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Cerebrovascular Disease and Stroke (D Greer, Section Editor)

Approach to Acute Ischemic Stroke in Childhood

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Opinion statement

Acute ischemic stroke in childhood is a medical emergency. Prompt recognition and intervention is necessary to rescue potentially viable brain tissue, prevent complications, and minimize the risk of recurrent stroke. Conditions that could result in recurrent stroke such as cardiac thrombus or cervical artery dissection need to be identified and treated promptly. Although the care of childhood stroke is based largely on extrapolation from adults, an organized approach to the care of these children is critical to optimize outcome.

Introduction

Childhood arterial ischemic stroke (CAIS) is rare compared with adults; the estimated incidence ranges from 2.3 to 13 per 100,000 children [1, 2], and the incidence appears to be rising [3]. Following arterial ischemic stroke (AIS), 6 %–10 % of children die, and over 75 % will suffer long-term neurologic and neuropsychological deficits [4, 5]. As many as one in five children will have another stroke [6].

In adults, evidence-based guidelines for management of stroke have led to the development of dedicated stroke protocols and units. In contrast, the care of children with acute stroke is often poorly coordinated, reflecting a paucity of research on which to base treatment recommendations. Nevertheless, clinical experience in pediatric stroke and extrapolation from studies in adult stroke have been used to formulate guidelines of care [7–10], and the presence of pediatric stroke programs in academic medical centers has become increasingly common.

Principles of acute management

Suspected acute stroke in childhood requires urgent evaluation in order to institute strategies to "rescue the penumbra," prevent recurrent stroke, which can occur immediately, and avoid unnecessary evaluation for other etiologies. Recognition of stroke in childhood is challenging, and significant delays in diagnosis occur because it is relatively rare and often not considered in the child presenting with an acute neurological deficit [11]. Mimics of childhood stroke are common, and the differential diagnosis is broad, including other diagnoses requiring urgent recognition and intervention [11–14].

Assessing neurological deficits in young children is challenging; however, signs and symptoms of stroke are similar to those in adults: aphasia, hemiparesis, hemisensory loss, change in vision, and loss of balance. History should include the time the child was last seen at baseline and whether the onset was sudden, gradual or stuttering, as is often the case in cerebrovasculopathy. The presence of underlying predisposing conditions such as heart disease, hematologic malignancy, inflammatory and autoimmune disease, sickle cell disease, infection, especially varicella zoster virus, and trauma with resulting cervical artery dissection, as well as a history of previous stroke, thrombosis, or bleeding problems should be sought. The time that the child last ate and last drank should be recorded, as sedation or anesthesia may be necessary.

In a recent series of children aged 2 months to 18 years with AIS, 22 % presented with seizures. Patients with seizures were significantly younger, with a median age of 1.1 years as opposed to 10 years for those without seizures. All had hemiparesis, and subclinical seizures were present in three of four children undergoing long term EEG monitoring [15]. This underscores the importance of obtaining a brain MRI in any child presenting with new onset "Todd's paralysis," and an urgent electroencephalogram (EEG) in a child with AIS whose sensorium is not clearing as expected.

The initial evaluation includes a general physical examination, including blood pressure and temperature, with particular attention to the cardiac exam. Neurologic deficits should be assessed. If possible, the child should be assessed using the Pediatric version of the NIH Stroke Scale (PedNIHSS), which has been validated for use in children ages 2–17 years [16•, 17].

Initial laboratory studies

A complete blood count (CBC) with differential, electrolytes, blood urea nitrogen (BUN), creatinine, glucose, prothrombin time (PT), partial thromboplastin time (PTT), erythrocyte sedimentation rate (ESR), fibrinogen, and D-dimer are indicated in all patients with suspected acute stroke. An arterial blood gas should be sent if clinically indicated. Females of child bearing age should be screened with a urine or serum pregnancy test. If the child is on chronic anticoagulation, studies to assess whether anticoagulation is outside the therapeutic range are indicated: low molecular weight heparin (LMWH) activity by protamine neutralization or anti-Xa assays if on LMWH, and PT/international normalized ratio (INR) if on warfarin. Urine toxicology for

drugs of abuse should be obtained [18, 19]. If the patient is at high risk for intracranial hemorrhage, or if tissue plasminogen activator (tPA) thrombolysis is being considered, a type and screen for packed red blood cells should be sent. Type and cross match in preparation for transfusion should be sent for a patient with sickle cell disease with possible stroke.

