Cinefluorographic Studies of the Extracranial Cerebral Circulation

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RECENT INTEREST in the surgical treatment of occlusive lesions in the extracranial cerebral circulation has stimulated the development of new angiographic technics for visualizing the extracranial cerebral vessels. Since the cerebral circulation often functions as a unit, the adequacy of blood flow through all, not just one, of the major arteries supplying the brain must be known before surgical correction can be undertaken. Adequate preoperative evaluation therefore entails visualization of the subclavian and innominate arteries as well as the extracranial and intracranial segments of both vertebral and carotid arteries.1,2

This report describes a method of selective catheterization and cinefluorographic visualization of each of the major extracranial vessels supplying the brain. This procedure not only demonstrates the site of occlusive lesions in the extracranial cerebral circulation, but also provides information in regard to dynamic changes in blood flow produced by head and neck movement as well as coughing, swallowing, and other physiologic maneuvers. The advantages and disadvantages of this method are compared to those of other angiographic technics.

Methods and Materials

Cinefluorographic studies were made in 35 patients with symptoms of cerebral occlusive disease thought to be due to atherosclerosis. The patients ranged in age from 28 to 72 years, with a mean age of 54 years. There was evidence of peripheral atherosclerosis, such as diminished pulses and bruits over peripheral arteries other than the carotid arteries in the majority of these patients. Prior to the procedure the patients received 100 mg. of Secobarbital intramuscularly.

A yellow Ödman-Ledin catheter,3 preformed in a partial S-shaped configuration (fig. 1), was introduced percutaneously into the right femoral artery by means of a modified Seldinger technic.4 Boijsen and Feinstein5 used this shaped catheter for retrograde femoral catheterization of the right subclavian artery. This configuration is particularly adapted to the anatomic relationship of the vessels arising from the aortic arch (fig. 2). The catheter was passed retrograde into the aortic root to a point just proximal to the origin of the innominate artery. Slow withdrawal of the catheter from this point usually allowed the catheter tip to enter successively the orifices of the innominate, left carotid, and left subclavian arteries. After the orifice of the carotid artery was entered, the catheter could frequently be advanced to the carotid bifurcation. Once in the subclavian artery, the catheter could be placed near the orifice of the vertebral artery. Since the vertebral artery can be adequately opacified by injection of contrast media into the subclavian artery, direct vertebral catheterization, with its attendant hazards, was avoided.6-8

All studies were carried out with an 8-inch image intensifier coupled to an Orthicon TV circuit and a 35-mm. camera. The position of the catheter was constantly visualized on the TV monitor, and its relationship to various vascular structures was frequently confirmed by the injection of 1 to 2 ml. of contrast media. Arterial pressure was monitored and recorded by means of a Statham P23D pressure transducer coupled to an Electronics-for-Medicine recorder. In two patients, the catheter fortuitously passed through a stenotic area in the subclavian artery and the arterial pressures proximal and distal to the stenosis were recorded (fig. 3).

When the catheter was in the desired vessel, 5 to 10 ml. of contrast media (meglumine iothala-
Results

Initial problems in entering each orifice of the major vessels emanating from the arch of the aorta were overcome through increasing experience and the use of the modified S-shaped catheter. The innominate and left subclavian arteries can be catheterized readily with any curve-tipped catheter. However, the orifice of the left carotid artery cannot be entered easily by a retrograde femoral catheter technic without using the S-shaped catheter to “hook” onto the lip of the origin of the artery.

A variety of lesions in the extracranial cerebral circulation, including partial and complete occlusion of the subclavian, internal carotid, and vertebral arteries have been demonstrated with this technic (figs. 3 to 7). In addition, anomalies of the aortic arch and other abnormalities such as loops, kinks, and dilatation of the extracranial arteries were found. Two patients were studied before and

Figure 1
Partial S-shaped configuration of catheter designed to selectively catheterize major extracranial cerebral vessels.

mate—60 per cent) were injected by hand while the cinefluorographic film was being exposed at a rate of 60 frames per second. Cinefluorographic studies were made in various positions of the head and neck in order to obtain multiple views of lesions and more adequate evaluation of the size of the lumen. When possible, alterations in the vascular lumen were also studied during physiologic maneuvers, such as coughing, straining, and swallowing.

