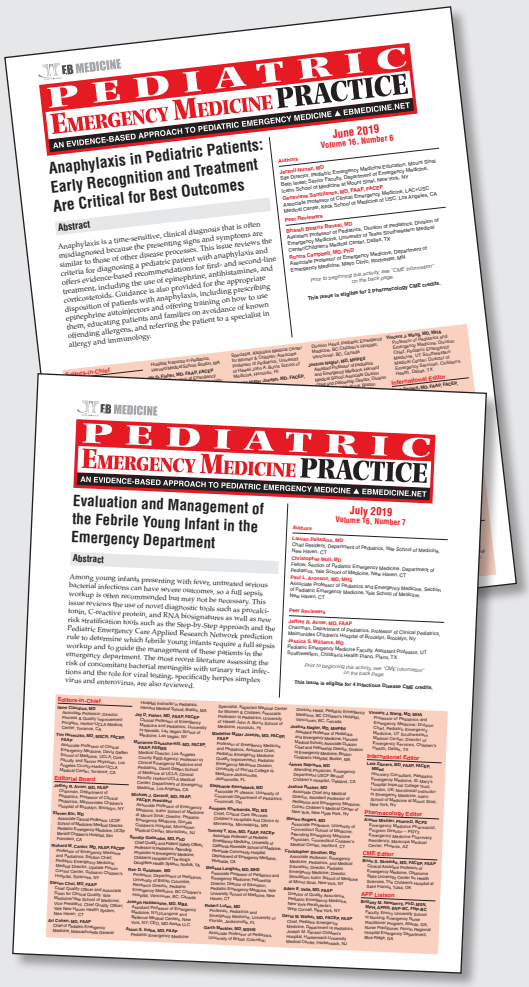
8. **When performing the PedNIHSS examination, total gaze paresis is present if:**
   a. The child is unable to track with her eyes but can involuntarily move her eyes
   b. The child cannot move her eyes, even when the oculocephalic maneuver is performed
   c. The child cannot look up but can look right and left
   d. The child is unable to track with her eyes but has eye movement during the oculocephalic maneuver

9. **A child with sickle cell disease presents with arterial ischemic stroke and a hemoglobin level of 9 g/dL. What is the preferred treatment?**
   a. Thrombolytics
   b. Heparin
   c. Plasmapheresis
   d. Exchange transfusion

10. **A child on chronic warfarin therapy presents with intracranial hemorrhage. The patient's international normalized ratio is 3. Which of the following is the most reasonable option for reversal of anticoagulation?**
    a. Fresh-frozen plasma
    b. Platelets
    c. Hemodialysis
    d. Protamine

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***Pediatric Emergency Medicine Practice....***

- Rashes With Fever
- Mild TBI/Concussion
- Septic Arthritis and Osteomyelitis

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**Goals:** Upon completion of this activity, you should be able to: (1) demonstrate medical decision-making based on the strongest clinical evidence; (2) cost-effectively diagnose and treat the most critical ED presentations; and (3) describe the most common medicolegal pitfalls for each topic covered.

**CME Objectives:** Upon completion of this activity, you should be able to: (1) diagnose pediatric stroke through recognition of risk factors and presentation; (2) determine the diagnostic studies to order; and (3) discuss the rationale and recommendations for different medical therapies for pediatric stroke.

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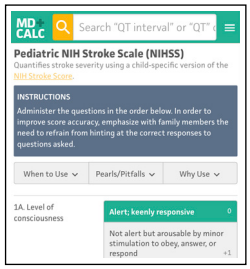


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# Pediatric National Institutes of Health Stroke Scale (PedNIHSS)

The PedNIHSS quantifies stroke severity using a child-specific version of the National Institutes of Health Stroke Score.

## Points & Pearls

- The presentation of stroke in younger children can be subtle and may include altered mental status, depressed level of consciousness, and apneas.
- Presenting the questions and tasks in the Pediatric National Institutes of Health Stroke Scale (PedNIHSS) as a game may aid in motivating patients, especially younger children.
- The developmental age of the child in the premorbid state must be considered. Consultation with the patient's primary care clinician may be useful in estimating the patient's developmental age; it may also be helpful to utilize a validated developmental screening tool that uses parental recall.
- Muscle strength in uncooperative patients may be assessed by careful observation of spontaneous movement or elicited movement, as compared to a developmentally and neurologically appropriate child of the same age as the patient.

## Critical Action

Pediatric patients with sickle cell disease who present with acute ischemic stroke will likely benefit from emergent blood transfusion to reduce hyperviscosity. Early consultation with a pediatric hematologist, in addition to a pediatric neurologist, is recommended for these patients.

CALCULATOR REVIEW AUTHOR

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## Why to Use

Pediatric stroke is relatively uncommon, but it remains an important cause of morbidity and mortality in children. Adult stroke scales have limited sensitivity when applied to pediatric populations (62%-67% sensitivity according to an analysis by Mackay et al [2016]). The PedNIHSS is up to 87% sensitive (Beslow 2012). It quantifies the severity of pediatric stroke and can be trended over time to assess recovery, while the initial score may be predictive of future disability at 90 days.

## When to Use

The PedNIHSS should be used in pediatric patients aged ≥ 2 years who have clinical and radiologic signs of acute ischemic stroke.

## Instructions

In order to improve the accuracy of the PedNIHSS, the patient's family members should be instructed to refrain from hinting at the correct responses to the questions asked.

## Next Steps

- The PedNIHSS has not been validated for hemorrhagic stroke; in such cases, emergent neurosurgical consultation is needed.
- Given the overall rarity of pediatric stroke, the benefit of tPA in children is not well supported in the literature, emphasizing the importance of expert consultation.

Abbreviation: tPA, tissue plasminogen activator.

## Advice

Pediatric stroke is rare, and the true predictive value of the PedNIHSS is subject to change as the scale continues to be studied. Retrospective application of the PedNIHSS has been shown to be valid and reliable in 1 cross-sectional study (Beslow 2012).

## Evidence Appraisal

The PedNIHSS was developed by expert consensus of a panel of adult and pediatric stroke experts (Ichord 2011). The panel adapted the validated adult NIHSS to be appropriate for age-related variations in the comprehension of examination materials. The scoring strategy and ranges were not changed. The panel evaluated the interrater reliability of the PedNIHSS among 113 patients aged 2 to 18 years in a multicenter prospective cohort study. Overall, the interrater reliability was found to be quite high, ranging from 0.63 to 1.00 among the evaluating pediatric neurologists.

The PedNIHSS was externally validated by applying it to 75 children enrolled in a prospective study (Beslow 2012). Patients were scored both prospectively and retrospectively (based on the chart). Retrospectively applied scores correlated well with prospective scores ($r^2 = 0.76$). Interrater reliability was good overall (intraclass correlation coefficient of 0.95; 95% confidence interval, 0.94-0.97), with similar findings for individual test items.

## Use the Calculator Now

Click here to access the PedNIHSS on MDCalc.

## Calculator Creator

Rebecca N. Ichord, MD
Click here to read more about Dr. Ichord.

## References


### Original/Primary Reference

- Ichord RN, Bastian R, Abraham L, et al. Interrater reliability of the Pediatric National Institutes of Health Stroke Scale (PedNIHSS) in a multicenter study. *Stroke*. 2011;42(3):613-617. **DOI: https://doi.org/10.1161/STROKEAHA.110.607192**

### Validation References

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