Neuroimaging

Urgent neuroimaging is needed for diagnosis and to identify possible neurosurgical emergencies, such as intracerebral hemorrhage, cerebral edema, and increased intracranial pressure. Identification of other possible etiologies, such as craniocervical arterial dissection (CCAD), cardiac embolus, or cerebral sinus venous thrombosis (CSVT) will alter initial management.

The optimal study for assessing possible acute stroke in childhood is head magnetic resonance imaging (MRI) with diffusion-weighted images (DWI), as well as head and neck magnetic resonance angiography (MRA). A rapid stroke neuroimaging protocol including axial T2 (or axial T2 FLAIR instead of axial T2 for children ages 2 years and older), susceptibility-weighted imaging (SWI) or gradient echo, DWI/apparent diffusion coefficient (ADC) maps, and time of flight (TOF) MRA of head and neck may be useful if the length of time to complete the scan is a concern. In many centers, this can be performed in 20–25 minutes. MR venography (MRV) should be performed if there is clinical or neuroimaging concern about CSVT.

A head computed tomography (CT) scan can rule out intracranial hemorrhage (ICH), but is not sensitive to early ischemia or ischemia involving the posterior circulation. CTA of the head and neck can be used to diagnose arterial abnormalities including stenosis, occlusion, and dissection. CTA requires significant radiation and may not add significant information to MRA.

If dissection is strongly suspected but not seen on noninvasive imaging, cerebral catheter angiography (cerebral CA) is indicated [20]. Cerebral CA is the most sensitive method of diagnosing cerebral arteriopathy. It requires significant radiation and anesthesia, but peri-procedural complications are very rare with experienced angiographers [21]. Transcranial Doppler may be useful to assess vascular stenosis or for monitoring microemboli.

Treatment

Principles of acute management

The goal of early intervention is to minimize injury and prevent early complications, including extension of the penumbra and recurrent stroke. Adequate oxygenation should be ensured, although, except for patients with sickle cell disease (SCD), supplemental oxygen is not necessary in the absence of hypoxia. Patients with SCD should continue oxygen supplementation to maintain SaO_2 >93 % through the completion of transfusion therapy, and then through the first night to minimize nocturnal hypoxemia.

To maintain cerebral perfusion pressure, the child should be kept flat, hypovolemia corrected, and large bore intravenous access established for maintaining hydration. The child should be allowed nothing by mouth for possible sedation, and to reduce the risk of choking and aspiration. Hypoglycemia

should be treated, and marked hyperglycemia avoided. Fever increases metabolic needs of the brain, so if present, excess clothing and blankets should be removed. Rectal acetaminophen can be administered for a temperature greater than 38 °C. Except in patients with SCD, in whom it is contraindicated, a cooling blanket should be used for temperatures greater than 38.5 °C.

Children with acute stroke often have hypertension. In adults, abrupt blood pressure reduction may extend the ischemic penumbra and is generally avoided, however optimal blood pressure parameters are not known [22]. Unless clinically indicated, mild hypertension immediately following stroke does not require acute treatment, although long term monitoring and treatment of hypertension is recommended.

Children with acute stroke should be admitted to the intensive care unit for neurologic and medical monitoring, and for aggressive management of complications [23]. The pediatric NIHSS scale can be used for serial assessment [16•].