Immediately following withdrawal of the catheter at the end of the procedure, manual pressure was applied over the femoral artery for 10 to 20 minutes and the patient was instructed to remain in bed for approximately 18 hours. During this period, careful attention was given to the right femoral region for evidence of bleeding, and the vital signs were recorded at frequent intervals. The pedal pulses and the site of the femoral puncture were examined frequently throughout the succeeding few days.

*Kindly supplied as CONRAY® by Mr. James Peterson of the Mallinekrodt Chemical Works, St. Louis 7, Missouri.
CINEFLUOROGRAPHY FOR CEREBRAL CIRCULATION

Figure 3
Frame taken from cinefluorogram showing partial occlusion in the left subclavian artery. Note the difference in the arterial pressures distal and proximal to the lesion obtained as the catheter was pulled back through the area of stenosis.

Figure 4
Partial occlusion in the right subclavian artery (A) just distal to the innominate artery and subsequent appearance following endarterectomy and patch graft (B).

after repair of subclavian artery stenosis (figs. 4 and 5).

In two patients the catheter traversed a stenotic area in the subclavian artery and the arterial pressures were recorded proximal and distal to the lesions (fig. 3). Although the catheter itself may further reduce the effective size of the lumen and thus limit the va-
lidity of the pressure gradient as measured, these pressure measurements may provide useful information as to the degree of stenosis. It must be recognized that this maneuver has potential hazards, such as dislodging thrombotic material from atheromatous plaques, completely occluding the already stenotic vessel, and stimulating thrombosis by traumatizing the intima.

Cinefluorography has provided a clearer understanding of the dynamic nature of the extracranial cerebral circulation by demonstrating alterations in the position of the vessel and changes in the vascular lumen during various physiologic maneuvers. Swallowing was associated with a pronounced serpentine movement of the carotid arteries in the region of the bifurcation. In the presence of stenotic lesions, turbulent flow of the contrast media was readily appreciated. In one patient with subclavian artery stenosis retrograde flow was observed in the vertebral artery ("subclavian steal") (fig. 6).

Both because of the design of the study and the limitation in resolving power of the cinefluorographic equipment, the intracranial circulation was not evaluated. Preliminary observations in three patients in this series indicate that the intracranial circulation can be visualized with adequate detail if certain modifications are made in the cinefluorographic equipment.

None of the patients developed neurologic complications following these cinefluorographic studies, despite the fact that most of them had advanced vascular disease and evidence of severe neurologic involvement. In the majority of the studies, 120 to 150 ml. of contrast media were injected in 2- to 10-ml. aliquots without apparent complication.

In three patients, the right pedal pulses were noted to be absent immediately after withdrawal of the catheter from the right femoral artery. In two of them, the pulses returned within 24 hours, and there was no evidence of peripheral vascular disturbance. The remaining patient, however, continued to have absent pulses in the foot 2 months after catheterization and complained of intermittent claudication of the foot.
Discussion

Although J. Ramsay Hunt emphasized in 1914 the importance of occlusive lesions in the extracranial cerebral circulation, it has only been within the past decade that the frequency of such lesions has been recognized. Arteriography is the most definitive means of evaluating the extracranial cerebral circulation, and many arteriographic technics have been developed to visualize all the major vessels supplying the brain.

Steinberg and Evans reported that the major extracranial cerebral vessels could be visualized by the intravenous injection of a large volume of contrast media and serial x-ray examination of the head and neck. The major limitations of this method have been the large amount of contrast media delivered in one injection and the difficulty in obtaining adequate detail because of dilution of the contrast media as it travels through the venous and pulmonary circulations. To overcome these disadvantages, Gensini and Ecker injected contrast media into the aortic root by means of a catheter introduced in the femoral artery. Whereas this method reduces the amount of contrast media and enhances the detail, it still does not provide the detail seen when each vessel is opacified selectively. The extent and location of the left subclavian artery occlusion illustrated in figure 7 was not adequately defined by aortic root injection, whereas selective catheterization combined with cinefluorography adequately demonstrated the site and degree of obstruction.

