NOTE TO READER:
The Joint Committee for Stroke Facilities was created through a contract with Regional Medical Programs Service. The project upon which this publication is based was performed pursuant to Contract HSM-110-69-436 between the American Neurological Association and Health Services and Mental Health Administration, Department of Health, Education, and Welfare to help fulfill the requirements of Section 907 of Public Law 89-239, which established the Regional Medical Programs in 1965.

The Committee hopes to review and update its guidelines periodically as new methods of diagnosis and treatment are developed. Comments, criticisms, and corrections are invited. They should be sent to:

General Chairman
Suite 1010, 1776 K Street, N.W.
Washington, D.C. 20006

The following subjects will appear in serial publications in STROKE, although not necessarily in the order listed:

Epidemiology for Stroke Facilities Planning
Clinical Prevention of Stroke
Medical and Surgical Management of Stroke
Strokes in Children
Guidelines for the Nursing Care of Stroke Patients
Stroke Rehabilitation
The Laboratory Evaluation of Neurovascular Disease (Stroke)
Special Procedures and Equipment in the Diagnosis and Management of Stroke
Community Health Services for Stroke
Training, Education, Manpower, and Research for Stroke Care
Transient Cerebral Ischemia: Epidemiological and Clinical Aspects

Cross-references will be indicated from time to time to material developed in other sections. Pages will be designated whenever possible, but the sequence of publications will not permit this in many instances. However, the Table of Contents included with each Section should aid in directing the reader to the appropriate pages.
REPORT OF THE JOINT COMMITTEE FOR STROKE FACILITIES

IX. Strokes in Children (Part 2)

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**NEURORADIOLOGY IN THE DIAGNOSIS OF CHILDHOOD STROKE**

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Neuroradiology in the Diagnosis of Childhood Stroke

Introduction

The neuroradiological examination plays an important role in management of the child suffering from a stroke. Vascular lesions of the central nervous system often can be demonstrated by angiography, permitting their precise localization and accurate morphological display. During the last decade, the incidence of angiographic complications has decreased remarkably so that utilization of this procedure has increased and may be recommended for children. Furthermore, significant improvement in the radiographic imaging systems allows reliable visualization of the vessels as small as 100 micra in diameter, thus increasing the diagnostic value of angiography. Guidelines for safety standard maintenance, as well as requirements of a modern angiographic installation, are discussed in addition to angiographic features of the various lesions related to childhood stroke.

The radiological study of the child with stroke, like any other clinical investigation, should proceed by using the test with lowest risk first. The detection of lesions is facilitated by plain skull radiographs, a radioisotope brain scan, and, whenever possible, a thermogram and an ultrasound echoencephalogram; these studies usually should be obtained prior to the angiographic examination (see also: Subsection on Diagnosis and Medical Treatment of Strokes in Children. Stroke 4: 871-894 [Sept-Oct] 1973).

Plain Skull Radiographs

Plain radiographs of the skull must be obtained before any special radiographic procedure is performed. Skull fracture or increased intracranial pressure must be identified early, and other cranial changes, both acute and chronic, also can be delineated by plain skull radiographs.

CRANIAL CHANGES

In the acute stage after the onset of stroke, plain radiographs of the skull are usually normal. Occasionally, however, they may contain clues indicating the nature of the vascular lesion, as follows:

1. Prominent meningeal grooves on the calvarium may be observed in cerebral arteriovenous malformations, because in these conditions frequently the meningeal arteries provide an additional supply to the malformation. Large meningeal grooves may be seen also in basal vascular occlusive disease with telangiectasia (Moyamoya). The large meningeal grooves in the latter instance are due to vascular collateral supply to the brain from the external carotid artery circulation. However, as a rule, these enlarged grooves are recognized on plain...
skull films with difficulty during the first few years of life.

2. Enlargement of the carotid sulcus in the parasellar region is often indicative of a cerebral arteriovenous malformation and results from enlargement of the feeding artery.

3. Intracranial calcification may be seen in children with arteriovenous malformations and in Sturge-Weber-Dimitri syndrome. Only rarely is intracranial calcification seen in association with cerebral infarction, and then one suspects that hemorrhage may have occurred in association with the infarction.

Although calcification occurs in about 25% of all arteriovenous malformations, these changes are unusual in children and they are encountered rarely under ten years of age. Infrequently, the aneurysmal sac in a vein of Galen malformation may be calcified. Calcification in arteriovenous malformations may appear: (1) curvilinear with multiple calcified rings, (2) patchy and shapeless, or (3) nodular and shapeless.

Calcification in cerebral aneurysms is rare (incidence under 1%, and less in children) and is usually limited to those which are large and in the parasellar region. When it occurs, a calcified aneurysm appears as a thin, curvilinear density.

Months after stroke in the young child, plain radiographs may show cranial asymmetry. Following an infarction cerebral calcification is visualized rarely and then one assumes that hemorrhage has occurred initially.

Asymmetrical growth of the skull is a sequel to cerebral infarction and subsequent atrophy of the affected hemisphere. The calvarium thickens, especially the diploë, and the ipsilateral frontal and mastoid air sinuses enlarge, as do the orbits on the side of the cerebral atrophy. Elevation of the ipsilateral petrous bone and slanting of the crista galli toward the affected side also are seen. Often the groove of the superior sagittal sinus is shifted to the side of the atrophy. The younger the age at onset of the stroke, the more common is the resulting asymmetry of the skull (Dyke-Davidoff-Masson syndrome). This syndrome is seen almost always if hemiparesis occurred before two years of age, and it develops in about two-thirds of the children between the ages of 2 and 12 with stroke.

**Radionuclide Studies**

**SAFETY FACTORS**

The advent of short-lived radionuclide and development of sensitive detectors now allow safe utilization of the radionuclide for children. The amounts of radiation dose in rads absorbed by critical tissues following administration of technetium 99m (Tc 99m) for brain scanning are listed in table 1. The radiation doses are small, and the valuable information derived clearly justifies use of the test.

**STATIC RADIONUCLIDE IMAGING**

Detection of a radioactive isotope in the brain may provide useful and important information with little risk or discomfort to the patient. The focal uptake of radionuclide may indicate the presence of a cerebral infarction, hematoma, brain tumor, arteriovenous malformation, or subdural effusion.

The detection of radioactive isotope uptake by a cerebral infarction is dependent largely on its size. Lesions smaller than 2 cm in diameter usually are not detected. The relation of time of optimal uptake to the clinical onset of the neurological deficit is variable. No controlled studies have identified the ideal time for administering the test after onset of the stroke, and data are insufficient to relate the rate of subsidence of the uptake with improvement of the neurological deficit. It is generally accepted, however, that cerebral infarctions are detected initially between the second and third week after the ictus, although occasionally lesions have been revealed as early as the first week. Thereafter, the test is positive in the majority of patients with vascular occlusions, gradually subsiding, as a rule, over a period of weeks. This sequence of events aids differentiation of a neoplastic process from stroke.

The time period necessary for the brain to take up isotope after injection of the tracer is important in diagnosis. With technetium 99m, an immediate uptake strongly suggests an arteriovenous malformation or telangiectatic collaterals in the basal ganglia such as may be seen with some occlusive vascular lesions. Cerebral infarctions are detected usually three to four hours after the injection. The positive pickup of the isotope is not pathognomonic of cerebral infarction, however, and may represent a neoplastic process. Differentiation on the basis of the isotope scan alone is difficult. A positive uptake of radioactive material in the brain may have to be verified by angiography.

**RAPID SERIAL SCINTIGRAPHY**

In rapid serial scintigraphy, a nondiffusible radioactive material is injected intravenously while isotope in the brain is monitored by means of an isotope camera capable of rapid imaging. Technetium 99m and Iodine 131-tagged serum albumin

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are commonly used tracers. The information obtained by this technique indicates whether one cerebral hemisphere has a decreased circulation as compared with the other. The method, however, does not indicate extent and severity of the stenosis. The procedure is without risk and, although often not definitive, may provide valuable data referable to cerebral circulation.

**Cerebral Blood Flow Measurements**

A variety of methods has been developed to measure regional cerebral blood flow. The most widely accepted are those based on the use of a diffusible tracer. All require cannulation of either the internal carotid artery or the internal jugular vein, and, therefore, carry a certain risk. Their routine application in patient management has been limited largely to patients with trauma. These methods, however, provide information about and understanding of the underlying pathophysiological processes in the stroke patient, and also are useful in evaluating the effectiveness of various therapeutic modalities.

The most popular method of regional cerebral blood flow measurement involves injecting radioactive xenon-133 into the internal carotid artery, and counting the isotope on the surface of the head. The appearance time and washout rate of the radioactive xenon in a given region of the brain are functions of the blood flow rate in that region. Sixteen or 32 regions of a cerebral hemisphere are counted simultaneously after a single injection of xenon-133. Most recently, gamma cameras capable of monitoring 294 regions have been developed.

The normal values of cerebral blood flow in children are higher than those in the adult. Before five years of age, the cerebral blood flow is estimated to be 100 ml/min/100 gm brain tissue and the oxygen consumption to be 5 ml/min/100 gm brain tissue. The flow rate gradually decreases with increasing chronological age until it reaches a stable level of 50 to 55 ml/min/100 gm brain tissue between the ages of 15 and 20 years. In the child, inhalation of 7% CO₂ in air can produce up to a 100% increase in the cerebral blood flow. This responsiveness decreases with age, and after 60 years there may be no detectable response to CO₂ inhalation.

With cerebral infarction, reduced blood flow to the entire cerebral hemisphere frequently is seen on the side of the lesion and on the opposite side as well. A 32% reduction in flow to the affected hemisphere was measured by Fieschi and others. The focal changes produced by a cerebral infarction are: (1) regional hyperemia, and (2) regional ischemia.

Regional hyperemia associated with cerebral infarction was first described by Lassen who labeled the phenomenon “luxury perfusion,” and attributed the condition to local vasodilation and paralysis of the cerebral vascular bed. If focal hyperemia occurs, it is seen usually within the first few days after the ictus but may be detected as long as two weeks later.

Focal ischemia is likely to occur later and may persist for a period of two months; thereafter, the cerebral blood flow gradually returns to normal levels, although occasionally the decrease lasts beyond six months. Most of the data on cerebral infarctions were obtained from observations on adults. No adequate studies have been reported on the duration of each of the above-described blood flow changes in cerebral infarction in children. The collateral circulation is much more effective in the child than in the adult; therefore, it is reasonable to assume that the regional hemodynamic changes will be different in severity, extent, and duration from those observed in the adult.

**Thermography**

Thermography makes use of an infrared detector to measure the heat emanating from the face. The regions of the inner canthus and of the medial supraorbital area are supplied by the terminal branches of the ophthalmic artery, which, in turn, arises from the internal carotid artery. Stenosis of the internal carotid artery proximal to the origin of the ophthalmic artery results in decreased perfusion over the medial canthus and medial supraorbital region, causing a drop in the temperature of the skin over these areas.

Thermography may be used for both diagnosis and follow-up evaluation. In the pediatric age group it is particularly helpful in identifying occlusions of the internal carotid artery in the neck. Occlusive lesions distal to the origin of the ophthalmic artery will not be detected by this method.

**Ultrasound**

Ultrasonic echoencephalography is useful in determining the position of the third ventricle. The method can detect reliably a shift of the midline structures as small as two millimeters. In acute stroke, a cerebral infarction may shift the third ventricle to the opposite side due to the mass effect produced by local cerebral edema. The third ventricle characteristically is shifted 3 to 5 mm. with maximal displacement occurring within 48 hours after the stroke. As cerebral edema subsides, follow-up echoencephalographic tests show the slow return of midline structures to their normal positions within a period of two to three weeks.

Ultrasonic echoventriculography provides a measurement of ventricular size. This test is particularly reliable in children because of the ease with which the ultrasound waves penetrate the thin calvarium. In the acute stroke, echoventriculography usually shows a lateral ventricle of normal size.
Demonstration of an enlarged ventricle in the acute phase of the stroke should suggest either a subarachnoid hemorrhage or an obstructive process due to a tumor. Ultrasonic echoventriculography is useful also in follow-up of patients after the vascular insult. The development of ventricular dilation resulting from cerebral atrophy and the presence of porencephaly can be detected readily by this technique.

**Angiography**

**Indications**

Contrary to some opinions, angiography in the child with a stroke is a rewarding diagnostic test. Thirty of 37 children with acute hemiplegia examined angiographically showed evidence of occlusive vascular disease. In most large centers, the bulk of angiographic experience with these children antedates newer radiographic imaging techniques. Continued improvement in imaging systems will increase further the usefulness of cerebral angiography in the child with acute stroke. In the series of 37 patients mentioned above, no neurological complications attributable to angiography were encountered. Thus it appears that a child with occlusive arterial disease may tolerate angiography better than does the adult with an apparently similar vascular problem. Cerebral angiography is indicated for children with vascular disease because: (1) it is a rewarding diagnostic test, (2) it is tolerated relatively well, and (3) it has significant value for treatment and prognosis when the disease entity is recognized.

Angiography should be done as soon as possible after clinical onset of the neurological deficit, preferably using the transfemoral catheter technique so that more than one vessel can be opacified. Because multiple lesions are encountered frequently, injection of a single carotid artery related to the clinical symptoms may provide incomplete information regarding the number and sites of the occlusions, number of aneurysms, or the variety of vessels feeding an arteriovenous malformation. We recommend, therefore, that selective bilateral carotid and vertebral arteriograms be obtained. Safety of the procedure is dependent on strict adherence to the guidelines described in the following discussion.

**Premedication**

Heavy sedation is usually preferred to general anesthesia during cerebral angiography. By excluding general anesthesia, the number of technical failures is decreased and postangiographic recovery time is shortened. Under supervision of a qualified anesthesiologist and with proper instrumentation, general anesthesia may be acceptable.

**Administration of Fluids**

A slow intravenous infusion should be started before beginning the angiographic study, using a solution of 0.5 normal sodium chloride in dextrose. The same solution should be used during the procedure to flush the needle and/or catheter. In infants and children, the amount of liquids injected should be carefully monitored. The rate at which total fluids are administered should not exceed 20 ml/kg/hour and preferably should be maintained at 10 ml/kg/hour.

**Contrast Media**

For carotid and vertebral angiography, contrast media containing 28% to 32% iodine is recommended. The methylglucamine salts of the opaque substances should be used instead of their sodium salts. In infants, 4 to 6 ml of contrast media are injected for carotid angiography, while for vertebral artery study 3 to 6 ml are sufficient to obtain adequate visualization. Above the age of five years, 6 to 8 ml are used for carotid, and 4 to 6 ml for vertebral artery injections. If multiple angiographic series are necessary, we recommend that 10 to 15 minutes elapse before a second injection of opaque medium is administered in the same artery.

**Complications**

Complications of cerebral angiography usually are due either to traumatization of the vessel or to inadvertent embolization. Rarely is a significant reaction to the opaque medium encountered. These tend to occur in instances of diffuse occlusive arterial disease and with vascular spasm such as may be seen in subarachnoid hemorrhage, in which the prolonged circulation time keeps the radiopaque medium in contact with cerebral tissue for an extended period. One serious reaction to contrast media is circulatory collapse and hypotension. In every angiographic room provision for handling complications and emergencies should include aramine, ephedrine, intravenous corticosteroid, oxygen cylinders, oxygen masks, airways of different sizes, and laryngoscopes.

Ansell, in a review covering the years 1966 to 1969 in England, reported that severe reactions to the contrast media administered intravenously occurred once in every 14,000 cases. Death attributable to intravenous contrast media occurred once in every 40,000 cases. Of the eight fatalities reported, two were neonates with death attributable to overdose of the injected opaque material.

**Technique**

In children, cerebral angiography by catheter through the femoral artery offers distinct advantages over direct carotid puncture. It permits visualization of multiple cerebral vessels from a single arterial entry site and avoids morbidity resulting from hematomas in the neck. Significant respiratory embarrassment may result from even small collections of blood near the trachea in infants and children.
JOINT COMMITTEE FOR STROKE

In childhood stroke, study of the entire cerebral circulation is desirable because lesions are often multiple and involve different vascular beds. Visualization of the vertebrobasilar circulation in the child is best obtained by catheterization of the vertebral artery. A direct vertebral puncture should be avoided. In order to conduct this selective catheterization, adequate fluoroscopic facilities are required.