Pharmacologic interventions

Anticoagulation

The optimal use of acute anticoagulation in CAIS is unknown, but expert consensus based guidelines exist [9, 10] (Table 1). Anticoagulation can be considered while etiologic evaluation is underway, for example, in children with possible extracranial CCAD, those at risk for cardiac embolism, children with recurrent stroke on aspirin, and selected children with hypercoagulable states [10, 24]. Anticoagulation may be more useful in children than adults, as the etiology of childhood stroke is often due to cardiac or vessel-to-vessel embolus, and children with stroke may be at a higher risk of having underlying thrombophilia. Counseling of parents should include the potential risks of heparin, including new or increased bleeding, and rarely, heparin-induced thrombocytopenia (HIT), a serious antibody-mediated complication of heparin [25]; the lack of compelling evidence regarding its use in nonembolic stroke should be included in the discussion.

Table 1. ACCP and AHA guidelines for childhood AIS

	American College of Chest Physicians (ACCP) guidelines 2012 [9]	American Heart Association (AHA) guidelines 2008 [10]
Initial treatment	UFH or LMWH or aspirin 1–5 mg/day until cardiac source or dissection excluded; if cardiac source or dissection excluded, then aspirin should be started	UFH or LMWH until etiology determined
Treatment of cardiac disease	LMWH	Cardiac specific treatment
Treatment of cervical artery dissection	LMWH	UFH or LMWH
Sickle cell disease	Exchange transfusion with goal HbS <30 %	Exchange transfusion with goal HbS <30 %
Use of tissue plasminogen activator	Not recommended for children outside of specific research protocols	Generally not recommended outside of a clinical trial

Intravenous unfractionated heparin (UFH) has an immediate onset, short half-life and is easily reversed with protamine. Disadvantages include the need for intravenous administration and frequent blood draws for monitoring. It can cause HIT, resulting in severe thrombotic complications. Monitoring for falling platelet counts, which may herald HIT is critical during the first weeks of therapy [25, 26]. When treating with unfractionated heparin, the aPTT therapeutic goal range is the individual laboratory aPTT equivalent to an anti-Xa level of 0.3–0.6 u/mL. An aPTT should be checked every 4 hours following dose changes until therapeutic, then daily with a CBC, and platelet counts to screen for HIT [26].

Potential contraindications to systemic heparinization include major bleeding and the presence of more than scant or petechial blood on neuroimaging. Large hemispheric infarcts with midline shift or involving more than 1/3 of the MCA territory are at highest risk of hemorrhagic conversion with anticoagulation or thrombolysis. Anticoagulation should be avoided in children with CNS vasculitis and moyamoya vasculopathy due to an underlying risk of intracranial hemorrhage in these patients.

If the child is stable and no invasive procedures including diagnostic conventional angiography are planned, unfractionated heparin by continuous infusion can be discontinued and low molecular weight heparin started. LMWH can reach therapeutic levels rapidly, but is incompletely reversed by protamine. Therapeutic levels can be monitored and established with the use of an anti-Xa assay obtained 4 hours following injection; the therapeutic range is 0.5 to 1.0 anti-Xa units/mL. The risk of intracranial hemorrhage or HIT appears to be lower with LMWH than UFH [27].

Antithrombin III (AT III) levels should be checked if a patient is requiring higher heparin doses than expected, as anti-Xa activity is dependent on a patient's AT III level. Anticoagulation is usually avoided in children with CNS vasculitis and moyamoya vasculopathy due to underlying risk of intracranial hemorrhage. Anticoagulation is not recommended for intracranial arterial dissection due the risk of subarachnoid hemorrhage [10], but antiplatelet medication has been used [28].

Newer oral anticoagulants such as dabigatran, a direct competitive inhibitor of thrombin, and rivaroxaban and apixaban, oral direct factor Xa inhibitors, have not been studied for use in childhood stroke.

Aspirin

If an antithrombotic or thrombolytic medication is not used, aspirin as an antiplatelet agent at an acute dose of 3–5 mg/kg/d should be started, if there are no contraindications such as intracranial hemorrhage [10]. Over time, this dose may be decreased to 1–3 mg/kg/d, earlier if there is excessive bruising or bleeding, usually in the form of nosebleeds or menorrhagia, occurs. Aspirin is usually continued for 3–5 years or indefinitely. The risk of Reye syndrome is likely dose dependent [29], and has not been reported in aspirin use for stroke prophylaxis in childhood.

