STROKES IN CHILDREN and adolescents are relatively uncommon since significant atherosclerosis is rare and sustained hypertension unusual in this age group. When strokes do occur, they are often severe, are frequently associated with major motor deficits and a convulsive disorder, and may prove fatal. Unlike adults, however, persistent aphasia rarely occurs in children.

The diagnostic approach must take into account three factors: (1) the patient's age, (2) the presence of underlying medical conditions (e.g., sickle cell anemia, congenital heart disease), and (3) the clinical pattern of the stroke. This discussion will be centered around some of the more common clinical syndromes.1,2

**Strokes Not Associated With Underlying Systemic Disease**

A previously well child with the sudden onset of a focal neurological deficit requires an efficient diagnostic approach that will rapidly exclude underlying systemic diseases and will aid in the neurological differential diagnosis. Computed tomography will effectively demonstrate the existence of an intraventricular, intracerebral, or extra-cerebral hematoma. If no systemic medical problems can be found and if there is no evidence of greatly increased intracranial pressure, a lumbar puncture should be performed to differentiate ischemia from subarachnoid hemorrhage which may not always be detected on a CT scan. On this basis the child can be placed in the proper diagnostic category.

**Acute Hemiplegia of Childhood (Acute Infantile Hemiplegia)**

This term is used to designate the clinical situation of the sudden onset of hemiparesis unassociated with intracranial hemorrhage. The syndrome includes a number of specific pathophysiological entities. It may become manifest by the sudden onset of hemiparesis which may or may not be accompanied by a single seizure. In 60% of cases, the onset is more dramatic, with severe convulsions and coma. Examination shows the presence of weakness.

Angiography will be abnormal in 65 to 80% of cases, and a number of clinicopathological groups can be defined: (1) occlusive vascular disease at the base of the brain associated with telangiectasia of the basal ganglia (Moyamoya syndrome), (2) occlusive vascular disease at the base of the brain without telangiectasia, (3) narrowing of the origin of the internal carotid artery, (4) distal branch occlusion of intracranial arteries, and (5) corkscrew pattern in small terminal arteries.

Little pathological material has been thoroughly studied. In the Moyamoya syndrome there is narrowing due to intimal thickening and abnormalities of the elastica. Segmental areas of arteritis account for the changes in many patients with other angiographic patterns.

Although over-all mortality is low, residual hemiparesis, mental retardation, and a chronic convulsive disorder are common.4 Negative prognostic indicators include age under two years, a prolonged seizure at the onset, or the presence of multiple seizures.

Treatment is largely symptomatic. There are no good data to support the use of anticoagulants and little experience with thrombectomy. Seizures should be treated vigorously.

**Intracranial Hemorrhage**

The diagnosis of intracranial hemorrhage, which may be strongly suggested by the apoplectiform onset of a neurological deficit accompanied by headache, somnolence, and nuchal rigidity, must be confirmed by CT scan or lumbar puncture. The presence of red blood cells in the cerebrospinal fluid is diagnostic. Differentiation from a traumatic lumbar puncture can only be made by examination of the supernatant fluid for xanthochromia following centrifugation. The use of crenation of red blood cells as a differential point is valueless.

Arteriovenous malformations are the most common cause of subarachnoid hemorrhage in children.5 This may or may not be associated with a neurological deficit. A history of previous seizures may be present. The exact diagnosis depends on angiography since it is important to define not only the presence and location of a malformation and any associated hematoma, but also the size and distribution of the feeding and draining blood vessels. Microsurgical techniques utilizing the operating microscope have allowed a more aggressive approach to surgery, although deeply placed lesions still may be inaccessible.

Aneurysms are rare in infants but become more common at older ages.6 The first episode of hemorrhage from an aneurysm may not be associated with focal neurological signs, but subsequent episodes often produce major deficits. Less frequently, aneurysms make themselves known by repeated headaches or cranial nerve palsies. The mortality rate increases sharply with subsequent hemorrhages. Diagnosis is dependent on angiography, and the only widely accepted current treatment is surgical.

Factors predisposing to aneurysms include coarctation of the aorta and polycystic kidney disease. A few familial cases are known.
Strokes Associated With Underlying Systemic Diseases

There are a number of specific syndromes in children and adolescents that are age and etiology related.