ANGIOGRAPHIC EQUIPMENT
Proper, safe angiographic examination of the child with stroke requires an angiographic facility with the equipment here described:

1. A fluoroscope with image intensifier and television display is necessary; vertical and horizontal beam fluoroscopy is highly desirable; a C-arm arrangement is satisfactory.

2. A serial film changer capable of at least two frames a second is necessary. Preferably, a biplane facility permitting an anteroposterior and a lateral projection of the cerebral vessels from a single injection should be available. Biplane angiographic equipment has the advantage of limiting the amount of contrast media administered, as well as the volume of liquids injected.

3. X-ray tubes with a small focal spot measuring 0.3 mm or less are mandatory. The small focal spot permits magnification angiography, which is essential to the study of lesions in the small intracranial vessels; a three-phase generator is needed to obtain a serial magnification angiogram with these tubes; the proper three-phase electrical supply should be provided in any new installation.

4. All radiographic equipment must be electrically grounded.

5. Physiological monitoring devices are recommended highly. Blood pressure monitoring through catheter or needle is helpful in indicating when a clot is developing at the tip of the needle, and is also useful in following the patient's condition, especially when an unusual response to the premedication or to the anesthesia has occurred. The angiographic suite should have at its disposal electrocardiographic equipment and a cardiac defibrillator.

6. Safety devices, such as oxygen cylinders, anesthesia masks, airways, and suction apparatus, must be present. A supply of medications to combat cardiovascular shock or allergic reactions should be available as well.

Arterial Occlusions

THROMBOSIS
Occlusions of the cerebral arteries may be either thrombotic or embolic. Thrombosis results either from a process starting primarily in the vascular wall or from secondary vascular involvement by lesions such as those of meningitis, brain abscess, and cerebral or meningeal neoplasms. Only primary occlusive arterial diseases will be discussed here. A practical and convenient angiographic classification of these lesions has been made. Histological diagnoses are difficult to obtain and the angiographic classification identifies those patients who possibly would benefit from medical and/or surgical therapy, as well as supplies valuable prognostic information. It has been shown that in children, some recognized angiographic lesions, such as basal occlusive disease with telangiectasia, and multiple occlusions of the perforating vessels, have a particularly bad prognosis.

Primary arterial thrombotic occlusions can be classified angiographically in the following groups:

1. Extracranial occlusive lesions
2. Basal occlusive disease without telangiectasia
   a. Congenital or perinatal
   b. Acquired
3. Basal occlusive disease with telangiectasia
4. Peripheral leptomeningeal artery occlusions
5. Perforating arterial occlusions
6. Arterial occlusions associated with neurocutaneous syndromes.

EXTRACRANIAL OCCLUSIVE DISEASE
Trauma to the neck is the most common cause of occlusion of the cervical carotid artery in a child. Trauma can be inflicted either by an external impact whereby the internal carotid is compressed against the transverse process of C2, or by penetration of the nasopharynx with a pointed implement. Traumatic occlusions are characteristically 1 to 2 cm distal to the carotid bifurcation.

Retropharyngeal abscesses and cervical lymphadenitis may cause cervical carotid arteritis with stenosis or even occlusion.

Stenosis
Stenosis of the internal carotid artery in the neck may occur without either history of trauma or demonstrable inflammatory process. The lesion appears radiographically as a tapered narrowing of the internal carotid artery starting about 1 cm distal to the carotid bifurcation. Flexion of the neck may reduce the periorbital perfusion as detected by thermography and further prolong the angiographic circulation time. This type of stenotic lesion can be differentiated from the normally tortuous internal carotid artery in the neck often seen in children. In tortuous
internal carotid artery, a normal variant has no change in the vessel diameter and there is no significant hemodynamic change with neck flexion.

**Retrograde Thrombosis**

Retrograde thrombosis of the internal carotid artery in the neck may occur as a result of a lesion affecting the supraclinoidal portion of the internal carotid artery.21-23 This diagnosis is difficult to make, based on the angiogram alone. The internal carotid artery fails to fill when the contrast medium is injected into the common carotid artery, and whether the thrombosis started at the proximal or the distal end of the vessel is difficult to ascertain. The definitive diagnosis may be made only at the time of surgery.

**Fibromuscular Dysplasia**

Fibromuscular dysplasia can affect the extracranial internal carotid artery in the child. The lesion characteristically starts 1 to 2 cm distal to the carotid bifurcation and shows more irregularity of one margin than the other.24 Such lesions often are associated with vascular narrowings in the renal circulation as well.25

**INTRACRANIAL OCCLUSIVE DISEASE**

**Basal Occlusion Without Telangiectatic Collaterals**

In this and the following group, the primary lesion is in the major vessels at the base of the brain, that is, in the supraclinoidal part of the internal carotid, the origin of the anterior and middle cerebrials, and the basilar artery. In the child, the vessels at the base of the brain are the most frequently affected by the occlusive process. Because of the peculiar distribution of primary vascular lesions, which affect so frequently the vessels at the base of the brain, the term “basal occlusion” has been adopted.

**Congenital or Perinatal Basal Occlusions.** Large porencephalic cysts seen in the neonatal period are often associated with occlusions of all or part of the middle cerebral artery. The vascular occlusive process usually involves the origin of the middle cerebral artery and the terminal end of the supraclinoid internal carotid. It is difficult to determine whether the lesion involves primarily the cerebral parenchyma with secondary attenuation of the vessel or whether the primary lesion is actually a vascular attenuation, with porencephaly developing on the basis of cerebral infarction.

**Acquired Basal Occlusions.** Acquired basal occlusions without telangiectasia affect the supraclinoidal portion of the internal carotid artery and the origin of the middle and anterior cerebral arteries. The stenosis is focal and the remainder of the cerebral vessels are normal angiographically.7, 26-29 The occlusion is usually unilateral. Some of the leptomeningeal branches at their origin in the Sylvian fissure, and the striate branches of the middle cerebral artery are also involved by the occlusive process. As a rule, the medial group of the striate vessels is affected maximally. Pneumoencephalography usually will demonstrate selective enlargement of the frontal horns in the region of the basal ganglia and internal capsule, corresponding to the area of distribution of the occluded striate arteries. The relatively selective occlusion of the medial striate arteries correlates with the distribution of motor weakness, which usually is more pronounced in the arm than in the leg.

Occlusions of the intracranial internal carotid and middle cerebral arteries tend to recanalize; follow-up angiography usually shows significant resolution of the stenotic lesions. In many cases, the only change remaining may be a paucity of striate vessels or a residual minimal stenosis of the internal carotid artery in its supraclinoidal segment. Occasionally, the origin of the anterior choroidal or the posterior communicating arteries show a narrow circumferential stenosis due to thickening of the wall of the carotid artery.

The etiology of the primary lesions is considered to be a vasculitis resulting from lymphatic spread of infection in the nasopharynx to the arterial wall. This assumption is supported by frequent association of the lesions with upper respiratory infection, and histological evidence obtained in a few surgical cases.22-30

Infrequently, other diseases produce stenosis of the arteries at the base of the brain. Granulomatous meningitis, especially of tuberculous origin, may cause bilateral narrowing of the supraclinoidal portion of the internal carotid artery as it pierces the dura, and dissecting aneurysm of the intracranial internal carotid has been reported to give rise to a similar change.31, 32

Tumor encasement may on rare occasions cause vascular narrowing at the base of the brain. The mass effect and the absence of cerebral atrophy or ventricular dilatation should serve as a clue to the diagnosis. In children, radiation therapy for paraspinal and intraorbital tumors has also been implicated in the production of vascular stenosis.33, 34

As a late sequel of occlusive arterial disease, cerebral atrophy and ultimately hemispheric asymmetry may result. The severity of the hemispheric asymmetry, which may be observed on plain radiographs of the skull, is dependent on the age of the patient at the time of the stroke. Of 75 children with stroke, hemispheric atrophy appeared within 6 to 12 months in all who were two years old or younger at the time of onset of the neurological deficit. Hemispheric atrophy developed in only 60% of the older children, and took a longer time to appear. The earliest observed change among the
older children was one year after the ictus. The growth of the cranium is stimulated by the growth of the brain. Atrophy of the cerebral hemisphere results in a smaller hemicranial cavity, a thicker and smoother calvarium, and elevation of the floor of the anterior and middle cranial fossae and the petrous bone as well. On the side of the hemicranial atrophy there is, as a rule, hyperpneumatization of the bone as well. On the side of the hemicranial atrophy.

One often observes direct anastomosis between the dural meningeal arteries and the common carotid, anterior cerebral arteries are angiographically seen to bifurcate into its anterior and middle cerebral branches. Frequently the tip of the basilar artery also is involved. In association with the occlusive lesions (usually bilateral), marked telangiectasia is found in the region of the basal ganglia and often around the corpus callosum.

The incidence of basal occlusion with telangiectasia has some characteristic features unlike those of the previously described group. The condition is more prevalent in girls and apparently is encountered more commonly in persons of Japanese descent. It is, however, not limited to orientals and recently a number of both white and black patients have been described with this disease.

Radiographically, the internal carotid artery in its extracranial course, and in its intrapetrous as well as intracavernous course appears reduced in diameter due to the decreased blood flow. This feature helps to differentiate the lesion from an arteriovenous malformation in which the carotid artery is hypertrophic, adapting to the excessive blood flow rate. The site of stenosis in the suprachinoidal segment of the internal carotid artery can often be demonstrated on the early films of an angiographic series. In addition to stenosis, there is a marked increase in vascularity of the basal ganglia, with enlargement of many striate vessels and of the anterior choroidal artery. This hypervascularity most likely represents a separate route for the collateral circulation to the brain. At the beginning of the disease, the telangiectasia is usually small, becoming more prominent with evolution of the lesion. When stenosis of the suprachinoidal portion of the internal carotid artery and the middle and anterior cerebral arteries becomes severe, the telangiectasia then becomes smaller.

Distal to the arterial stenosis at the base of the brain, the branches of the middle cerebral and anterior cerebral arteries are angiographically normal. In addition to basal telangiectasia, another channel of collateral circulation is commonly found in this disease. One often observes direct anastomosis between the dural meningeal arteries and the leptomeningeal vessels on the surface of the brain across the subarachnoid space. In this route the middle meningeal artery branches are seen to anastomose with the branches of the anterior and middle cerebral arteries. The enlargement of the middle meningeal grooves on the inner table of the skull is due to the important collateral function this vessel plays in the condition. Except for the prominent meningeal grooves, as a rule the plain film examination of the skull shows no asymmetry because of the bilaterality of the lesions.

Peripheral Leptomeningeal Arterial Occlusions

Peripheral leptomeningeal arterial occlusions can occur secondary to cerebral abscesses, trauma, or tumor encasement. Neoplastic encasement is most often seen with slowly growing astrocytomas. Among the diseases causing primary changes in the vessel wall and leading to occlusion of the peripheral leptomeningeal arteries are diabetes mellitus, sickle cell disease, intravenous drug abuse, and the neurocutaneous syndromes. The last entity will be discussed further.

Occlusions of Perforating Arteries

Occlusions of the small perforating arteries of the brain have been demonstrated angiographically in periarteritis nodosa and homocystinuria. Angiographically, the lesion is usually demonstrated in the striate arteries on the anteroposterior projection. In periarteritis nodosa, the clinical signs and the radiographically demonstrable lesions are frequently bilateral. Other organ systems, particularly the kidneys, may be involved. A renal angiogram should be performed to demonstrate the generalized nature of the disease. The advent of magnification angiography will undoubtedly facilitate visualization of lesions in the lenticulostriate and other perforating arteries. Patients with these lesions, as a group, have a poor prognosis.

Arterial Occlusions in Neurocutaneous Syndromes

The most commonly known neurocutaneous syndromes are neurofibromatosis, tuberous sclerosis, Sturge-Weber-Dimitri syndrome, and Von Hippel-Lindau syndrome. Other rare conditions have been described recently. The primary condition, e.g., neurofibromatosis, should alert the clinician to the possibility of vascular complications in the brain. Angiographically, cerebral arterial occlusions in the neurocutaneous syndromes are well documented. The peripheral leptomeningeal vessels are usually involved, showing occlusive lesions and dysplastic morphology.

Cerebral Embolism

Emboli to the cerebral circulation in children are usually associated with cardiac and pulmonary disease. Congenital right-to-left cardiac shunts which
permit a bypass of the pulmonary vessels allow direct access of venous emboli to the arterial circulation. A variety of cardiac conditions provides a source of emboli to the cerebral circulation, including rheumatic or bacterial endocarditis, enlargement of the cardiac chambers, and atrial myxoma. Pulmonary infection also may be the source of either sterile or septic emboli.

The most common sites for lodgment of a cerebral embolus are the internal carotid artery in its supraclinoidal segment and the middle cerebral arteries. The anterior cerebral artery is seldom the site of an embolus. Angiographically, the occluded artery usually shows a normal caliber up to the level of the obstruction where the head of the contrast column outlines a cup-shaped defect. The hollow of the cup represents the intravascular thrombus. Septic emboli may result in brain abscesses or may produce mycotic aneurysms. Multiple small aneurysms of the leptomeningeal vessels may be caused by emboli from an atrial myxoma.15

**Arteriovenous Malformations**

In the child, arteriovenous malformations are more common sources of subarachnoid hemorrhage than are aneurysms. Radioisotope scans and plain skull radiographs may be helpful in providing clues to their presence. Nevertheless, in subarachnoid hemorrhage, ordinarily, radiographic examinations should not be limited to plain films, and in almost all cases angiography is indicated. Sometimes a careful survey (including angiography) for possible causes of focal or generalized seizures, or focal neurological deficit, will reveal unexpectedly an arteriovenous malformation which has not bled.

**Percutaneous Embolization of Arteriovenous Malformations**

There have been recent attempts to obliterate surgically inaccessible arteriovenous malformations by embolization with silastic (silicone rubber) spheres. The success of the procedure depends not only on the natural disposition of emboli to follow the largest stream of blood to the malformation but also on the geometry of branching of the several vessels feeding the malformation. To date, the lesions most amenable to successful embolization are those supplied by the leptomeningeal branches of the middle cerebral artery, where the procedure is performed via the carotid. Encouraging results were achieved in patients with arteriovenous malformations in the diencephalon and posterior thalamus where they receive their arterial supply from the thalamoperforating and posterior choroidal arteries. The technique of therapeutic embolization is new; continuous radiographic control is necessary to detect the point at which the emboli start lodging in the normal vessels.

**Aneurysms of the Vein of Galen**

Aneurysm of the vein of Galen is actually the dilated outflow of an arteriovenous shunt usually in the territory of the posterior cerebral artery. Frequently this arteriovenous malformation receives feeders from both the middle and anterior cerebral arteries. The primary lesion is thus a cerebrovascular malformation which can be demonstrated clearly by studying angiographically both carotid circulations and, most importantly, the vertebral circulation.

**Cerebral Arterial Aneurysms**

In general, intracranial arterial aneurysms appear in children less frequently than in adults. Posterior communicating artery aneurysms are particularly rare in children. The relative distribution, however, between the supratentorial and infratentorial compartments is similar to that in the adult; 15% of the lesions are infratentorial.

The examination of a child suspected to have cerebral arterial aneurysm should be done, as indicated previously, by selective angiography of each carotid artery and at least one vertebral artery. Rarely, aneurysms are not demonstrated on initial study; the failure is due either to vascular spasm or to a temporary thrombus. Repetition of angiography is highly desirable if the source of a clinically suspected subarachnoid hemorrhage has not been identified.

Angiography may have to be halted in the presence of cerebrovascular spasm, and the examination completed at a future date after it subsides. Spasm slows the circulation and prolongs contact of contrast media with the cerebral tissues, thus increasing the possibility of an adverse reaction to angiography.