Thrombolysis

Thrombolysis is used acutely in adult stroke to restore perfusion to salvageable penumbra. When given at a dose of 0.9 mg/kg in selected adults, it is associated with improved neurological outcome at 3 months, but also a ten-

fold increase in symptomatic intracranial hemorrhage to 6.4 % [30]. In The European Cooperative Acute Stroke Study (ECASS) III, intravenous tPA was found to be beneficial at 3–4.5 hours, with a SICH rate of 2.4 % [31]. The American Heart Association/American Stroke Association advisory recommends a time window of 4.5 hours for intravenous tPA in adults, however this does not have FDA approval [32].

Intravenous tissue plasminogen activator (tPA) is not FDA approved for use in childhood, but could be considered in the older adolescent who otherwise meets the criteria for its use in adults [10]. Absolute contraindications to intravenous tPA in acute childhood stroke include time of symptom onset greater than 4.5 hours to initiation of treatment, baseline neuroimaging with evidence of intracranial hemorrhage, significant bleeding diathesis, and known cerebral arterial venous malformation, aneurysm, or neoplasm.

If systemic thrombolysis has been given for acute stroke, post-thrombolysis care should include frequent neurological checks and blood pressure monitoring to avoid a blood pressure greater than 15 % over the ninety-fifth percentile for age. Insertion of an indwelling Foley catheter should be avoided during the tPA infusion and for as least 30 minutes after the infusion ends. Placement of a nasogastric tube should be avoided for 24 hours. Venipuncture sites should be monitored frequently during the first 24 hours, and arterial sticks and other procedures with risk of bleeding should be avoided for 24 hours. Antiplatelet and anticoagulant medications should be avoided for 24 hours.

Endovascular intervention

There are reports of successful use of endovascular intervention in CAIS; however safety and efficacy are unknown and its use is not FDA approved. Recently it was shown that in adults the use of endovascular treatment alone or following IV tPA did not improve outcomes compared with IV tPA alone [33]. There may be a role in selected children, for example, an older child with posterior circulation stroke [34], but routine endovascular intervention is not recommended.

Acute treatment in patients with sickle cell disease

Sickle cell disease (SCD) is a potent risk factor for stroke [35]; therefore a patient with SCD and presentation consistent with stroke should be approached as a possible stroke. This does not preclude work-up for other etiologies such as infection, vaso-occlusive crisis, and acute chest syndrome. Therefore, exchange transfusions, which are commonly used to treat acute stroke in SCD, should not be delayed to obtain an MRI.

The American College of Chest Physicians (ACCP) guidelines recommend urgent erythrocyte transfusion to reduce hemoglobin S levels to less than 30 % in acute stroke [9]. Typically, an exchange transfusion or erythrocytapheresis to a hematocrit of 30 % and Hb S≤30 % is performed. If exchange transfusion cannot be done acutely, a simple transfusion with RBC for a Hct of 30 % may be done and should be followed by an exchange transfusion when available. There is an increased risk of ischemia due to increased viscosity if hemoglobin rises to >13 g/dL following exchange or simple transfusion, and this should be avoided. Patients who underwent simple transfusion only at the time of presentation of initial stroke were five

times more likely to have a recurrent stroke than patients who underwent an exchange transfusion or a combination of simple transfusion and exchange transfusion [36]. If a femoral line was used for exchange transfusion, it should be removed as soon as possible following transfusion to decrease thrombosis risk.

The relatively common occurrence of hemorrhagic stroke in adults with SCD has led to a presumption that acute ischemic stroke carries a high risk of hemorrhagic transformation. While this remains unproven, thrombolysis is not recommended, and the use of systemic anticoagulation (except in the case of symptomatic cerebral sinus thrombosis) is usually avoided. There may be a role for antiplatelet agents in patients with recurrent stroke while on chronic transfusion therapy, but there is no data to guide this approach.