Direct percutaneous injection of the carotid, vertebral, or the subclavian arteries provides adequate visualization of the vessels distal to the needle puncture, but seldom is the origin of these vessels from the aortic arch well outlined. The direct percutaneous puncture and injection of these vessels has certain inherent dangers, such as dissection of the vessel wall, formation of peri-arterial hematomas, embolization of atheromatous material from plaques, and the production of vasospasm. In addition, errors in diagnosis due to these complications have been reported.

Figure 6

Marked stenosis of the left subclavian artery (A) associated with retrograde blood flow through the vertebral artery (B). Cinefluorograms showed only a few centimeters of the vertebral artery opacified by contrast media and subsequent run-off into the subclavian artery ("subclavian steal"). The vertebral artery was later demonstrated to be fully patent by retrograde brachial arteriography.

Either catheterization or needle puncture of the brachial artery with retrograde injection of contrast media has provided another avenue of approach. These retrograde technics provide adequate visualization of all the major vessels arising from the aortic arch except the left carotid artery. To opacify this vessel, direct puncture is often necessary or the brachial catheter can be advanced to the root of the aorta and contrast media injected. These technics cannot be used when subclavian artery occlusion prevents cannulation of the brachial artery.

Retrograde femoral catheterization and selective opacification of the extracranial cerebral vessels avoids the hazards attendant with direct puncture of the diseased vessels sup-
Catheterization and cinefluorogram of an occluded left subclavian artery (A) with injection of 6 ml of contrast media. Enlargement of an angiogram (B) taken in the same patient an hour prior to the cinefluorographic study shows that injection of 30 ml of contrast media into the aortic root failed to demonstrate the location and extent of subclavian obstruction.

It provides a means of visualizing all the extracranial cerebral arteries during one examination and with little discomfort to the patient. Repetitive injections of small quantities of contrast media into the diseased vessel provides a high degree of opacification and eliminates the single injection of a large quantity of this material required by nonselective arteriographic technics.

The utilization of cinefluorographic technics allows observation of dynamic changes in patterns of flow in the extracranial cerebral circulation. The effect on the position of the arteries induced by swallowing and movements of the head and neck can be well documented on the cinefluorograms.

As with other methods, there are certain disadvantages associated with the technic described in this report. Current cinefluorographic equipment does not give the detail available with other x-ray technics. Although stenotic lesions are readily demonstrated, small collateral channels associated with these lesions may not be seen. The intracranial circulation is not so well visualized as would be desirable, and occasionally difficulty is encountered in catheterizing the left carotid artery.

The major potential complication of the retrograde femoral approach is impairment of the distal circulation of the right leg. Two patients did have a transient loss of pedal pulses and one patient had permanent loss of pulses below the popliteal artery. The risk of distal arterial insufficiency secondary to dislodged plaques, arterial dissection, periarterial hematoma, or arterial spasm may be inherent in this group of patients with evidence of peripheral arterial disease. Further modification of the percutaneous technic to allow the use of smaller catheters may reduce the incidence of such complications.

At the present time it is believed that a clear-cut history of intermittent claudication,
the absence of pedal pulses, or signs of an abdominal aneurysm are contraindications to retrograde aortic catheterization.

Summary

Selective retrograde femoral catheterization with cinefluorographic visualization of the major extracranial cerebral vessels has been carried out in 35 patients with cerebrovascular insufficiency. Examples of partial and complete arterial occlusion have been illustrated. Selective retrograde catheterization avoids the hazards associated with the percutaneous injection of the arteries supplying the brain. Cinefluorography has demonstrated alterations in flow associated with occlusive disease and physiologic maneuvers. Although the combination of selective catheterization and cinefluorographic visualization of the extracranial cerebral circulation has certain limitations, it has proved to be a valuable diagnostic tool.

References

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