**Intracranial Venous Thrombosis**

Thrombosis can affect the cerebral venous system at any point between the cerebral veins and the jugular vein in the neck. The veins over the cerebral convexity are much more prone to thrombosis than is the deep venous system. Angiographically, the involved vein is not visualized and prominent collateral venous channels may be detected over the unaffected part of the cerebral convexity and the deep draining veins. The medullary and subependymal veins draining into the internal cerebral vein, particularly, may become quite prominent and tortuous. The cortical veins carry the largest fraction of the returning blood when the deep veins are occluded.

The dural sinuses, and particularly the lateral and sigmoid sinuses, may be occluded by a thrombotic process. The obstruction is most commonly associated with inflammation of the middle ear extending to the sigmoid or lateral sinus.
Occasionally metastases to the calvarium, particularly from a neuroblastoma, may invade the sinuses and cause thrombosis.

Since the advent of modern contrast media and selective injections of the internal carotid and vertebral arteries with a sufficient amount of radiopaque material, adequate visualization of the entire venous system is possible on the late phase of an arteriogram. Current serial arteriography is quite sufficient for demonstration of these areas, making sinography unnecessary to visualize the superior sagittal or lateral sinuses.

**Vascular Lesions of the Spinal Cord**

**Technical Considerations**

Study of the spinal cord by selective segmental arteriography is possible in children above the age of eight years. The injection of 4 to 6 ml of 60% meglumine iothalamate into each segmental vessel can demonstrate the vascular supply. The details of the cord vascular system are enhanced by the use of direct magnification angiography and subtraction. A single end hole curved French catheter (#7 or #6) is used, depending on the size of the child. In general, before eight years of age spinal angiography should be limited to a midstream injection in the aorta to avoid a spinal cord vascular complication. Embolization or trauma to the anterior spinal artery system is potentially extremely hazardous. The need for selective study in young children is usually not as significant as in those who are older. The anterior spinal circulation in the young child is prominent and can be seen readily with midstream injections in the thoracic aorta. When selective angiography is performed in the older child, emboli can be avoided by adding heparin liberally to the solutions used for catheter flushing. Prolonged obliteration of the segmental vessels must be avoided, and the catheter should be withdrawn from the midstream of the aorta immediately after the injection is completed.

**Vascular Anatomy of the Cord**

The arterial supply to the spinal cord is divided into two main territories served by the anterior and the posterior spinal arteries, respectively. The ventral two-thirds of the cord is supplied by the anterior spinal artery and its feeding branches. The anterior spinal radicular branches are limited in number, especially in the thoracic region. In approximately 25% of children there is only one anterior radicular artery between T4 and T12. In another 30% there are two anterior radicular arteries between T4 and L2, and in 30% of the patients there are three radicular arteries in this section of the spinal cord. A small number of children have four feeding vessels. The anterior spinal arterial circulation is considered marginal in its ability to provide a collateral supply to the spinal cord. The posterior spinal circulation, on the other hand, receives multiple feeding branches which communicate freely and form a network on the posterior aspect of the cord.

In the adolescent child with scoliosis and a curvature larger than 65°, blood flow in the anterior spinal artery may be compromised at the summit of the curvature. Selective spinal angiography performed on patients with severe scoliosis both above and below the summit of the curve fails to show opacification of the artery beyond the tip of the curvature. After corrective surgery, the anterior spinal artery is more readily filled with opaque medium and can be visualized beyond the summit of the curve.

**Arteriovenous Malformations of the Cord**

The most useful application of spinal angiography is in the demonstration of arteriovenous malformations of the spinal cord. When a lesion such as this is suspected, the selective injection of all segmental level vessels should be performed, as well as injection of the subclavian arteries on each side. The subclavian arteries supply the cervical spinal artery via the vertebral and the ascending cervical arteries. It is important to demonstrate the exact source of supply to the arteriovenous malformation if a rational plan for its management is to be formulated. (See also: Subsections on Neurosurgical Management of Strokes in Children and Diagnosis and Medical Treatment of Strokes in Children.)

**Recommendations of the Study Group**

1. The delivery of proper neuroradiological care to the pediatric patient requires professional personnel specifically trained in pediatric neuroradiology. Neuroradiology of the child differs sufficiently from that of the adult to warrant this subspecialization. The conduct of special procedures in the child, including premedication, the administration of fluids during the procedure, the catheterization approach and its complications, are different from those used for the older patient. As can be seen throughout the several sections of Guidelines for Stroke Care, the pathological entities affecting the child differ from the lesions seen in the adult as to etiology, radiographic appearance, and prognosis. A neuroradiologist familiar with the biological aspect of diseases in the child is essential to the proper diagnosis and management of childhood stroke.

2. Stroke centers should have proper radiographic facilities to permit fluoroscopy, catheterization, and the generation of images of good quality. The facility should have the usual complement of safety devices.

3. Research should be encouraged on the development of new contrast media and catheter materials to render angiograms safer by permitting
the use of smaller catheters than at present, and to improve diagnostic quality by the use of safer, denser contrast agents.

4. The study group recommends that a special investigative protocol be instituted that may be followed by a large number of centers for the study of children with strokes or mental retardation with the purpose of detecting vascular occlusions in the small vessels. With current techniques, channels as small as 100 μ in diameter can be visualized. The correlation of these findings with the clinical course and prognosis is believed to be of basic importance for understanding the evolution and progression or regression of the stroke process. Such an investigative effort should include follow-up angiography as well as high-quality imaging.

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REPORT OF THE JOINT COMMITTEE
FOR STROKE FACILITIES
IX. Strokes in Children (Part 2) (continued)

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**NEUROSURGICAL MANAGEMENT OF STROKES IN CHILDREN**

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Neurosurgical Management of Strokes in Children

Introduction

Until recently neurosurgical interest in childhood stroke has been confined to a limited number of extracranial vascular disorders. Newer techniques, however, have extended our spectrum to include intracranial vascular disorders previously considered to be well beyond the reach of neurosurgical therapeutic measures. Advances in the neurosurgery of vascular disorders have opened new vistas in the treatment of occlusive arterial disease, a common cause of stroke in adults. Major efforts have been directed toward the extracranial arteries where atheromatous or thrombotic disease remains localized predominantly to the region of the carotid bifurcation. The ease with which this area may be exposed surgically has encouraged the use of endarterectomy and vascular bypass procedures to reestablish continuity within the carotid and other cervical vessels supplying the brain. The results have been gratifying in terms of preventing progression or recurrence of strokes.

In children, trauma and localized inflammation are the most common etiologies of extracranial occlusive arterial disease, while atheromatous involvement is encountered only rarely. In spite of the different etiologies, the surgical principles that apply to occlusive cervical arterial disease in adults hold true also for children. The primary aim is to reestablish flow within the affected extracranial vessel. When surgical intervention is indicated in children, usually the necessity is urgent, since at these ages the onset of many vascular disorders is abrupt, and the development of devastating neurological deficit rapid.

Extracranial Vascular Disorders

TRAUMATIC OCCLUSIVE DISORDERS

Occlusion of the internal carotid artery in the neck should be considered as a possibility in any child who develops evidence of ipsilateral cerebral ischemia within 24 hours following a minor or major blunt trauma to the oropharynx or, less commonly, to the anterolateral portion of the neck. Although a delay between the appearance of neurological disorder and the injury is characteristic, the cause and effect relationship between the trauma and the neurological deficit is evident.1 Few successful operations for reestablishing patency of the affected artery have been reported.2-9 When the carotid artery has been exposed, usually after some delay from onset of the neurological syndrome, an organized thrombus has been observed extending from the site of injury to the intracranial portion of the artery, and this usually has precluded establishment of normal blood flow.7 The case described by Jernigan and Gardner8 is noteworthy, in that apparently insignificant trauma, with slight laceration of the oropharynx, produced a tear in the carotid artery which was discovered only at operation. Prompt suturing of the involved segment resulted in successful restoration of flow in the artery. Cases such as this with a satisfactory outcome stress the importance of early diagnosis and expeditious surgical exploration. On the basis of a limited number of operative observations, laceration of the arterial wall, especially with injury to the intima and subintimal hemorrhage, appears to be the cause of carotid artery occlusion. The delay in development of neurological findings may be explained by the slow expansion of the arterial wall secondary to intramural hemorrhage.5 In some children,1,8 a dissecting aneurysm has been the cause of carotid occlusion. Whether the aneurysm predated or was induced by the trauma in these cases is unclear.

NONTRAUMATIC OCCLUSIVE DISORDERS

In the few cases explored surgically, enlarged lymph nodes and inflammatory reactions were noted in the region of the occluded cervical carotid artery.9-11 Atheromatous plaques within the arterial wall are observed rarely.12 Most specimens removed during surgery show organizing thrombi without evidence of inflammation.9,10,13,14 In none of the 20 cases of carotid artery occlusion in children reviewed by Davie and Coxe9 was there evidence of cardiac abnormality, congenital defect, rheumatic heart disease, bacterial endocarditis, or septicemia. However, emboli emanating from the endocardium frequently may lodge in the cervical carotid bifurcation as well as in the intracranial carotid bifurcation and middle cerebral artery ramifications.

Unfortunately, in all but a few cases,10 these systemic disorders have resulted in occlusion of the involved vessels; the stenosis frequently seen in adults is uncommon in children. Although principles recommended in the treatment of extracranial vascular disease in adults15 dictate against operation in cases of occlusion, such guidelines may be modified for application to children, in whom occluded vessels are the rule. The ages of the patients and the nature of the lesions in this particular group have encouraged surgeons to explore the damaged areas in an attempt to reestablish patency of the vessel lumen. The lack of preexisting collateral circulation in the cases marked by acute onset renders the situation even more urgent.

A number of alternatives are open to the surgeon exploring children with spontaneous carotid artery occlusion. The most expeditious procedure is endarterectomy or thromboembolectomy with removal of the offending lesion. In many instances, a
thrombus extends over a considerable distance involving most of the internal carotid artery and may necessitate removal by an embolectomy catheter. Rarely, a thrombus such as this, extending as far as the region of the carotid siphon, may be removed by this procedure. Failing reestablishment of flow through the involved artery, recently developed microvascular neurosurgical techniques utilizing bypass grafts offer some hope for establishing blood flow. Microvascular surgery will be discussed in greater detail under intracranial occlusive disease.

At the present time, successful surgery depends largely on early diagnosis. For this reason, children in whom this condition is suspected should undergo rapid work-up, in anticipation of surgery, if indicated. Anticoagulant therapy would appear to play no role in the treatment of carotid artery occlusion since the obstruction, once established, will not be relieved by this form of treatment.

The prognosis in carotid artery occlusive disease is dependent on the site of the occlusion. When the lesion involves the common carotid artery bifurcation or the origin of the internal carotid artery, the mortality is sharply lower and the degree of recovery from neurological deficit greater than when the intracranial carotid or other major intracranial arteries is compromised.

**TORTUOSITY**

Arteriographic evidence of reduplication or kinking of the cervical carotid arteries, seen occasionally in the adult, is observed commonly in children. Opinions differ regarding the significance of this anatomical variation, which has been attributed to incomplete straightening of the third branchial arch and its junction with the aorta. Sarkari et al. reviewed the problem of carotid arterial kinks and reported on eight children under ten years and one 16 years of age. All had histories suggestive of recurrent ischemic episodes involving the hemisphere opposite to their neurological deficit and a kinked or tortuous carotid artery on the appropriate side. None had corrective surgery and therefore the cause and effect relationship of the carotid abnormality to the neurological deficit could not be determined. Parrish and Byrne reported a group of children in whom they considered carotid kinking and elongation the cause of neurological defects, and operated on four children to correct the deformity. The children were reported to have been improved by the surgery. Eggers and Willich recently reviewed the relationship of kinking to the acute hemiplegic syndrome.

Notwithstanding these reports and others dealing with tortuous carotid arteries in adults, the relationship of this anatomical variation to strokes in children has yet to be determined. Therefore, we recommend a cautious surgical approach after thorough search for other etiological factors of the stroke syndrome, since many asymptomatic children have tortuous extracranial carotid arteries. Modern techniques of evaluating cerebral blood flow should help to clarify the dynamics of this condition (see: Subsection on Neuroradiology in the Diagnosis of Childhood Stroke, and Section on Special Procedures and Equipment in the Diagnosis and Management of Stroke. Stroke 4: 111–137 [Jan-Feb] 1973).

**Intracranial Vascular Disorders**

**ARTERIAL OCCLUSIVE DISEASE**

Intracranial occlusive vascular disease presents an even greater challenge to neurosurgical management than does its extracranial counterpart. Recent reviews by Taveras, Harwood-Nash et al., Solomon et al., and Hilal et al. indicate that in almost all instances of intracranial disease affecting the large vessels at the base of the brain, the occlusive process involves large segments of the middle cerebral artery, internal carotid bifurcation, and initial portion of the anterior cerebral artery. Many of the lesions demonstrate anastomotic channels, suggesting chronicity. Notwithstanding these reports, in a small group of children the stenosis or occlusion remains localized in an intracranial area accessible to neurosurgical techniques which can reestablish luminal continuity. Similarly, in rare instances, a dissecting aneurysm involves the middle cerebral artery.

Few cases of these occlusive lesions without anatomical correlates have been operated on or subjected to detailed postmortem examination. The consequent lack of basic information has led to widespread speculation on their nature. Most authorities attribute the stenotic areas or occlusions to a preexisting arteritis or vasculitis triggered as an allergic response to some systemic inflammatory disorder. A frequent history of preexisting pharyngitis, fever of unknown origin, and pneumonitis lends credibility to these theories.

Surgery has been performed in some children in an attempt to reestablish patency of the involved vessel. New microvascular neurosurgical techniques can be used to anastomose vessels as small as the middle and anterior cerebral arteries. Anastomosis of the superficial temporal artery to major branches of the middle cerebral artery also has been performed, using the operating microscope.

Embolic phenomena occur most commonly in children with cardiovascular disorders. The direct pathway from the aorta to the intracranial carotid bifurcation and middle cerebral territory, especially on the left side, has made these vascular channels prone to embolic occlusion. Although emboli are frequent complications in children with cardiac
abnormalities, as yet none has had successful intracranial embolectomy.

VENOUS OCCLUSION

Occlusions of major venous sinuses, although often associated with seizures and acute or subacute neurological deficit, may be characterized solely by a chronic elevation of intracranial pressure. Such pseudotumor syndromes have been labeled otitic hydrocephalus because of their association with sigmoid and lateral venous sinus occlusion secondary to suppurative otitis. More recently Strand has shown a high percentage of jugular vein thrombosis in cases of pseudotumor without antecedent history of inflammation. The resulting intracranial hypertension without ventricular dilatation is occasionally refractory to intensive conservative treatment (frequent lumbar punctures with drainage of cerebrospinal fluid, high doses of corticosteroids, administration of dehydrating agents, and surgical drainage with extenteration of the mastoid cavity). In these circumstances, the classical neurosurgical attempt to reduce intracranial pressure has been subtemporal or occipital decompression. Unfortunately, these procedures provide little more than additional space for the intracranial contents, without allowing for significant drainage of the cerebrospinal fluid. The decompression is often unsightly, and the subtemporal procedure especially leads to migration of brain tissue into the cranial defect. Lumboperitoneal shunt is the preferred neurosurgical procedure, carried out with silastic tubing, with or without a valve. By this technique, continuous drainage of cerebrospinal fluid may be accomplished until a remission takes place. The results of this treatment have been gratifying and are directed primarily toward prevention of visual loss and secondary optic atrophy associated with papilledema.

HEMORRHAGIC DISORDERS

If the numerous systemic disorders resulting in coagulation defects and vascular fragility are excluded, then the remaining etiologies for hemorrhagic stroke in the child are few. These include intracranial arterial aneurysms, arteriovenous malformations, and intracerebral hemorrhage from other causes.