Etiologic investigations

Almost one-half of children presenting with acute stroke will have a known pre-existing risk factor, and following a thorough etiologic evaluation, up to 90 % will have at least one risk factor identified [37, 38•].

Cardiac evaluation

Most children presenting with cardioembolic stroke have a history of heart disease, however stroke can herald cardiomyopathy. Transthoracic echocardiography (TTE) is routinely performed in childhood stroke and should be done urgently to evaluate for suspected cardiac thrombus or vegetation. "Contrast" with agitated saline is indicated in children with recurrent strokes of unknown etiology or in whom embolization from systemic venous thromboses are the suspected etiology. In rare cases, transesophageal echocardiography may detect abnormalities not seen on TTE, particularly vegetations and left atrial thrombi [39]. At least one in four children with stroke due to congenital heart disease will have a recurrent stroke; children with mechanical valves, thrombophilia, and infection at the time of initial stroke are at highest risk [40].

Although stroke because of cardiogenic embolism in SCD is assumed to be rare, SCD can be associated with a chronic high output state, and rarely, with acute cardiac failure [41]. In patients with signs or symptoms of cardiac instability or failure, emergent echocardiogram may be needed to assess the cardiac implications of volume fluctuations associated with exchange transfusion, as well as assessing for potential embolic sources.

Monitoring

Children with acute stroke should be admitted to the PICU for neurologic and medical monitoring and aggressive management of complications. Neurological status should be monitored by the bedside nurse and medical staff. The pediatric NIHSS can be used to serially assess the patient [16•].

Elevated intracranial pressure

Children with large AIS are at risk for increased intracranial pressure due to edema and ventricular outflow obstruction, particularly in the first 72–96 hours following stroke. In seven children treated with surgical decompression for malignant middle cerebral artery infarction, moderately good outcomes were reported [42]. If this option is considered, however, the possibility of survival with severe disability needs to be discussed with the family.

Hemorrhage

In a series of children with AIS, hemorrhagic transformation occurred in 19 (30 %), of whom two were symptomatic. Increased infarct volume was associated with hemorrhagic transformation, but not with use of anticoagulation vs. antiplatelet therapy [43]. With any otherwise unexplained neurological deterioration, intracranial hemorrhage needs to be considered. If a tPA or heparin infusion is ongoing, this should be discontinued immediately, and further doses of anticoagulant or antiplatelet medications should be held. Neurosurgery should be notified and emergent neuroimaging obtained, usually a head CT. Urgent CBC, PT, PTT, fibrinogen, electrolytes, BUN, creatinine, glucose, type and hold for possible packed red blood cell transfusion should be sent.

Coagulopathy due to tPA is likely to consist of hypofibrinogenemia, elevated PT secondary to decreased factor V, and elevated PTT due to decreased factor VIII. Hypofibrinogenemia (fibrinogen <100 gm/dL) should be corrected with 1 donor unit (bag)/5 kg body weight cryoprecipitate; this can be expected to raise the fibrinogen level by 50 mg/dL. Cryoprecipitate also contains factor VIII (~100 units/donor unit) and can be expected to raise the factor VIII level approximately 40 U/dL (%). This dose of cryoprecipitate is thus likely to raise both fibrinogen and factor VIII into a hemostatic range. Since the hemostatic level of factor V is about 30 %, correction of factor V by the infusion of FFP is not likely needed unless the PT is above 20 seconds. In this case, 10–15 mL/kg FFP should be given. If the platelet count is less than 100/μL in addition to decreased fibrinogen and elevated PT and PTT, disseminated intravascular coagulation (DIC) should be suspected and both platelets (1 donor unit/5 kg body weight) and FFP (10–15 mL/kg) administered in addition to cryoprecipitate. tPA also has an antiplatelet effect, and random donor platelets may provide additional benefit. If hemorrhaging is severe and uncontrollable with replacement therapy with cryoprecipitate, FFP and platelets, consideration may be given to use of recombinant FVIIa at a dose of 30 mcg/kg in consultation with hematology, as recombinant FVIIa carries a thrombosis risk.