Congenital Heart Disease

A child with congenital heart disease, especially a cyanotic type, is at risk for developing a stroke for a number of reasons. A right-to-left shunt allows emboli from peripheral veins to bypass the lungs and enter the arterial circulation of the brain. During surgery with cardiac bypass for congenital lesions, air emboli, thrombi, or foreign material may produce cerebral deficits. If postoperative neurological abnormalities are present, embolism should be considered as well as brain damage from hypoxia or hypotension.

Arterial thrombosis is uncommon, but children under one year of age with cyanotic congenital heart disease are predisposed to venous thromboses. These present with focal signs, increased intracranial pressure, seizures, and coma. The majority of these children have polycythemia, but there may be a microcytic, hypochromic anemia.

Purulent Venous Thrombosis

Unlike children with cyanotic congenital heart disease, this group of patients has pyogenic infection of the mastoids, paranasal sinuses, scalp, or face. In general, the clinical presentation is the same as with nonpyogenic venous thrombosis, but certain features predominate depending on the vascular structure involved. Lateral sinus thrombosis may be relatively benign, increased intracranial pressure with or without abducens paralysis being the most common finding. Sagittal sinus thrombosis presents more acutely with multifocal or generalized seizures, changing neurological signs, and increased intracranial pressure. Cavernous sinus thrombosis, as in the adult, is associated with proptosis, vascular engorgement of the bulbar conjunctivae, retinal hemorrhages, and extraocular muscle palsies.

Trauma

Head trauma is one of the most frequent causes of acquired focal neurological deficits in children. In addition to direct brain injury, another mechanism is damage to the carotid artery, due either to trauma to the neck or intraoral trauma to the posterior pharyngeal wall. There is a latent period of 2 to 24 hours and then the onset of a hemiparesis, often associated with increased intracranial pressure and somnolence. The injury causes an intimal tear, and during the latent period a dissecting aneurysm forms, followed by thrombosis of the vessel. There are permanent residua in the majority of patients.

Sickle Cell Anemia

Hemiparesis as a complication of sickle cell anemia generally occurs in older children and adolescents. Thrombosis in capillaries and venules in multiple areas of white matter produces patchy lesions. Arterial thrombi in major vessels are less common. Intracranial hemorrhage also may occur.

Homocystinuria

This rare autosomal recessive defect in methionine metabolism is associated with a cystathionine synthetase deficiency. The children have a Marfanoid habitus, usually with ectopia lentis. The pathophysiology is not clear. A urinary screening test (nitroprusside reaction) is available.

Rare Causes

The following is a list of other underlying systemic diseases which are infrequently associated with strokes in children:

2. Cardiac disorders: arrhythmias, bacterial endocarditis, atrial myxoma.

Diagnostic Approach

When faced with a child or adolescent with the sudden onset of a hemiparesis, the initial task is to attempt to define the presence of any underlying medical condition. Although treatment of the primary disorder will probably not improve the neurological deficit, it may prevent further progression or new complications. An example would be the prompt treatment of a patient with sickle cell anemia to prevent a severe crisis. Another situation requiring prompt specific treatment would be the presence of a septic venous thrombosis.

The next question to be answered is whether or not the patient has had a subarachnoid hemorrhage. Although this may be seen with venous thrombosis and to some extent with emboli, any significant hemorrhage should suggest the presence of an aneurysm or arteriovenous malformation. The presence of obtundation, severe headache, back pain, or nuchal rigidity all suggest bleeding.

Definitive diagnosis depends on CT scanning or the examination of cerebrospinal fluid. The presence of red blood cells and discoloration of the supernatant from a centrifuged specimen differentiates subarachnoid hemorrhage from a traumatic lumbar puncture. The fluid becomes pink within two hours due to the presence of oxyhemoglobin and truly xanthochromic within four hours.

Two cautions should be noted. The presence or absence of crenation of red blood cells in the CSF is of no significance. This phenomenon may take place very rapidly or barely occur at all. Also, if the specimen is centrifuged in a microhematocrit tube, discoloration of the supernatant, even to a marked degree, may not be visible because of the small volume of fluid used.

Routine laboratory studies have a low yield. A complete blood count may give evidence of a hematological disorder and should be supplemented by a sickle cell test for appropriate patients. Urinalysis is of use in providing a clue to the diagnosis of renal disease, which can be associated with hypertension and a stroke. If the patient has a Marfanoid
appearance or dislocated lenses, a nitroprusside test performed on the urine will rule out homocystinuria.

Skull X-rays also have a low yield of diagnostic information. Calcifications can be seen in vascular malformations, brain tumors, and occasional aneurysms. Evidence of unsuspected increased intracranial pressure may also be present.