Aneurysms

Successful operation has been carried out on an intracranial aneurysm of the middle cerebral artery in an infant as young as four weeks. This child presented with subarachnoid hemorrhage and severe neurological deficit. The operation resulted in an eventual complete return of function after a period of postoperative convalescence. In Matson's series of 14 children, the youngest was a one-year-old child and the oldest, 13. The operation was carried out successfully in all but three in whom death resulted—two after operation and one who died from a fatal hemorrhage prior to surgery.

The occurrence of a secondary hemorrhage following rapidly upon the initial bleed is surprisingly uncommon in children. This is converse to the frequency of secondary, often fatal, hemorrhage in the adult, which is high within the first two weeks. Because of this unique situation in children, conservative management may be applied following the initial subarachnoid hemorrhage until the child is in optimal condition to tolerate intracranial surgery.

Arteriovenous Malformations

Hemorrhage most commonly brings a child with an intracranial arteriovenous malformation to the physician's attention. In a recent review, Moyes reported on 11 children with arteriovenous malformations, the youngest of whom was two years old and the oldest was 17. Despite the progressive nature of the neurological deficit in some of these children, all were considered for surgery when subarachnoid hemorrhage occurred. Ten malformations were removed completely without mortality and in one remarkable case a malformation involving the proximal middle cerebral territory on the left side was excised almost totally without resulting neurological deficit. None of the children had severe neurological deficit following surgery. These results indicate possibly that: (1) the arterial blood supply to the malformation is independent of the blood supply to cerebral structures and therefore may be interrupted safely, or (2) collapse of the malformation after interruption of its blood supply allows it to be separated from surrounding cerebral tissue.

In spite of encouraging results of standard and microneurosurgical techniques used in resection of these arteriovenous malformations, there is still a group of malformations which would be considered inoperable because of their size and location. These include deep-seated brain stem, basal ganglionic, and internal capsule malformations as well as extensive lesions involving the motor-speech area. Malformations involving the temporal, frontal, and occipital areas (comprising approximately 20% of malformations) are generally good candidates for surgical resection; others should be judged only after meticulous angiographic evaluation of their blood supply.

Intracerebral Hemorrhage

Without systemic disorder or signs of preexisting intracranial vascular disease, spontaneous hemorrhage may occur within the cortex or in immediate subcortical regions. Such hemorrhages are presumed due to cryptic vascular malformations which probably destroy themselves during the process of
bleeding. In some instances, during evacuation of the hematoma, the surgeon may encounter a small 1-mm or 2-mm conglomerate of thrombosed and abnormal vessels which is the presumptive source of such hemorrhages. These lesions often are not seen on the preoperative angiograms because of their small size, thrombosis following the hemorrhage, or reduced blood flow in the lesion. Other intracerebral or intraventricular hemorrhages may be a manifestation of disseminated vasculitis. The clinical picture and therapy are the same in either event.

Surgical evacuation of these hematomas is indicated, if possible. Unless the child has deteriorated progressively, the operation should be delayed until the patient has stabilized, when the hematoma is usually well defined and removed more easily than if the operation is carried out immediately. High doses of steroids have been invaluable in tiding the patient over both the preoperative and postoperative periods. Cortical hematomas are approached readily through transcortical incisions, and even those underlying the motor or speech areas may be removed satisfactorily via strategically placed cortical incisions. A transcortical callosal incision may be used to approach intraventricular hematomas and to avoid producing severe neurological deficit. Such surgery may forestall progression of the lesion and even be lifesaving.

**Spinal Cord Disorders**

The pathology of vascular malformations of the spinal cord was described in detail by Wyburn-Mason, but it was not until the late 1960s that these lesions were removed successfully. This progress in neurosurgery has been dependent on the development of refined neuroradiographic techniques whereby selective portions of the spinal vascular anatomy are visualized angiographically. These techniques using special transfemoral artery catheters have few untoward effects.

The lesion which has been of most interest to the neurosurgeon is the arteriovenous malformation of the spinal cord. Many of these malformations involve dorsal portions of the spinal cord and derive their blood supply from the dorsal medullary arteries. Not infrequently one or two arteries represent the only source of supply. In certain instances these malformations are accessible surgically because they do not penetrate the spinal cord and are not an essential element of the spinal cord blood supply. The clinical manifestations result from pressure effects of the vascular malformation and/or from cord ischemia produced by “steal” phenomena. However, the spinal cord in the areas involved by the malformation may obtain its primary blood supply from the anterior spinal artery and its branches.

The juvenile form, which occurs almost exclusively in children, is the most difficult type to treat surgically. This type of malformation has a strikingly unique morphology. Its multiple large feeding arteries result in an extensive malformation which encircles the cord as a cuirass, and involves the internal aspects of the spinal cord as well as its anterior portion.

Prior to the development of microvascular neurosurgery, the accepted approach to vascular malformations of the spinal cord was a decompressive laminectomy, with or without radiotherapy. There was no evidence that radiotherapy had a beneficial effect on the lesion, and the decompressive laminectomy proved to be little more than a palliative measure.

The use of the operating microscope with microneurosurgical instrumentation has opened a frontier for neurosurgical treatment of these heretofore inaccessible lesions. The ideal surgical treatment consists of complete excision of the lesion. In Yasargil’s series of 44 cases, 13 radical removals were accomplished. In the more extensive or juvenile type of arteriovenous malformation, little more than ligation of some of the feeding vessels may be attempted. Surgically, the ligation of the posterior afferent vessels presents no problems, and only the anterior arteries are beyond the scope of surgery in view of the functional and segmental dependence of the spinal cord on this blood supply. Embolic techniques have also been used successfully to occlude various vascular efferents of these malformations, and although it is unusual to thrombose the entire formation, Ommaya et al. observed significant improvement in many of these which were partially treated.

Only after detailed evaluation of the spinal arteriovenous malformation by selective arteriography should surgical resection or partial ligation be attempted. An extensive laminectomy is performed so as to encompass the range of the vascular malformation. From the dural opening, the operating microscope and microsurgical cautery and instruments are used. The thickened arachnoid must be opened and stripped from the underlying formation. The dorsal malformations are removed by meticulous ligation and section of the feeding vessels. Attempts at removal of intramedullary extensions are hazardous and carry a high risk of spinal cord impairment. At the point where the malformation appears to merge with the spinal cord, it is prudent to terminate the operative procedure. Other more extensive malformations are treated by partial resection or ligation of the dorsal arteries feeding the malformation.

By following these surgical principles, gratifying results have been obtained in a high percentage.
of vascular malformations of the spinal cord. Not only is progression arrested, but in many cases the patient is distinctly improved.34,56

Scoliosis is considered a cause of spinal cord ischemia because of spinal distortion and compromise of the medullary vascular supply. Selective spinal angiographic studies performed prior to corrective orthopaedic surgery have alerted physicians to the potential for vascular catastrophe associated with this form of treatment.55 Once acute vascular compromise has occurred in a scoliotic condition or during the correction of scoliosis, it is unlikely that foraminotomy at the level of medullary arterial compromise will reverse neurological deficit. Rather, corrective procedures must be terminated immediately, and the patient either placed in traction or allowed to return to his previous alignment. (See also: Subsections on Neuroradiology in the Diagnosis of Strokes in Children and Diagnosis and Medical Treatment of Strokes in Children.)

**Procedures To Alleviate Chronic Disability**

Most aspects of the treatment of chronic disability in children fall in the realm of the physiatrist or orthopaedic surgeon (see: Subsection on Rehabilitation of Children with Stroke). Certain neurological procedures, however, should be considered.

Vascular occlusion occurring early in infancy or in utero, especially of the middle cerebral arterial distribution, may produce infarcts of cerebral tissue which lead eventually to scarring and cystic encephalomalacia. Depending on the severity of the vascular occlusion, the result of this process may be infantile hemiplegia with an uncontrollable seizure disorder and personality disturbance. Hemispherectomy can result in dramatic improvement in personality and complete cessation of seizures without increasing the motor defect. Children who respond well to hemispherectomy are those: (1) under adolescent age, (2) with personality and seizure problems uncontrolled by medicinal measures, (3) with cerebral hemiatrophy demonstrable by pneumoencephalogram, and also (4) with electroencephalographic abnormalities confined principally to the involved hemisphere.57-60

Other neurological procedures designed to minimize or eliminate the complications of stroke are directed primarily at spasticity, and involve section either of motor fibers or of the sensory portion of the reflex arc of the spastic muscles. The most popular procedure is obturator neurectomy, in most cases bilateral for cerebral diplegia, but which may be performed unilaterally. The nerve is easily exposed and sectioned. The result is flaccidity of the large adductor muscles, to alleviate the scissor tendency of the lower limbs. This procedure at least facilitates nursing care and, in some cases, allows the child to achieve limited ambulation. More destructive methods consist of procedures aimed at the spinal axis that destroy by surgical or chemical means the dorsal or ventral roots of the involved segments.

One should remember that all of these procedures are ablative in nature and should be considered from that standpoint before they are performed. In most instances, orthopaedic procedures and physical therapy will accomplish the same or better results without destruction of neural tissue. Therefore, these children should be transferred to a well-equipped rehabilitation facility for evaluation and therapy whenever possible.

**Summary**

The role of neurosurgery in the treatment of cerebrovascular disorders in the child is somewhat limited. Nevertheless, technical advances have allowed the neurosurgeon to approach vascular disease and vascular disorders in children with increasing success. The primary aim has been to restore flow in compromised vessels and to remove offending vascular lesions which have resulted in damage to the surrounding neural tissue by wave of mass effect or shunting of blood. With the refinement of neuroradiological and neurological techniques and a combined approach to these problems, two factors play a major role in the ultimate prognosis:

1. In children, the rapid onset of a potentially reversible disorder requires immediate recognition of the problem and prompt referral for evaluation and treatment.

2. The sophistication of techniques as well as the necessity for a multidisciplinary approach to diagnosis and therapy make it advisable that these patients be referred to specialized centers equipped to deal with all aspects of their problem.

If these clinical principles are adhered to, then one may reasonably expect a moderate degree of therapeutic success in dealing with the problems. To date, surgery has produced its most gratifying results in the management of aneurysms and arteriovenous malformations. As these lesions were considered inoperable in years past, so the occlusive disorders, which are now approached with caution, also should become more amenable to surgery as microvascular techniques, by means of which diseased segments of vessels may be bypassed or revascularized, are developed in both the laboratory and the clinical situation. One may expect continued improvement in results as the neurosurgeon's skill and techniques in dealing with small blood vessels are refined.
**Recommendations of the Study Group**

1. Recognition of neurovascular disease in children and its angiographic evaluation must be facilitated by: education of practicing pediatricians, development of referral systems through satellite centers affiliated with major medical centers equipped to handle pediatric neurosurgical problems, and expeditious handling of referred cases by having available emergency arteriographic facilities and a trained neuroradiologist, preferably one with a special interest in pediatrics.

2. Cooperation between vascular surgeons and neurosurgeons is essential in a team approach to complicated pediatric vascular problems involving the central nervous system.

3. Basic research aimed at development of small vessel suture techniques is indicated, the eventual goal being the standard use of bypass procedures designed to circumvent occluded vessels, both extracranial and intracranial.

4. Need exists for the development of centers for comprehensive treatment of childhood stroke, comprised of the following:
   a. A pediatric neurologist or a neurologist who has had experience in the area of pediatric neurology.
   b. A neuroradiologist capable of utilizing catheter techniques.
   c. A neurosurgical group which includes members familiar with pediatric neurosurgery and with the surgery of vascular disease of the extracranial arteries and intracranial vessels, and
d. A physical therapy rehabilitation service which can be called upon to exert its influence early in the treatment of the child with stroke in order to ensure maximal recovery.

**References**


Stroke, Vol. 4, November-December 1973
36. Strand R: Unpublished data

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IX. Strokes in Children (Part 2) (continued)

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Rehabilitation of Children With Stroke

Introduction

The functional loss produced by cerebrovascular disease in children may seem to be similar in clinical manifestation to stroke syndromes in adults. However, the damaged immature or newly matured nervous system may follow a course of functional recovery significantly different from that of the adult brain. Although this is due in large measure to the child's adaptability in relearning functional skills, there may be, in addition, greater potential for development of compensatory neural pathways via undamaged areas in the brain. Whatever the process of compensation, neuromuscular deficits acquired in childhood often appear to have the best functional prognosis if treatment is begun early and is carried forward consistently.

On the other hand, when neuromuscular dysfunction and/or muscle imbalance affect a growing skeletal system, the potential for developing deformities is considerably greater than it is in an adult stroke victim. Measures to prevent deformity, therefore, assume a critical role in the rehabilitation of the child with stroke, and they must be vigorous, persistent, and initiated early. The younger the child at the onset of disability, the greater is the problematical skeletal and adaptive neural plasticity.

The central idea in rehabilitation of the pediatric stroke victim, therefore, can be thought of as the superimposition of training for functional change in a child for whom definite skeletal and neurophysiological changes (maturational and adaptive) are in progress. A therapy program must then be both adaptive and developmental, thus necessitating frequent reassessment and adjustment. Because the developmental therapy program may be a long-term process, specific therapies must be both coordinated with one another, and constantly made comprehensible to the parents. Early involvement of the parents in a home program to supplement formal therapy does much to relieve parental feelings of helplessness in the face of their child's sudden disability.

The functional deficits which accompany the more obvious motor impairments may include visual problems, speech disorders, perceptual distortions, learning disabilities, hyperactivity, distractibility, and behavior disorders. Although a combination of deficits is likely, each may exist singly. When isolated perceptual dysfunction or learning disabilities occur, parents often find it difficult to grasp the nature of the problem. Early recognition and therapy are as essential for these impairments, however, as for motor disorders.

One should stress that treatment of the child without involving the family is incomplete treatment. The child's disability causes emotional and often financial upheavals within the home, as well as disruption of his own educational and social growth. If the goal of treatment is restoration of the child to a meaningful, functional role in his family and school/peer milieu, then many services must be brought to bear on multiple aspects of his problem; a multiphasic approach to treatment is mandatory.

The time invested in treating a child is aimed toward ensuring growth and function in a future measurable usually in multiples of decades, as contrasted to the relatively shorter span of functional years probably remaining to an adult stroke victim. For this reason, the expense, time, and personnel mobilized for the child are generally considered to be well invested. In summary, efforts at rehabilitation the young with stroke residua are rewarding because of the child's greater neural compensability and general adaptability, and his expectation of a long life span.

Impact of Acquired Disability

Reactions of the Child

Many, if not all, children have experienced at some time a minor, temporary illness with a convalescent period probably characterized by close parental attention and emotional and physical support. For most children, however, there is no past experience which might prepare for a sudden, possibly painful disability necessitating multiple diagnostic tests administered by strangers in a frightening environment. The child may feel that the hospitalization which separates him from his parents, and the discomfort of his illness constitute punishments for an offense of which he is unaware. He may look forward to rapid restitution to normal, as in previous minor illnesses. To one extent or another, the fear with which the patient exists in the earliest stages of his stroke may be augmented by other fears if prolonged hospitalization is needed; he may feel that he will never be better or comfortable, that he may never have control over the small aspects of his life, which hospital routine necessarily reduces, and/or that he may never return to his home and family. The adjustments which the child makes to a sudden onslaught of troubles affects his personality in many ways.

The younger the child at the onset of central nervous system injury, the more diffuse the potential personality alterations may be. The child's ability to adjust to the acquired deficits will depend not only on the nature and extent of physical limitation, but also on: (1) whether there is concomitant impairment of integrative and emotional control, (2) whether the disease is progressive, stationary, or intermittent (i.e., seizures), and (3) the child's
original intellectual endowment and emotional background. The last factor includes position in the family order, parental and sibling reactions to the child, and general family stability.

In physical functioning, weakness or lack of voluntary motor control may predispose to excessive dependency and passivity. Problems are compounded when bowel and bladder control is impaired, thus augmenting loss of self-esteem. Additionally, it may be difficult for the patient to distinguish between the discomfort or limitation imposed by his condition and that associated with medical or physical therapy. Even more important is the child’s inability to accept present, temporary discomfort on the basis of promised future gain or physical improvement.5

PARENTAL REACTIONS
Prospective studies of the handicapped child’s interaction with his family are sparse, and those which exist are subject to cultural, population, and observer bias.4 However, a detailed review of research to date is not the aim of this brief consideration of family impact. Our primary concern is with management of the child and the family, and with difficulties that may be encountered. The paramount aim in dealing with parental reactions is achievement of emotional as well as intellectual acceptance of the diagnosis, problems, and possible disability, as well as realistic acknowledgment of reasonable goals for the child’s present and future functioning.