Laboratory studies

Most laboratory investigations of possible underlying prothrombotic states do not need to be obtained urgently when maintaining an optimal hematocrit is critical, and not all are necessary in every patient. Urgent evaluations may include CBC, toxicology screen, screen for systemic inflammatory disease (ESR, CRP, ANA), and antiphospholipid antibodies (lupus anticoagu-

lant, anticardiolipin antibodies, anti-beta2 glycoprotein 1 antibodies), and urine β-HCG. The role of individual thrombophilia in childhood stroke is an area of active investigation, and amongst neurology and hematology stroke experts, this is an area of intense discussion. Multiple risk factors appear to confer the greatest risk of stroke [40, 44, 45] (Table 2).

Table 2. Common laboratory studies in childhood AIS

Laboratory tests	Associated risk factor for childhood AIS
CBC	Iron deficiency anemia and hematologic malignancy [60, 61]
Hemoglobin electrophoresis (if not done in newborn screen)	Sickle cell disease [35]
Iron and total iron binding capacity (TIBC)	Iron deficiency anemia [60]
Antinuclear antibodies (ANA)	Central nervous system vasculitis/collagen vascular disease [62]
Rheumatoid factor	Central nervous system vasculitis/collagen vascular disease [62]
Antiphospholipid antibodies (includes anticardiolipin antibody IgM, IgG, and IgA; Anti-beta-2 glycoprotein-1 IgM, IgG, IgA; and lupus anticoagulant	Antiphospholipid antibody syndrome [44, 45]
Factor V Leiden mutation (FVL)	FVL is most common cause of activated protein C resistance [44]
Prothrombin gene mutation (factor II/G20210A)	Elevated prothrombin [63]
Protein C activity and antigen	Protein C deficiency [38•, 45, 48, 63] May be lowered by warfarin.
Protein S activity; total and free protein S antigen	Protein S deficiency associated with childhood stroke [38•, 63] May be lowered by warfarin, Vitamin K deficiency, liver disease, DIC; only free Protein S is functional as a co-factor for Protein C
5,10 Methylene tetra-hydrofolate reductase (MTHFR) mutation	Elevated homocysteine [63] Useful if homocysteine is elevated and MTHFR mutation suspected [64]
Homocysteine	Hyperhomocysteinemia [65, 66]
Antithrombin III (AT III) activity	Antithrombin III deficiency [38•, 63] Heparin and direct thrombin inhibitors can affect results.
Prothrombin time (PT)/International normalized ratio (INR)	
Activated partial thromboplastin time (aPTT)	If prolonged, consider screen for lupus anticoagulant
C reactive protein (CRP)	Acute infection [67]
Erythrocyte sedimentation rate (ESR)	Acute infection [67]
Urine β-HCG (pregnancy test)	Strongly consider in any female of childbearing age as pregnancy is hypercoagulable state
Toxicology screen-serum or urine	Amphetamine, cocaine , marijuana and opiate abuse [18, 19]
Lipoprotein (a)	Elevated lipoprotein (a) [45, 48, 68]
CSF for varicella zoster virus (VZV) testing	Varicella is well associated with stroke [50] CSF antibody titers more sensitive than polymerase chain reaction (PCR). Both should be sent [52]

Cerebrovasculopathy

Approximately half of all children with stroke will have an underlying nonatherosclerotic cerebral arteriopathy identified, including children with other known risk factors for stroke [38]. In one series, one-third of children with cardiac disease and acute stroke who had vascular imaging performed have an underlying cerebrovasculopathy [37]. Cerebral arteriopathy is a potent risk factor for stroke recurrence, including early stroke recurrence, and diagnosis may alter management [6, 46–48]. The initial treatment recommendation for cervical artery dissection in childhood is anticoagulation with heparin [9, 10]. In adults, anticoagulant therapy or aspirin is recommended [49]. Varicella is well associated with stroke [50]. Varicella vasculopathy is due to active viral proliferation; therefore antiviral therapy with intravenous acyclovir is indicated [51]. Diagnosis is confirmed by demonstration of varicella zoster virus antibodies or viral DNA in the cerebrospinal fluid [52].