The major decision is whether angiography should be performed. In the presence of subarachnoid hemorrhage, this is mandatory since surgically approachable lesions such as aneurysms or vascular malformations are most probably present. The presence of a major hematoma will also be indicated. Although CT scanning may show an infarction with a typical wedge shape or indicate the presence of a hematoma, the information obtained is incomplete. Only angiography can provide a knowledge of the detailed vascular anatomy of the lesion and its feeding and draining vessels. This knowledge is vital for the surgeon.

In those patients without subarachnoid hemorrhage and with their first episode of stroke, angiography is not obligatory but should be considered since definition of the vascular pathology may be useful prognostically. If a child has had recurrent hemipareses, arteriography is more urgent.

Treatment

Treatment does not differ in any significant way from that of adults with strokes. Support of the patient's cardiorespiratory function is always an overriding concern. Treatment of any underlying medical condition that may in itself be life threatening is next. In children this would include sickle cell crisis, cyanotic congenital heart disease with severe polycythemia, pyogenic infections of the scalp and face, and any bleeding diathesis.

The next major issue is the control of seizures. Status epilepticus can compromise respirations and, if prolonged, cause cerebral damage even with adequate air exchange. In addition, it can further increase intracranial pressure. The majority of clinicians use intravenous diazepam (0.25 to 0.5 mg/kg) as the drug of choice to stop seizures. This should be followed by a loading dose of phenobarbital (5 to 6 mg/kg body weight) by the intravenous or intramuscular route. If diazepam does not stop the seizures, phenobarbital is the next drug used and, if there is still therapeutic failure, intravenous phenytoin. It is occasionally necessary to use an intravenous paraldehyde drip or general anesthesia.

The development of increased intracranial pressure should be closely monitored and treatment started promptly if it becomes manifest. In general, dexamethasone (1 to 4 mg initially and then 0.25 to 0.5 mg/kg/day) intravenously will keep the situation under control. If there is progressive increase of pressure, intravenous mannitol (2 mg/kg of a 20% solution) should be instituted.

Surgery is generally indicated in the presence of a clearly defined arterial aneurysm. The situation is less clear with arteriovenous malformations. Those that are located at the frontal, temporal, or occipital poles can often be excised in toto with good results. The role of surgery with lesions in other locations is more difficult to define, although the use of the operating microscope has decreased the morbidity. If all of the feeding vessels are not ablated, however, recurrence of the malformation is likely. There is even less unanimity of opinion concerning the place of surgical endarterectomy if major vessels are thrombosed.

Medical therapy directed toward an intracranial lesion provides little assistance. Anticoagulants give little or no benefit with vascular occlusions and are obviously contra-indicated in the presence of subarachnoid hemorrhage. There are some indications that epsilon-amino-caproic acid may prevent rebleeding with intracranial aneurysms.

Prognosis

Because of the large number of syndromes with varying underlying pathology, specific prognostic statements are difficult to make. Certain general rules hold. Bad prognostic factors include young age at the time of onset of the hemiparesis, onset with coma, a prolonged seizure or multiple seizures, and failure of rapid resolution of the deficit. An angiographic picture of thrombosis at the bifurcation of the carotid artery in the neck or of basal artery thrombosis with telangiectasia of the basal ganglia (Moyamoya syndrome) is also bad.

The major residua are motor and cognitive deficits and a convulsive disorder. If the child is under four years of age at the time of the stroke, there is almost always functional return of language, although detailed testing may show some residual deficits. Between ages four and eight years there may be mild clinical language disability, and after this age permanent residua are common.

The risk of development of a convulsive disorder is dependent on two factors. The younger the child, the higher the risk. If no seizures have developed by age 11 years, very few patients will then have a convolution. The second factor is the presence or absence of spikes on the electroencephalogram. Their existence at any age puts the child at high risk for the development of epilepsy, but this is an even greater factor under age two years.

Summary

Strokes in children and adolescents, although rare, are serious when they occur. A practical clinical approach is to differentiate between those events that occur in the presence of systemic disease and those that are restricted conditions involving just the intracranial circulation. Division on the basis of the presence or absence of intracranial hemorrhage further narrows down the differential diagnosis and dictates the urgency with which angiography should be performed. Treatment depends on the underlying condition and on the development of seizures, increased intracranial pressure, or subarachnoid hemorrhage. Prognostic statements are difficult and must be highly individualized.

References

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