One of the most frequently encountered parental reactions to acquired disability in a child is nonacceptance or denial either of the diagnosis, certain aspects of the disability (i.e., decreased intellectual potential), or the prognosis of permanent disability; this may lead to “shopping” from one doctor or therapist to another.5

The counseling of parents should be consistent and continuous. During the earliest phases of the illness, the physician working toward the diagnosis is most likely to be the counselor. One person should assume this counseling role, ideally, in order to prevent disparate opinions or terminology from confusing the parents. During the early stage of the illness, careful introduction of some functional prognosis, if it can be ascertained, is particularly helpful. Avoidance of an overly optimistic or overly pessimistic picture must be stressed. Also during early stages of the illness, the physician may be able to prevent or reduce any tendency of the parents to blame themselves or other relatives for the child’s problem, thus minimizing the interference that guilt may cause in the natural handling of the child.

Anger directed toward medical or allied medical personnel, or to society in general, may arise particularly when community resources for handling severe or multiple disability are inadequate or lacking. Intelligent, empathetic listing is often the most useful means of dealing with parents since it not only permits them to ventilate their feelings of frustration, but also allows them to bring to light other underlying reactions (e.g., ambivalence, denial, guilt, blame).

Many of those working in treatment facilities caring for young stroke victims have found that parent group meetings are valuable at a certain stage in the counseling process.6,7 Sharing of daily problems and practical suggestions for solutions within the parent group may be beneficial. In addition, a lessening of anxiety regarding many common difficulties previously thought to be unique may occur. Teams in other treatment centers have observed benefits to the parent-counselor relationship derived from questionnaires circulated to parents after a significant period of therapy.8 These surveys may reveal many areas where prior counseling had not answered fully the parents’ questions, sometimes to a startling degree.

Whatever the techniques, frequency, duration, or success of the counseling process, the parental counselor must expect to repeat a good part of the material explained at various times, according to the parents’ increasing ability to assimilate unwelcome or unpalatable facts. This calls for an extraordinary amount of patience from both counselor and staff.

The Team Approach To Rehabilitation
The multiple needs of a child entering a rehabilitation program for treatment of stroke require the services of many medical and allied medical staff members (table 1). While each of these professional

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<td>Recreation staff*</td>
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*While each member of the team may be involved on either an inpatient or an outpatient basis, in most centers the visiting nurse serves only in outpatient therapy, and the recreation staff only during hospitalization.

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disciplines will be intimately concerned with improving a specific area of the child's function, their total effort may be a potential source of confusion to both the child and his parents. Patient and parents must be introduced gradually to specific therapeutic roles in terms easily understandable to each. Reasonable therapeutic goals should be set sequentially as the patient improves. The total picture presented by the child determines the priorities for therapeutic goals. Within the therapeutic team, communication and coordination should be constant, since the child and parents may become increasingly insecure when faced with conflicting statements, overly optimistic or pessimistic goals, or treatments for which advance discussion has been minimal.

**MEDICAL STAFF**
The pediatrician, the neurologist, and the nursing staff will be among those participating in the patient's earliest management. Although "rehabilitative" measures should be started immediately in the acute phase of treatment, with the nurse positioning paretic limbs to prevent joint contractions, formal rehabilitation begins with the physiatrist's assessment made as soon as the child's neurological and/or medical problems begin to stabilize. As therapy progresses, more members of the therapeutic staff participate in the child's care; their presence in staff discussions is invaluable.

**Pediatrician and/or Neurologist**
The role of these professionals has been described in detail in Diagnosis and Medical Treatment of Strokes in Children (see also: Section on Training, Education, Manpower, and Research for Stroke Care. Stroke 4: 497-535 [May-June] 1973).

**Neurosurgeon**
Functions of the neurosurgeon have been described under the Subsection, Neurosurgical Management of Strokes in Children.

**Physiatrist (Rehabilitation Medicine)**
The physiatrist makes an initial assessment of the patient's joint flexibility, neuromuscular control, current functional potential, ability to understand and communicate, and tolerance for physical activity. Based on this initial examination, the physiatrist writes prescriptions for the physical, occupational, and speech therapies, indicating areas for concentration in their separate evaluations, noting precautions for activity or positioning, and outlining short-term goals for therapy.

As soon as the therapists have completed their individual evaluations and have initiated therapy, the physiatrist discusses the patient with them jointly in order to achieve a coordinated therapeutic approach. As treatment progresses, the patient is reassessed and discussed periodically by physiatrist and therapists, and long-range goals are outlined.

The physiatrist also initiates prescriptions and/or procedures for:

1. Orthoses for extremities. These may be resting splints fabricated by therapists or commercially supplied braces for functional use. Their greatest use is in prevention of contracture in spasticity and in alignment of the extremity for function, as in ambulation. While splints, braces, and positioning devices are indicated in the management of patients with spasticity, they rarely provide significant benefit to patients with ataxia or ataxia, with two exceptions: (a) if ataxia and athetosis with spasticity are present in combination, or (b) to provide adequate sitting support for ataxic or athetoid patients.

2. Appliances for patients with motor residues of stroke. Because wheelchairs, walkers, and assistive devices for self-care are designed to fulfill highly individual needs, the therapists are involved integrally in suggesting adaptive devices and training the child to use them.

3. Work physiology studies to gauge accurately a safe exercise level. These are warranted for children with congenital or rheumatic heart disease complicated by stroke. While rehabilitation has continued in centers where resources for special studies are not available, these should be part of the ideal pediatric rehabilitation facility, whether in the Rehabilitation Medicine Department or incorporated in existing cardiopulmonary function laboratories.9-11

4. Muscle relaxants such as diazepam (Valium), orally administered, which may be included in the nonsurgical management of spasticity.

5. Use of recently developed techniques for motor point or peripheral nerve block: (a) local anesthetic block as part of an evaluation for tendon-release or neurectomy; (b) dilute alcohol (30%) motor point or epidural block for more prolonged relief of spasticity12; and (c) peripheral dilute phenol (1% to 3%) blocks also for long-term effects. Electromyographic and biopsy studies have shown denervation of muscle as well as local muscle necrosis to be complications of the procedure; a less spastic but significantly weakened muscle may result.13-15

6. Evaluation prior to orthopaedic surgery, indicated when disorders of muscle tone distribution make the functional results of a tendon lengthening, release, or transfer open to question. Preoperative evaluation aims to reveal: (a) the positions and activities during which spasticity is most disabling, (b) the specific muscles contributing maximally to disability in each position or activity, and (c) the effect of temporary block or decreased muscle activity for the offending muscle(s) on total neuromuscular function.16
7. Implicit in the role of the physiatrist as coordinator of the therapeutic milieu is a predominantly cooperative rather than authoritative interaction with other therapies and allied medical professions. A cooperative, coordinative, integrative philosophy is inherent in the concept of the team approach to rehabilitation; its application should prevent fragmentation of treatment. Thus, in the course of a rehabilitation program, a group of therapists may treat a patient jointly among themselves and/or within other remedial settings, particularly in school. Where there are overlapping areas of expertise, a single specialist may take over a given aspect of the child's program. Part of the physiatrist's ongoing reevaluations will take place with the therapists, and often the orthopaedist, within the therapy setting. Not only is this mutually educational, but it is a logical extension of the need for communication through staff conferences. The various disciplines are thereby encouraged to see the child as he/she functions totally, rather than as a set of problematic muscles and joints.

Throughout the course of the rehabilitation program, an attempt is made to set up a therapeutic milieu, rather than limiting therapy to small, fixed segments of the day. Thus, specific techniques suggested by the therapists for a given activity, after instruction in therapy and after joint staff discussion, may be practiced with the school teacher (writing), by the nurse (positioning or splint application), with the nurse aide (dressing), with the recreation staff, or with all the staff members (speech). Whenever possible, the demands of therapy are introduced with some element of choice for the patient. For the younger children, specific activities are incorporated in play. For all patients, therapies are altered as the child's mood, motivation, and neuromuscular status change.

For the child whose disability requires long-term hospitalization for medical and/or rehabilitation programs, weekend home visits should be initiated as soon as feasible medically. This encourages parents to see the child as a continuing member of the family. Liberal policies with regard to sibling visits and visiting hours should have the same effect. In addition, the parents have more opportunity for contact with staff and a greater feeling of participation in the child's care and progress.

Orthopaedic Surgeon

The surgical management of children with stroke residua attempts to influence either the imbalance of muscle tone around a joint, or the bony deformity produced by the imbalance of muscle tone. In a few patients, spasticity is so great that even early, assiduously applied therapy cannot prevent contractures. Most often, however, contractures are the result of delayed or insufficient therapy. In either case, their release may be necessary before functional retraining can begin.

Upper Extremity. The typical dynamic flexor synergy affecting the hemiparetic upper extremity involves finger, wrist, and elbow flexion, forearm pronation, and humeral abduction and internal rotation (adduction at rest). Sensation in the paretic upper extremity is usually limited to touch, pain, and pressure. While sensory defects will be discussed in more detail in relation to physical and occupational therapy, the absence of cortical sensation, particularly stereognosis, has considerable surgical importance.

Since sensory assessment is difficult in the very young child, prior to surgery the surgeon may rely on the therapist's evaluation of the child's tendency and ability to use his paretic hand. It is the experience of most surgeons and physiatrists that the child will rarely use an astereognostic hand, despite suitable tendon release or transfer.17-21

Often, a presurgical trial of splinting may help in evaluating the influence of positioning of a joint on total upper extremity function.20, 21 For this purpose, positioning devices for the wrist are used most often to note the effect on finger function. Opponens splints to counteract the "flexed-adducted thumb" ("thumb in palm" or cortical thumb) deformity are also recommended. Thumb and wrist control orthotic devices can be used alone or in combination. If the externally applied stabilizing devices demonstrably improve function, then benefit from surgical stabilization can be expected. Splints should not be considered solely as presurgical devices, however, since their more frequent use by far is to provide function and stabilization, or to prevent contracture in patients where surgery is not a consideration.

Among the most frequently suggested and successfully used upper extremity surgical procedures is transfer of the flexor carpi ulnaris to the extensor carpi radialis longus, providing both wrist extension and forearm supination.22 In addition, transfer of the flexor carpi ulnaris to the radial styloid for supination, and transfer of the brachioradialis to the wrist extensors have been used with some success.17

For some children, the paretic upper extremity may remain nonfunctional or minimally functional despite prolonged therapy. For these, even the nonfunctional spastic hand may need finger flexor releases to allow the palm of the hand to be washed and the fingernails cut, or wrist flexor releases to permit donning a garment with long sleeves. Both procedures may also be used solely for cosmesis, but only after therapy or splinting over a period of years has failed either to prevent contractures or to allow compensatory means for handwashing and dressing.
Tendon releases are performed for cosmesis extremely rarely in childhood, and are best left until the teenage patient can participate in the decision for surgery, with full understanding of the limited goals surgery can achieve.

Lower Extremity. Because fine, isolated muscle control is needed less in the lower extremity, tendon releases (tenotomies), lengthening, and/or transfers are most often beneficial for function. Again, prevention of contractures should eliminate the need for many release procedures. In the intracatayly spastic patient, Achilles tendon, hip flexor, hip abductor, or hamstring release or recession may be necessary. Equally often, however, surgery is needed to prevent or minimize secondary bony deformity.

At the hip joint, the unbalanced pull of adductors and flexors predispose to superior and/or posterior femoral head subluxation.23, 24 This tendency is aggravated further by the coxa valga deformity produced by weak abductor pull, since the gluteus medius insertion and tension on the greater trochanter (a traction epiphysis) determines the femoral neck-shaft angle. Tight iliopsoas and hamstring muscles, if injudiciously stretched, may also contribute to femoral head subluxation. When hip adductors are tight or contracted, a trial of progressive splinting or bracing is warranted as early as possible. A variety of static night abduction splints, and long or short hip control braces for ambulation are available. Procedures used to prevent or control femoral head subluxation include adductor tenotomy, obturator neurectomy, and transiliac transfer of the iliopsoas posteriorly to insert on the greater trochanter, or varus osteotomy of the femur.23, 25, 26

For knee flexion deformities, a variety of hamstring transfer procedures is available.27, 28 Accurate assessment of the share of semimembranosus, semitendinosus and biceps femoris spasticity in causing tightness or deformity is crucial. It is in this connection that preoperative electromyographic-kinesiological studies and/or motor point blocks are most revealing.

At the ankle, a tight Achilles tendon may cause an equinovarus deformity or a compensatory hyperextensibility of the intertarsal and tarsometatarsal joints in an attempt to avoid toe-walking. Initially, the forefoot is hypermobile, but later may become rigid and painful in accentuated forefoot pronation and abduction, with a valgus position of the calcaneous, and plantar flexion of the talus.19 Peroneal muscle spasticity may complicate this problem. If the early tendency to forefoot hypermobility cannot be controlled by adequate therapy and bracing, procedures such as Achilles tendon lengthening, gastrocnemius aponeurectomy or soleus neurectomy may be required.29 If one of these procedures is insufficient to control the valgus, then either calcaneous ostectomy or subtalar arthrodesis prior to local osseous maturity may be necessary. If the patient is older than 12 years, the procedure of choice would be either triple arthrodesis or calcaneal osteotomy to stabilize the subtalar joint.20-23 Early attention to adequate bracing can often obviate the need for this type of surgery.

In summary, the deformities produced by muscle imbalance are extremely difficult to control, but usually may be prevented or minimized by active therapy, splinting or bracing, and particularly by attention to the child's avoidance of abnormal functional postures. If these deformities cannot be prevented, derotation osteotomies may be needed to realign the lower extremities, thus preventing further deformity and (it is hoped) promoting function.

In evaluating the child for surgery, the orthopaedist is presented with a major challenge. He must select a muscle as being the one producing deformity or hindering function, with full knowledge that several other muscles may produce the same effect during different phases of a single activity or during different activities. He must release or recess one deforming muscle, knowing that the antagonist may also have relative overactivity that has been masked while the agonist was intact. He must project the resultant function after transferring an inappropriately active tendon to another tendon of disordered activity in an extremity with abnormal control. Clearly, the orthopaedist needs all the information obtainable about the child's neuromuscular status, including the physiatrist's assessment of the patient's evaluation in, and responses to, therapies.24

Psychiatrist

While most members of the rehabilitation team acknowledge that emotional disturbances are frequent in young stroke victims, the psychiatrist often is thought of only as the last resort after problems are full-blown,25 thereby missing many benefits which early involvement of the psychiatrist as a team member may contribute, especially in preventing the development of abnormal psychological states. Just as the psychologist detects areas of specific dysfunction which may be reflected during therapy and in school performance, so the psychiatrist may detect personality problems with similarly widespread influences. Early recognition enables the psychiatrist to give the therapeutic team members valuable insights into the patient's behavior, as well as suggestions for management or approach in various areas, even when formal psychiatric therapy is infeasible.

The psychiatrist is aware that in addition to readily diagnosed physical deficits, children with stroke may show many other impairments in: (1)
the type and strength of response to environmental stimuli; (2) suitability of affective responses; (3) reception of and reaction to communications; (4) behavior pattern and consistency. Early identification of these dysfunctions may minimize negative interactions arising during therapy, at school, or at home. In addition, the rehabilitation team psychiatrist will have available the psychologist's evaluation revealing the specific aspects of possible perceptual dysfunctions. This area will be discussed subsequently, particularly as it is reflected in school performance.

Interactions between the child and parents or peers may be discovered to elicit from him or to perpetuate inappropriate affective responses. For example, in the absence of significant motor deficit, unrecognized perceptual distortions may cause poor school performance that results in pressure from the family, thereby frustrating the child and giving rise to anxiety or withdrawal from reality.