Moyamoya is a chronic cerebrovasculopathy characterized by progressive stenosis of the terminal internal carotid arteries and proximal middle cerebral arteries and formation of compensatory collateral arterial rete at the base of the brain [53]. There is no effective medical treatment for moyamoya, and anticoagulation is usually avoided due to risk of hemorrhage. Surgical revascularization, either indirect procedures such as encephaloduroarteriosynangiosis or encephaloduroarteriomyosynangiosis, direct revascularization, usually superficial temporal artery to middle cerebral artery anastomosis, or combined procedures are used [54–56]. Hyperventilation is avoided during EEG in patients with moyamoya due to the risk of ischemia from vasoconstriction.

Rehabilitation

Measures to minimize complications due to the child's functional status or medical treatments are important. A swallowing evaluation is needed prior to institution of feeding. For children with mild deficits, a behavior swallowing evaluation may be adequate, but frequently a formal swallowing study is necessary. The Pediatric Stroke Outcome Measure (PSOM) is a measure of sensorimotor, language, and cognitive/behavior function following stroke that has been shown to be a valid and reliable outcome measure [57•].

Rehabilitation needs, both inpatient and at discharge, need to be determined. Physical therapy to maintain range of motion should be started as soon as possible. Initial neuropsychological screening and consultation to discuss brain injury recovery and school reintegration should occur prior to discharge. Comprehensive assessment should occur once the patient has reached a more stable degree of functioning, optimally at 3–6 months poststroke, depending upon the nature and severity of stroke.

Follow-up

Follow-up MRI and MRA is often performed at 3–14 days following stroke to confirm expected evolution of stroke and ensure that further strokes have not

occurred. Follow-up neuroimaging will be done as clinically indicated to assess for new strokes and to follow for development or evolution of cerebral arteriopathy.

Patients should be advised to avoid dehydration and prolonged immobilization, as well as medications that can induce a thrombophilic state such as estrogens. Stroke symptom recognition and the need for urgent evaluation for possible recurrent stroke should be discussed. Patients with cerebrovasculopathy should avoid vasoconstricting medications, such as those used specifically for migraines [sumatriptan, other triptans, dihydroergotamine (DHE)] and illicit vasoconstricting drugs such as cocaine and methamphetamine. Selected patients with arterial dissection may need formal evaluation for possible connective tissue abnormalities. In addition to recurrent stroke, recurrent dissection is not uncommon following cervical artery dissection [58]. Rapid head and neck movements such as can occur with bumper cars, roller coasters, and contact sports are contraindicated.

Psychosocial

Most families are not previously aware that children can have strokes, and education and support is important. Families should have a clear understanding of their child's final diagnosis, for example, stroke, probable stroke, or transient ischemic attack. Resources that allow these families to feel less isolated, such as stroke clinics and local and international support groups, can be helpful.

Conclusions

Stroke in childhood is an important cause of long-term morbidity in childhood, with significant neurologic deficits present in at least two-thirds [5, 59], and emerging deficits over time. Approximately 10 % of children will die following a stroke, and up to 20 % will have recurrent stroke. Currently, most treatment recommendations are based on extrapolation of adult studies and expert consensus. Nevertheless, an organized approach to the acute care of the child with AIS will optimize short term outcome and long term recovery in these children.

Compliance with Ethics Guidelines

Conflict of Interest
Dr. Catherine Amlie-Lefond declares that she has no conflicts of interest.
Dr. Joan Cox Gill is a consultant for Baxter, Bayer, Octapharma, and CSL Behring.

Human and Animal Rights and Informed Consent
This article does not contain any studies with human or animal subjects performed by any of the authors.

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