**ALLIED HEALTH PROFESSIONALS**

A recurring theme in discussing physical, occupational, and speech therapy modalities is the coordination of approach which is required by the child with stroke and which may be achieved by several therapists working together. When there is incomplete coverage, one therapist temporarily may take over the treatments required by more than one aspect of the program. For example, the physical therapist may delineate the optimal body mechanics for transferring in and out of bed or for bathroom activities, even if this is the traditional role of the occupational therapist.

A second recurring theme is the translation of therapy into the daily handling of the patient and his activities. For the hospitalized child, this means nursing personnel for positioning or dressing; school staff for writing activities and communication; and the recreation staff for many other areas of functioning. At some point in the rehabilitation program, the patient will have learned the therapist's specific methods for a given activity well enough so that he may be supervised by other staff members when the activity occurs naturally during the day. In bathing or dressing, for example, the nurse aide must be aware of the therapist's recommendations for: (1) amount and nature of assistance the child needs, (2) proper positioning, and (3) the use of assistive devices. If writing or manipulation is to be practiced, the teacher must be aware of the therapist's recommendations concerning the same items.

Similarly, for weekend home visits or for nonhospitalized children, the parents must be aware of recommendations for handling the child during daily performance of naturally occurring events. In general, children respond best to specific suggestions added to their normal activities rather than to exercises limited to a fixed, circumscribed segment of the day.

The coordinator or conductor of the total therapeutic ensemble is the physiatrist, or, on occasion in some treatment centers, the pediatrician. The physiatrist reevaluates the patient periodically, observes him in therapy, and adjusts the total approach on the basis of progress reports from all medical and allied professional staff at regular staff conferences.

**Nursing Staff**

The most important role of the rehabilitation team nurse, next to maintaining the medical regimen, is to serve as surrogate parent of the hospitalized child with stroke. During the long hours of the day when visiting is not permitted—and perhaps most crucially, at night—the nurse must be available as a sympathetic adult with whom the patient may ventila many of his fears and questions regarding his illness and disability. Much of the guidance and training ordinarily handled by parents thus becomes the nurse's responsibility: supervision of daily hygiene, toilet training for the youngest children, encouragement of good peer relationships while in the hospital, and discipline. The nursing staff must beware of allowing the pressures of medical regimens to occupy so much of their time that the only supportive attention given the patient is discipline for refractory behavior. The prevalence of understaffing in many hospitals makes this a particular liability (see also: Section on Guidelines for the Nursing Care of Stroke Patients. Stroke 3:631–681 [Sept-Oct] 1972).

With a firm but kindly attitude, the nurse can maintain discipline while remaining sympathetic. Early introduction of the recreation staff allows the child periods of relative freedom from medical routines and diverts energies into constructive channels.

Because nurses have more prolonged daily contact with the child than do the medical or therapy staffs, the patient often tends to ask them direct or indirect questions regarding his illness or prognosis—questions which the child may find difficulty in addressing to the physician or therapist. Parents, similarly, may question the nurse, who is usually the team member most readily available. The consistent, coordinated team approach which has been stressed as essential in adequate management of the stroke patient will have prepared the nurses for many of these questions, and they will know, therefore, which can be answered directly, and which are best referred to the physician.

Similarly, coordination of treatments into a total therapeutic day involves the nurse in daily practice of the various therapists' recommendations.
These may range from positioning in bed or chair to splint or brace application; from bathing, transfer, or dressing techniques to eating methods, or use of adaptive or assistive devices. Coordination of approach will alert the nurse repeatedly to just how much assistance the child requires in his daily activities.

The nurse must be alert to signs both of progress and of problems which must be communicated to therapists, teachers, or physician. The nurse’s observation of unsupervised, spontaneous transfer of functions learned in therapy to daily ward routines may provide valuable clues to the patient’s actual, as opposed to verbal or apparent, motivation. Comparable observations of the child’s interactions with peers and visiting parents can supplement the social worker’s or psychiatrist’s impressions of family dynamics.

For children whose medical or rehabilitation treatment programs necessitate prolonged hospitalization, it may be necessary for the nursing supervisory staff to relax visiting hour regulations. For example, working parents may see their child as often as possible, thus preserving the patient’s role within the family. For the same reason, it may be wise to lower or omit the age limit for sibling visits. Allowing the parents to visit during therapy and school hours, as long as they do not interfere with actual therapy or classes, encourages them to communicate with all rehabilitation staff, and allows early participation of the parents in home therapy for weekend visits or for eventual discharge.

The rehabilitation nurse clearly has a pivotal position in the successfully coordinated treatment program. She is one of the main channels for communication within the rehabilitation team, and between team members and the patient’s family constellation. This role begins, ideally, prior to the child’s entering the rehabilitation ward, with the nurse providing a picture of what he can expect in his new surroundings. Not only are preadmission contacts important, but the nurse may join the therapist in preparing programs for discharge to the home, particularly if a visiting nurse or nurse-therapist is to be involved.

**Physical Therapist**

In evaluating and treating each child, the physical therapist must be sensitive to the factors which motivate him, and must be creative and flexible in selecting therapeutic activities. Pediatric therapists must have had considerable exposure to neuromuscular and developmental problems of childhood, and should be as much of a specialist in the therapy area as the pediatrician, pediatric neurologist, or pediatric physiatrist in the medical area. These requirements apply equally to pediatric occupational and speech therapists, and only if they are met can the child with stroke be treated optimally. Unfortunately, many physicians believe either that the child’s problems will “take care of themselves” or be outgrown, or that nonspecific treatment administered by a therapist accustomed to treating adults primarily will suffice. Often this is not effective in producing results.

Basic considerations in the application of physical therapy evaluation and treatment procedures include: (1) stimulation of areas of motor activity which are vital to life, i.e., respiration; (2) documentation and maintenance of range of joint motion; (3) documentation of muscle strength and endurance, with selective strengthening where needed; and (4) encouraging functional mobility within the environment. Equally basic is the concept of developing the child’s strengths and avoiding over-emphasis on disability. Beyond these fundamental principles, the therapist must have considerable acuity in observing the child’s performance, because the largest portion of the therapy program may be based on observed problems, rather than on measured joint and muscle limitations.

**Evaluation.** Muscle testing and joint mobility forms and procedures vary little from one treatment center to another. In contrast, daily activities of living evaluation and treatment methods differ not only in procedure, but as to whether the treatment is performed by physical or occupational therapists. In general, activities related to self-care requiring gross body coordination and equilibrium are best handled by the physical therapist. The patient’s ability to perform a given activity should be evaluated as to efficiency of performance, the possibility of joint malalignment caused by the method of performance, or the possibility of accentuating abnormal tone in certain muscle groups during the performance. Each of these possibilities, if found, may indicate need for attention in therapy to the nature of performance, despite demonstrated ability to complete an activity.

One of the most significant additions to the traditional evaluation approach is the growing emphasis on observation and description of: (1) variation of muscle tone from normal, particularly the changes in tone accompanying changes in body position and attempted voluntary motion; (2) involuntary motions and the positional and emotional factors which increase or inhibit these; (3) asymmetries of muscle tone imbalance and their influence on posture; (4) disorders of control, coordination, motor planning, and sequencing; (5) the ability to learn and to retain voluntary motion control in therapy; (6) the presence or absence of abnormal reflexes due to delayed neurological maturation; (7) general body awareness and balance; and (8) kinesthetic and protective...
sensory awareness, in addition to epicritic sensation.

The description resulting from these detailed observations provides a narrative indicating the child's style of moving within his environment. Based on the observed variations from normal, activities and positions are selected to stimulate kinesthetic awareness of movement within a new positional context, and to discourage joint malalignment and involuntary (spastic or athetotic) motions.49

Treatment. Both remedial positioning and activities are applied to supine, prone, sitting, kneeling, and standing functions. In each of these positions, the therapist will try to influence: (1) distribution of abnormal tone and lessening of flexor or extensor tone predominance; (2) symmetry of posture; (3) ability to control head and trunk; (4) ability to rotate the trunk to initiate motion or as part of upper extremity reaching; (5) ability to use hands; and (6) ability to support and shift weight. Finally, if ambulation is possible or eventually reached, the gait pattern will be improved as far as possible.50, 51 Body control in each of these positions in sequence forms the basis of a motor development treatment program.

All therapy is discussed and evaluated in terms of the child's ability to function in the home/school/community, circumscribed by his stroke residua and performance capacities. Knowledge of the architectural features of the patient's home and school may be as essential to the therapeutic program as awareness of the child-family interaction and sensitivity to the influence of that interaction on the child's performance in therapy.

While therapeutic approaches differ in the various centers treating stroke residua, the goal is the same—improved function for each patient. Knowledge of several approaches to managing a given problem allows selection of the treatment type best suited to a given child.

Treatment Timetable. The need to prevent contractures dictates that the physical therapist participate in the patient's care as early in the hospitalization as is feasible medically. Initially, the therapy may involve positioning, splinting, and/or passive range of joint motion. As the patient's medical problems stabilize, or as awareness following coma increases, the child will be asked to participate more actively in functional reeducation. At this stage speech and occupational therapy may be introduced if needed. However, if the child shows considerable confusion during this early recovery period, the number of therapists involved in evaluation and treatment may be minimized by having the parents and/or nurse administer selected portions of the therapy program, with supervision and guidance from the therapists.

In general, improvement following acquired neuromuscular deficit in childhood can be expected within the first 12 to 18 months after onset, with progress becoming slower in the last part of the period. The more rapid the recovery immediately after onset, the greater the functional ability reached ultimately. Thus therapists are demanded on a more frequent schedule during the patient's early stages of recovery. Later, therapy aims to maintain rather than improve function, so that therapy sessions are needed less frequently. However, because the child is growing and developing, periodic reassessments should continue over many years. Specific time patterns for therapy must be determined by the specific complex of problems presented by each child.

Occupational Therapist

Traditional approaches to occupational therapy for children with strokes have stressed self-care, independence in age-commensurate activities of daily living, manual dexterity, and fine coordination. Because impairment of sensation is so closely related to the aspects of function with which occupational therapists deal, detailed evaluation of sensory modalities is part of the initial assessment. Interest in the integration of sensory-motor and visual-motor abilities necessary to allow function in the areas mentioned has led occupational therapists to become increasingly concerned with perceptual disturbances. This area overlaps that of the pediatric neurologist and psychologist in terms of testing, and the educator in terms of remediation52–54 (see: Subsection on Psychosocial and Educational Management of the Child With Stroke).

Activities of Daily Living. In evaluating the ability or inability of a child with stroke to wash, dress, feed, and transfer himself, the therapist must keep in mind the possible structural problems of the home in which these skills will be used. One or more home visits may be necessary, not only to assess the functional techniques which will be most effective for a given child's disability, but also to suggest means of facilitating the parents' handling of the child in the home environment.

Once activities are learned, the therapist then times performance. If a youngster requires excessive time or energy for dressing, for example, his parents are likely to dress him when he is at home. In order to preserve independent function, specific types of clothing or garment fastenings, or the use of assistive devices may be necessary.

Manipulatory Skills and Eye-Hand Coordination. The fine coordination needed for manipulatory skills is reflected not only in areas of self-care (e.g., garment fastenings), but in writing and many other

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school activities. For the older child, manual dexterity may influence the choice of vocation. The therapist begins initial hand function evaluation by observing the child's tendency to use the hand spontaneously, the positioning of the hand during use, the types of activities for which the patient chooses to use his hand, and the influence of body posture or position on hand function. For some children with severe spastic quadriparesis or moderately severe athetosis, adequate attention to sitting posture may determine whether the patient achieves functional hand use. Yet, in many cases, little attention is paid to sitting position at home or in school. For exceptionally severe athetosis, mouth-controlled devices may be used.

Perceptual-Motor Programs. The term, perceptual-motor deficit, is used interchangeably with or includes elements of, visual, perceptual, visuospatial, visuomotor, or constructional dysfunction. Each of these terms describes inadequately the complex sequence of cerebral functions from reception of initial multisensory stimuli via peripheral mechanisms (skin, joints, eyes, ears) to central perception of these stimuli as meaningful, then through central integrative and associative processes, with ultimate organization into and production of verbal emotional and/or motor responses.

In this sequence of events, it is easy to understand the adverse influence of auditory, somatic sensory, or visual acuity disorders. However, when deficits or distortions involve the next stages in the sequence, the resulting problems may be less clear, and the specific area of dysfunction more difficult to delineate. Examples of some of the less complex disorders include: (1) cortical blindness or deafness, in which peripheral receptors are intact, but there is visual or auditory cortical neuron dysfunction; (2) dysfunction of pathways involving interpretation of sensory impulses received (agnosias); or (3) disorders of perception involving intrasensory versus intersensory selection of competing stimuli.

Speech Therapist

The processes of hearing, comprehension, language development, and oral communication fall within the scope of the speech clinician's evaluation and treatment programs (see also: Section on Stroke Rehabilitation. Stroke 3: 373–407 [May-June] 1972).

Hearing. The importance of auditory acuity for volume and sound discrimination is self-evident. In many speech therapy departments the audiometric screening examination is performed by the therapist, while formal audimetrics are carried out by the audiologist in conjunction with an evaluation by the otorhinolaryngologist. When expressive or receptive language disorders coexist with a motor deficit which limits conditioned motor response to an auditory stimulus, formal audiometrics may not be feasible. However, a gross estimate of hearing can be based on responses to sounds of different intensities delivered from different directions.

Language. Language may be thought of as the formulation of ideas (with sounds, words, or gestures as their symbols) into a meaningful system, which is communicable to, and comprehensible by, others. Language may be expressed as speech or gesture, or may be unexpressed inner language. While detailed standardized tests exist to assess expressed language, inner language is intangible, and best evaluated in children by observing their use of common objects and toys, and their ability to understand the use of these items. The importance of assessment of inner language is greatest where environmental deprivation or different language and/or cultural background make the use of some standardized test items inappropriate.

Comprehension. Verbal comprehension is usually considered to be directly related to level of intellectual functioning. Scales of comprehension are standardized in terms of age level in many intelligence tests, usually emphasizing vocabulary items. Comprehension can be evaluated independently of speech, by using finger or eye pointing, or gestures for selection of presented choices, or by observing compliance with verbal requests.

Oropharyngeal Function and Speech. Speech refers to the oral production of language, for which intact function of oropharyngeal musculature is needed, as well as adequate lip and tongue mobility. Disorders of oropharyngeal muscle control in children first may be recognized as impaired sucking and subsequently as drooling, feeding, and chewing difficulties. The speech therapist's treatment program often begins with feeding in order to obtain increased lip closure (related to p, b, and m sounds) and tongue lateralization. Later, circumoral contraction for sucking through a straw and blowing may be the aim of therapy (related to future w, f, and v sounds). These activities may be introduced into a developmental program. As coordination of oropharyngeal musculature improves in feeding, articulatory performance should also improve. This program should start in infancy, but is applicable also to older children with acquired deficits.

The familiar diagnostic headings of aphasia (receptive and/or expressive language disorder), dysarthria (disorder of the speech-producing musculature), and apraxia (disordered patterning of the component movements of speech) omit many areas of potential difficulty. The complex sequence of
hearing, comprehending, and expressing ideas in speech or writing involves several modalities of sensory input, integration, and motor output, portions of which may be tested. The auditory-vocal area may reflect aspects of automatic language learning through hearing, i.e., grammar and syntax. Visual input may be evaluated by the child’s comprehension of pictures, objects, or printed words. Communication of ideas by gestures, auditory-vocal associations, visual or auditory memory for ordered stimuli or sequences, and auditory discrimination each may represent an area of deficit with a need for accurate diagnosis and specific therapy.

**Developmental Programs**

A common belief among some physicians is that when cerebrovascular disorders cause stroke syndromes within the first years of life, no rehabilitation therapy need be offered. However, the pediatric physiatrist is aware that developmental lags are an unmistakable indication for developmental therapy. The primary aims of this program are stimulation of motor, language, and adaptive functions, and training in appropriate movement habits. Children with spasticity and/or athetosis often are unable to overcome the stereotyped movements imposed by their neuromuscular imbalance; indeed they often try to make use of these motions. For example, an infant with spastic quadriparesis may react to joyful or stressful situations with an “extensor thrust”; excessive spasticity in all axial and lower extremity muscles. The infant may use this thrust to flip over in bed. Later, the uninformed parent may prop the infant in bed. Later, the uninformed parent may prop the child in a standing position, again relying on this extensor spasticity. However, the infant and child totally lack control of this spasticity. Once in the extended position, no further voluntary motion is possible. Therapy aims to discourage overuse of, and to provide functional, voluntary alternatives to such stereotyped movement habits.

Maintenance of the focus of therapy in the home is integral to developmental programming. It is the parents’ handling of the infant or child according to the therapist’s suggestions which accomplishes the aims of the program. The severity of the physical problem, the parents’ understanding of the program, and the family’s distance from the treatment center will determine the frequency with which the child is seen by the therapist.

**Evaluation of Therapy**

Evaluation of therapeutic efficacy is a logical and necessary procedure. The objective measurement of the relative effect of specific therapeutic approaches remains to be achieved, although attempts have been made to compare portions of them. Charts of normal developmental progression for each of the therapies may be compared with a specific child’s rate of improvement. If the two curves are parallel, then maturation rather than therapy may be responsible for observed changes. One may still question, however, whether change would have occurred even at that parallel rate without the stimulus of therapy. If the child’s graphed progress measured from inception of therapy exceeds the rate of expected change, the progress may be attributed to therapy rather than to maturation.

The establishment of a total therapeutic milieu which seeks to avoid compartmentalized therapy tends to obscure identification of causal effects. Thus, if an association between better test scores and improved function is shown, the actual cause of that associated change may be hidden within the multiple modalities of therapy offered. The same may be said of certain areas of demonstrated improvement in language ability, and of changes in physical function in children whose stroke residua showed minimal neuromuscular involvement, i.e., clumsiness without neurological abnormality. For all therapies, however, work-time studies, electromyographic kinesiology records, and video taping may provide objective records of progress, thus eliminating observer bias and the ambiguities of the written record.

**Psychologist**

The psychologist’s role is of particular importance in the team responsible for diagnosis and long-term management of a child with acquired neurological deficit. For a detailed discussion, see the Subsection on Psychosocial and Educational Management of the Child With Stroke.

**Social Worker**

The social worker’s contact with the family of the pediatric stroke victim often begins with exploration of needs for and sources to provide concrete services, i.e., finance clarification or referral to community agencies. The preferred area of initial contact may be preparation for transfer to a rehabilitation unit, or discharge planning at the time of the physiatrist’s earliest programming if further hospitalization is unnecessary. As rehabilitation assumes an increasing responsibility for management of the child, initiation of contact with the rehabilitation case worker by the social worker involved during the acute illness is optimal for coordination of care. Whatever the origin or timing of the initial contact, the subsequent casework may include many problems in the family unit.

**Counseling.** Within the context of the coordinated program, the social worker may give supportive counseling in order to promote or accelerate acceptance of a disabled child, and to help the parents deal with reactions and problems related to...
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the illness. As with other aspects of the child's care, problems should be handled by the staff member best equipped to deal with that specific family unit. In many cases a major portion of the counseling role is assumed by the social worker. However, this is not a decision to be determined by an individual, but must occur within the context of the coordinated program, after staff evaluation and discussion. The handling of family interpersonal relationships is certainly one of the major concerns of the social worker.

Community Services. Many medical, educational, and social service organizations publish lists of agencies serving children with handicaps. While aspects of disability may be tabulated (i.e., agencies for children with visual, cardiac, communicative, orthopaedic, or seizure problems), neither children with strokes nor children with combinations of disorders ordinarily are included among the lists. Therefore, those available may serve only as general guidelines for the specific community service explorations to which the social worker devotes considerable time. This exploration should be aided by recommendations from specific rehabilitation team members. In some communities, school programs include therapy for certain aspects of a problem, but rarely for all areas of dysfunction. Thus, a school may offer speech therapy, but not physical therapy, or physical therapy for orthopaedic problems; neither of these will be specific or optimal for the child with neuromuscular residua of stroke.

School resources may be supplemented by visits and/or recommendations of therapists from the rehabilitation center, with ongoing coordination of communication by the social worker. Alternatively, the rehabilitation team may feel that maximal emphasis on a home program of therapy, with periodic outpatient reevaluations, best meets the aims of the therapy team. In either case, periodic team reevaluations should be scheduled and coordinated with the services delivered by the community.

Visiting Nurse

Home application of nursing care or a limited program of physical therapy may be required of a visiting nurse, after a child with stroke is discharged from the hospital. This is particularly necessary when parental supervision of therapy is hindered by young siblings, by parental illness, and/or by the necessity for both parents to work. The therapist must not expect the brief paragraph available on most visiting nurse referral forms to convey adequately the goals, methods, and cautions regarding therapy. Either a detailed treatment outline must be supplied or, preferably, the nurse should have one or more sessions with the therapist for treatment discussion and observation. This can be accom-

lished either in the hospital prior to discharge or at home after discharge, or both. Because the treatment of children with spasticity, ataxia, and/or athetosis is decidedly beyond the traditional stretching and strengthening approach, appropriate therapy is unlikely to be given without specific discussion for the individual child.

Often the visiting nurse is the only person able to assess directly the consistency of carryover of functional training and parental counseling into the family's daily existence. In this capacity she also may supplement the services of the social service case worker. In addition, the nurse can supervise administration of medication, can encourage dietary controls when indicated, and can suggest evaluation for or revision of appliances and assistive devices, based on the child's daily needs.

Recreation Staff

Play is an integral part of normal growth, and recreation staff and facilities are, therefore, essential to a pediatric inpatient service, particularly when long-term care is contemplated. Too often, however, this aspect is neglected. Relief from the boredom of hospital routine should be provided through interesting activities using a wide range of stimuli. Ideally, enough space should be set aside for mobile patients to have the chance to interact socially. For nonmobile children, bedside play activities may be supplemented, if the medical regimen permits, by changes in positional outlook (e.g., a tilt bed).

Modified sports activities, dependent on the type and severity of the disability, may be incorporated into a recreation program under the guidance of the physical therapist. This activity permits the child to interact successfully and competitively with peers of similar ability. Achievements which increase the child's sense of self-worth need not be competitive if the child's frustration tolerance is poor. Games allowing a winner, and craft activities encouraging creative expression help to build confidence. Similarly, crafts projects that produce a visible or useful endproduct for display as evidence of creativity and ability aid in building self-esteem.

Current Research

Current research findings in the treatment of childhood strokes have contributed to expanded objective documentation of motor development and its disorders, as well as to techniques for definitive assessment of motor performance in the presence of neuromuscular dysfunction. Attempts have been made to employ the Methods-Time-Measurement procedures used in industry to quantify manual efficiency. Similarly, quantitative evaluation of upper extremity function using cine recording of flashing lights applied to the extremity
provides objective assessment of direction, tortuosity, range, and regularity of rate. Computers may be used to analyze these data, as well as to store and analyze the historical, general physical examination, neurological examination, and laboratory results produced during diagnostic evaluation.

Electrodiagnostic methods should increasingly clarify the basic neurophysiology of spasticity. Further studies may identify muscle relaxants with predictable effect on the offending loci causing spasticity, as well as aid in the evaluation of their clinical efficacy. Electrodiagnosis has additional application in the evaluation of laryngeal and pharyngeal muscle function as it relates to speech.

Evoked cortical potentials have been used in the past to demonstrate integrity of auditory, visual, and somatosensory pathways. Also, latency changes in evoked potentials have been correlated in adults with such psychological variables as motivation and decision-making. Significant differences in evoked responses have been shown between children with the high and low IQ scores. Further use of these techniques in children with stroke may clarify some aspects of sensory, perceptual, and cognitive functions.

Work physiology studies are being applied to gross and fine motor function. Standardized tables of physiological parameters and energy consumption levels for various activities peculiar to children should be accumulated for normal children. These would provide both a basis for comparison with the handicapped, and an added area for quantitative evaluation of therapy. Certainly such studies are indicated where cardiac problems coexist with cerebral vascular disorders in children.

**Recommendations of the Study Group**

**EDUCATION OR TRAINING FOR:**

1. All physicians treating neonates and infants, in the detection of early signs of neurological deficit and developmental delays; this should lead to the earliest possible referral of patients to a diagnostic center or rehabilitation unit when indicated;
2. All physicians, to awareness of the indications for and the benefits of early developmental programming;
3. Medical students and resident physicians, in pediatric orthopaedic, pediatric rehabilitation medicine, and pediatric neurology specialties in the principles of developmental pediatrics and developmental diagnosis;
4. All allied health professionals treating children in the specialized areas, with longer undergraduate exposure to the problems of pediatric neurological deficit; this particularly applies to pediatric physical, occupational, and speech therapists, who must have the special characteristics, interests, and knowledge to be effective pediatric therapists; and
5. Psychologists and educators, in the diagnosis and remediation of learning and developmental disorders.

**TREATMENT**

6. Centralization of treatment facilities, so that evaluative and therapeutic expertise can be coordinated;
7. Early initiation of the treatment of any neuromuscular disorder, thus ensuring the best possible chances of success; the “wait and see” attitude is nonproductive and frequently detrimental; and
8. Abandonment of rigid territorial boundaries between types of therapy or between therapeutic disciplines, so that coordination of approach can be a reality.

**RESEARCH**

9. Continued development of objective measurements of severity, distribution, and amount of neuromuscular imbalance as well as development of parameters of neuromuscular and sensory function, with both objective and quantitative measurement of the effectiveness of all therapeutic modalities which are essential; and
10. Further neuropsychological research to clarify sensory, perceptual, and cognitive function and to document the effect of remediation on these areas.

**COMMUNITY SERVICES**

11. Planning for and providing special public education resources for handicapped children if these are lacking in a community;
12. Adequate funding for research, education, and treatment outlined in this section; and
13. Deemphasis of the “territorial” outlook of organizations serving the handicapped child, so that those currently existing in isolation according to diagnostic categories or types of disability may merge to represent all disabled children; this coalition should then have the representation, the financing, and the power of numbers and needs necessary to ensure provision of optimal resources.

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STROKES IN CHILDREN (REHABILITATION)

JOINT COMMITTEE FOR STROKE

REPORT OF JOINT COMMITTEE FOR STROKE FACILITIES
IX. Strokes in Children (Part 2) (continued)

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Psychosocial and Educational Management of the Child With Stroke

Age-Related Effects of Acquired Neurological Deficit

Interpretation of the effects of brain injury on the learning process must take into account the fact that efficiency of performance not only depends upon integrity of the cortex, but also is related to original mental endowment, chronological age, previous learning sets, and environmental opportunity. Particularly important are the considerable plasticity and potential for adaptation which characterize a developing organism.

However, the degree of plasticity and rate of maturational change vary for particular functions and within the developmental period. Consequently, the influence of both the organic injury and the environment on subsequent learning will depend upon the maturity and rate of change for each particular skill which prevail at the time of the stroke. The interaction among these variables in addition to the location and degree of stroke damage and opportunities for learning prior to the injury creates patterns that influence further learning. Thus, expecting one-to-one correspondence between the child's age when the insult occurred and later performance oversimplifies and obscures both the character of the lesion and the processes which contribute to recoverability.

Many researchers have attempted to clarify possible developmental differences following neurological deficits acquired early and later in life. Rapin hypothesized that a lesion which occurs early in a child's life will have consequences different from those resulting from a lesion sustained by a mature individual. She reports that after a focal neurological injury, the child has a better prognosis for improvement and recovery than does the adult after similar neurological damage. Hebb, however, found that injury early in life may prevent development of some intellectual capacities which an equally extensive injury sustained at maturity would not destroy.

Basser reported no difference in language development in children with right and left infantile hemiplegias, thus supporting the hypothesis that at birth both cerebral hemispheres have the potential for developing language function. This flexibility did not persist after cortical areas responsible for speech had become specialized. In children older than six years a lesion in the speech area was more likely to result in permanent language deficit. Basser also reported that early injury is likely to have a pervasive effect on cognition. For example, while right and left infantile hemiplegics showed no difference in language development, they evidenced a more generalized intellectual retardation than was likely to accompany a hemiplegia acquired later.

Graham and Ernhart conducted numerous studies concerning the psychological effects of brain injury on the child of preschool age. Their data suggest that vocabulary impairment is related inversely, while perceptual-motor impairment is related directly, to the age at which the injury was sustained. Later research, however, suggests this observation to be an oversimplification. For example, Birch and Lefford presented data to indicate only slight differences between normal and neurologically impaired children in simple perceptual recognition; however, in both perceptual analytic and perceptual synthetic ability, these two groups differed significantly. As the perceptual tasks became increasingly complex, the impairment from early sustained injury became evident. Therefore, perceptual impairment in some aspects, also appears to be inversely related to the age at which brain injury occurs.

Teuber and Rudel pointed out the extreme complexity of the relationship between development and neurological injury. They compared children ranging from 5 to 18 years of age who had sustained perinatal injury with a group of normal children of similar ages. Systematic age-related changes were demonstrated in both groups. However, the degree of impairment was not a single fixed value, but varied with the function being evaluated and the child's age at assessment. Results have been shown to differ also depending on the child's age at onset of injury (e.g., stroke) and the design of test procedures. These various studies indicate that for the child with stroke, evaluation as well as treatment should be a continuing process. Developmental programs require consideration of factors such as age at disease onset, the design of the assessing procedure, the dynamic character of impairment, and the different relationships which will appear among a child's various skills as he matures.

The Family and the Handicapped Child

A child's development or maldevelopment is, to a significant degree, an interaction rather than an autonomous process. Consequently, study of the child with stroke isolated from the family matrix would constitute an oversimplification likely to distort understanding of the child and to thwart the best therapeutic efforts. Three components of family interaction play a decisive role in teaching the child a basic repertoire of behaviors which mediate the effect of stroke, as follows: (1) the mechanisms through which parents assist normal children in developing competencies which prepare them for future learning experiences including those of formal
education, (2) the impact of acquired deficit on the family's ability to provide supportive experiences for their child, and (3) the results of the child's deficit or his ability to respond to what the family provides.

**IMPACT ON THE FAMILY**

Within recent years, many investigators have studied changes in the family resulting from one member's illness. While exact comparisons of these studies are difficult, it is evident that the better the organization and integration of the family prior to the illness, the more effectively they meet the problem.11

**CHANGES IN FAMILY FUNCTION**

Significant illness often alters relationships both within and outside the family. The impact of acquired neurological deficit may have either negative or positive long-term effect.11 In some cases the deficit stimulates understanding of oneself and others, and this understanding extends to many facets of the family's interactions. Two reciprocal problems are involved: the patient must learn to adjust to illness, and family members must learn to respond appropriately. Stroke has particular psycho-social accompaniments for both the child and his family. Each member must arrange a new pattern of living around the constraints of illness.

The following list represents possible responses of parents and siblings to a child with acquired neurological deficit:

1. Parental grief, depression, or mourning in expectation of possible dire or fatal consequences, or as chronic response to unmet developmental milestones;
2. Parental disappointment, embarrassment, or feelings of guilt about having a child who is atypical;
3. Parental resentment, anger, or bitterness in reaction to their misfortune or burden;
4. Parental anxiety contributing to excessive protection, indulgence, or control of the sick child;
5. Focusing of parental attention on the affected child with consequent fatigue, dissension, financial strain, or underattention to the needs of other family members;
6. Parental transference of overprotection or overexpectation to siblings in order to compensate for experience with the affected child;
7. Sibling hostility or resentment because of special attention or leniency accorded the affected child;
8. Sibling embarrassment or guilt related to having an atypical family member;
9. Distortion of family socialization and activity patterns with resultant friction or isolation;
10. Increase in parental and sibling empathy and understanding of individual differences with consequent improvement in personal interactions;
11. Direction of anxious, negative, or empathetic feelings into constructive activities with consequent benefit to self and others.

**REALISTIC CONCERNS**

It is important to recognize that many of the concerns with which parents must cope are realistic. They may have anxiety about ability to provide all the care their child may need, worry concerning ability to meet the expense of such care, and concern about the effect of this financial strain on other members of the family. Parents often fear that in giving so much attention to one child they may neglect the others. Parents are anxious also about the child's eventual ability to lead an independent, satisfying life, since questions about the child's future often cannot be answered with certainty. If the child is severely disabled, then parents must provide care indefinitely and project alternative plans for care beyond their own life span.

Many new activities must be assimilated into the family routine. Medical treatments necessary during the acute period of illness as well as a regimen of continuing therapies often must be incorporated into the family schedule. The father's occupational requirements, the mother's responsibilities in outside employment and/or in the operation of the household, and particularly the maintenance of equilibrium if there are other children in the family contribute to stress. The ordering of so many priorities would require a person of considerable skill and efficiency under the best of circumstances. The professional who senses a feeling of harassment and resentment in the parent should recognize also that these responses are not necessarily equated with rejection of the child. Someone on the treatment team should be available to help parents organize the many complex and often conflicting demands into a manageable productive program for all family members.

**HABILITATION**

Agencies working with handicapped children have found it advantageous to involve parents in the therapeutic/educational process.12-14 Parent involvement often provides a positive course of action which relieves their anxiety and feelings of inadequacy. The handicapped child who is not hospitalized spends a far greater portion of his time within the family than he does in a formal therapeutic setting. Utilization of the family as active participants jointly with professionals in the habilitation process extends the effectiveness of treatment and may contribute to understanding by those providing medical care, since parents are often the first to detect symptoms and recognize changes in the child's functioning.

**Education of the Child With Stroke**

The essential characteristic of a satisfactory educational program is that it meet the needs of the child
for whom it is designed. Planning for the education of a neurologically handicapped child requires attention to special aspects of his individual problems and also to concepts applicable to educational processes in general.

THE PHYSICIAN'S ROLE

Significant aspects of the physician's role in the educational enterprise may be listed as follows: to (1) facilitate the child's optimal physical function; (2) describe and report existing medical problems in terms of the effect such factors have on the child's skills, behavior, and feelings; (3) interpret these findings to educators working with the child; (4) familiarize himself with educational options available in the community; (5) participate with others in the design and support of effective educational programs.

THE PSYCHOLOGIST'S ROLE

The psychologist can encourage evaluation of the total functioning of a child within his environmental setting. Such a global approach is necessary in order to understand the interaction between behavioral adjustment and basic cognitive and functional skills. These must be understood in relation to possible medical and social etiological factors in order to develop realistic priorities for intervention. The psychologist can formulate a composite description of the child's abilities in the areas of behavior, information processing, cognitive efficiency, and academic achievement, and then relate these various skills to the ways in which the child adjusts to the demands of his living experiences. As one trained to be particularly sensitive to factors which enhance or damage a child's image of himself as a secure and adequate person, the psychologist can assess the influence which the child's deficits and living experiences have on his self-concept* and his relationship with others. The above factors constitute a portion of the diagnostic function which a psychologist performs.

A second major aspect of the psychologist's role involves implementation. The psychologist interacts with the child and assists others to recognize the adjustment processes which the child demonstrates. It is then possible to formulate procedures through which a child's assets and strengths are encouraged while functional deficits and feelings of inadequacy, anxiety, and frustration are modified.

This conception of the psychologist's function is considerably broader than traditional understanding of the role and requires that the psychologist operate as a child development specialist. In order to do so, he/she must understand developmental milestones and be informed concerning the interrelatedness of the biological, neurological, and psychological efficiencies of the child. The psychologist must: (1) evaluate or utilize data concerning strengths and weaknesses in the child's auditory, visual, tactile, and motor systems, (2) assess the influence of these systems on the child's level of cognitive development and his potential for cognitive growth, and (3) understand the emotional support or stress which environmental and educational circumstances provide for the child.

The above aspects of his role require that the psychologist: (1) be able to analyze characteristics of the home, the classroom, or the learning experience on the child's ability to attend, organize, and evaluate his own behavior; (2) be able to analyze specific educational tasks in order to understand the particular skills which these tasks require of the child; and (3) be able to suggest modification in the environment, teaching strategy, method, and level of materials presented in order to assist the child to make use of his learning or interaction opportunities.

The traditional psychologist role has concentrated on two components:

1. Assessment of a child's level of intellectual functioning, including areas of intellectual strength and weakness, through the use of precisely standardized intelligence and behavioral tests;
2. Evaluation of a child's social-emotional adjustment including his image of himself, his ability to relate to his parents, siblings, other adults, and peers as well as his pattern of dealing with the environment in which he lives, plays, and goes to school.

In these capacities, the psychologist must be aware of the testing instruments and procedures available at each age level.

THE EDUCATOR'S ROLE

Central components of the educator's role are: (1) to match the child's learning opportunities with his learning needs (social, emotional, physical, and intellectual); (2) to understand teaching behavior as it affects development of the child; (3) to establish a coherent, comprehensive educational program. Teachers must understand child development and be able to identify the developmental levels of each child; understand the relationships of one aspect of the child's behavior with others; design a program tailored to the individual child's strengths, weaknesses, and learning styles; and be able to implement this program effectively.

While physicians are encouraged to describe medical findings in terms relevant to education, educators should understand the influence of particular organic and medical factors on learning and

*For more extensive exploration of the theoretical and methodological complexities involved in the investigation of the important and interesting areas relating to the child's 'self-concept,' see references 15 to 46.
behavior. Teachers can develop precise observational skills which make useful information available to the physician, the parent, and others who work with the child. Furthermore, they must be able to translate data from other disciplines into educationally appropriate procedures for the child's benefit.

The child with stroke deficits, like all children, requires assistance in learning specific competencies which he must utilize at once, at the same time that he is acquiring skills which allow him to adapt to future requirements. While the child with impairment usually needs to devote increased attention to skill acquisition, it is important not to allow diligence in skill training to supplant delight in learning. One function of education is to guide children in learning how to live full and satisfying lives. This requirement poses a particular challenge for educators of children with impairments. Singular inventiveness and determination are necessary so that remediation and prevention of future deficits do not exclude variety, accomplishment, and immediate pleasure. The child with residual deficits of stroke is first of all a child, and he should have the full range of experiences appropriate to his age in preparation for future achievement. Educational opportunities are necessary for developing strengths as well as correcting weaknesses; this calls for devising programs which meet individual needs.

THE TEACHING/LEARNING PROCESS

Three concepts are basic in education for the child with stroke:

1. Learning occurs as a consequence of information which is processed, and a child must have the requisite behavioral organization, auditory-verbal, visual-perceptual-motor, and body awareness and control skills to participate effectively in the learning opportunities presented to him in the classroom.

2. Teaching involves matching effectively what is expected of and provided for the child with the levels of his cognitive and information processing skills, with the degree of his behavioral organization, and with the pattern of his interaction with other people so that desired behaviors are likely to be elicited and maintained.

3. Basic components of any learning situation may be described in terms of:
   a. Preceding conditions—those which have occurred prior to the child's response and which influence how and when the child will respond;
   b. Observed behavior—including any of the child's behavioral, information processing, cognitive, or academic skills;
   c. Consequent conditions—those circumstances which occur immediately after the child responds and either increase or decrease the likelihood of that behavior occurring again. Both preceding and consequent conditions influence learning. Each child has a unique reaction to these conditions based on his own developmental efficiencies and his past learning experience, and this reaction governs the effect that particular preceding and consequential stimuli have on that child's behavior.47-50

TRENDS IN EDUCATION

Fortunately, several trends likely to stimulate development of educational alternatives appear to be gaining momentum. These have specific benefits for the child with stroke. One of these is the recent direction of federal and state legislation. The Handicapped Children's Early Education Assistance Act of 1968, for example, recognized the importance of beginning the habilitation of high-risk and special-needs children in the preschool years and had the effect of encouraging public educational systems to extend their programs down to age levels not previously considered a public school responsibility. This had the additional effect of encouraging school systems to seek out and support highly specialized services for exceptional children when they were not available in the public education structure. Further, several states have passed types of legislation extending the range of educational services provided to include children with severe and multiple deficits. As a result of the Education Professions Development Act, the Bureau of Educational Personnel Development (now known as the National Center for the Improvement of Educational Systems) of the U. S. Office of Education was established. This Center and the Bureau of Education for the Handicapped sponsor programs for training of special teachers, to increase their ability to accommodate to the varying needs of children.

A second trend is the increasing commitment of educators to the concept of continuous progress, individualized or personalized instruction. The intent is to develop an administrative and curricular structure which accepts and plans for differences in children. This procedure involves:

1. Identification of the various sensory modalities through which children learn,

2. Recognition that a particular content can be taught through different modalities and that the effect of selecting any one method or a combination of methods as a teaching approach may have significant influence on a child's ability to learn,

3. Understanding that a child's rate of learning in various content areas (i.e., subject fields) and his rate of development in various modalities of learning will vary from one to another within himself, and will vary between himself and other children of the same chronological age,

4. Reorganization of administrative, teaching, and curricular structure to accommodate individual differences, so that each child can achieve desired...
educational goals at his own rate and with his own particular learning pattern.

This trend is of particular interest since the likelihood is increased that one will find public educational facilities which are sensitive, accepting, and organized in a manner which can be utilized for normal children as well as for those with stroke.

A third major trend has been the development of a number of models for the diagnosis and management of special populations which recognize the complexity of a child's learning and behavior patterns, as well as continuity and comprehensiveness that must characterize approaches to his medical, therapeutic, and educational management. These models are significant because: (1) they effectively utilize interdisciplinary organization; (2) they are appropriate from early childhood through maturity; (3) they are applicable to both normal and special populations. By utilizing models such as these, it is possible increasingly to meet the variety of needs of any child and it is necessary less often to remove a handicapped child from the educational mainstream in order to provide the educational services he requires.

Summary

For the child who has had a stroke, the socioeducational goal is earliest possible identification, earliest meaningful intervention, most effective service, and prevention of further deficits, whenever possible. Four principles are basic:

1. A total management program is necessary, involving a comprehensive view of the child's development, illness, and its aftermaths, relating these to all aspects of the child's life at home and at school, and maintaining long-term continuity of service, flexibly combining treatment alternatives as needed;

2. Prompt identification of the child and the handicap is highly desirable, with early involvement of the family and use of community resources for the immediate initiation of medical/therapeutic/educational programming;

3. Parents maintain primary responsibility as long-term managers of the child, thus significantly influencing treatment outcome; consequently, they should be active partners in planning, implementing, and coordinating services;

4. Treatment priorities should be decided and supportive services utilized to facilitate attainment of the maximal function possible in all significant areas of the child's life—medical, social, and educational.

These four principles have implications for:

(a) the training of physicians, psychologists, educators, therapists, and a variety of personnel providing service and care to children with stroke and their families; (b) the design and organization of medical/educational programs; and (c) the sociology of medical community relationships.

Recommendations of the Study Group

1. Planning is essential to systematic change of educational processes, staff training, and rigorous program design to permit meaningful evaluation of results. Therefore, planning grants should be made available to school systems, colleges and universities, hospitals, and other agencies desiring to develop, expand, or improve services for children with special needs (e.g., stroke residua).

2. Program development

a. Comprehensive preventive health services which provide for the family as a unit and which make available a continuum of prenatal, postnatal, and medical/educational service as may be necessary are mandatory.

b. Screening programs for the earliest possible detection of the high-risk or atypically developing child must be instituted in hospital nurseries, pediatric clinics, private pediatric practice, day care and school settings. Prompt implementation of the appropriate range of remedial, compensatory, and supportive services for the child and family must follow.

c. Health care for both handicapped and high-risk infants and educational services for mothers with emphasis on information and techniques for day-to-day child rearing, understanding of developmental sequences, and optimal habilitation should be augmented shortly after birth of the child. A variety of options should be available including home visits by professional staff or health aides, center-based programs, and media-distributed information.

d. Programs to maintain the child as nearly as possible in his normal life situation and to minimize psychological, social, or physical impediments are recommended.

e. A well-defined system should be established for providing the child and family with appropriate information and referral to local and regional resources to include the escort, transportation, and supportive services required to utilize specialized facilities.

f. Data regarding medical/educational resources, advances, techniques, and materials should be made available through media and computer systems.

g. Development should be continued of prediction and intervention techniques related to stroke in infancy and early childhood through research programs with sufficient scope and funding base to permit comparison studies and long-term follow-up.

h. Underlying all the above recommendations is the need for: (1) programs which increase
opportunity for interdisciplinary diagnosis and treatment on a continuing basis as the needs of the child and family require; and (2) programs which provide increased involvement of the family in the rehabilitation process.

i. Adequate funding must be obtained for the comprehensive implementation of quality education for all handicapped children through development of settings which reflect individual differences, if opportunities for each child to reach optimal potential are to be provided.

j. Further research and development of exemplary education models must be provided with adequate funding for implementation, evaluation, revision, and staff training so that advances can be introduced into the educational mainstream.

k. Legislative and fiscal support must be increased for preschool education to supplement that obtained through the family. These programs should be carefully interdigitated with medical diagnostic and treatment resources and with the primary and elementary school programs of the community.

l. Programs to increase the efficiency of health care and education delivery systems should include systematic planning and cooperation among local, state, and federal agencies; among various organizations dealing with particular diagnostic categories; and between professional and lay individuals. Constructive revision of health and education manpower systems to assure best use of resources is necessary.

3. Training

a. Programs concerning child growth and development should be provided to expand the knowledge of parents, expectant parents, teachers, physicians, psychologists, therapists, and all child care personnel, to increase sensitivity to the full range of children's biosocial needs, and to recognize indications for specialized diagnostic or health/education service.

b. Training and retraining for all teachers, to make available up-to-date information concerning interaction among developmental stages, learning processes and organic conditions, and to develop skills necessary to accommodate individual differences among children is urged strongly.

c. Classroom and in-service training of physicians and therapists should include emphasis on psychosocial needs and processes as they influence habilitation and as they help or hinder medical/therapeutic treatment.

d. Training of psychologists through classroom and in-service programs should:

(1) Emphasize the interrelations of biological, neurological, and psychological efficiencies of the child;

(2) Develop assessment techniques for the entire spectrum of the child's functioning, stressing adaptations necessary for evaluation of the handicapped child;

(3) Stress the dynamic quality of developmental processes and of deficits, as well as the necessary continuity between diagnosis and treatment;

(4) Prepare psychologists to function in helping to translate psychological and medical/therapeutic findings into home or school situations;

(5) Provide greatly increased opportunity for psychologists to participate in interdisciplinary settings.

e. Increased communication and more closely articulated relationships between research, training, and service institutions are recommended strongly.

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NIH-NHLI RESEARCH MANPOWER PROGRAM ANNOUNCED

The National Institutes of Health have announced a new research manpower program. Under it the National Heart and Lung Institute will make available individual research fellowship awards for postdoctoral training in basic biomedical sciences and research in clinical specialties related to heart and lung. More detailed information concerning specific fields and program areas in which research fellowships will be awarded may be obtained from:

Dr. Donald M. MacCanon  
Division of Heart and Vascular Diseases  
Landow Building, Room A-918  
National Heart and Lung Institute  
National Institutes of Health  
Bethesda, Md. 20014

Dr. Jay Moskowitz  
Division of Lung Diseases  
Building 31, Room 5A-10C  
National Heart and Lung Institute  
National Institutes of Health  
Bethesda, Md. 20014

Dr. Harvey Klein  
Division of Blood Diseases and Resources  
Building 31, Room 4A-04  
National Heart and Lung Institute  
National Institutes of Health  
Bethesda, Md. 20014

Deadlines for receipt of application are January 15, and May 1, 1974. Application forms may be obtained from the Office of Research Manpower, Division of Research Grants, National Institutes of Health, Bethesda, Maryland 20014.
IX. Strokes in Children (Part 2)
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