Anatomic Considerations in Carotid Endarterectomy

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It has been reported that Dr. M. E. DeBakey performed the first carotid endarterectomy in 1953 for atherosclerotic obstruction of the carotid artery. The report in 1954 of Eastcott, Pickering, and Rob on the reconstruction of the internal carotid artery in a patient with intermittent attacks of hemiplegia stimulated many surgeons to consider further the problems of cerebral vascular insufficiency. Our original experiences with the surgical treatment of strokes at Piedmont Hospital were reported in 1959. Considerable experience has now been accumulated which seems to show that approximately 60 to 70 per cent of patients with cerebral vascular insufficiency have stenotic, ulcerative, or occlusive lesions in the extracranial portion of one or more of the four major arteries that supply the brain. Various authors suggest that these data implicate these extracranial lesions as the cause of cerebral vascular insufficiency. Unfortunately, experience has at times proved this assumption wrong, much to the disappointment of the operating surgeon.

Caution in the Selection of Patients for Surgery

Even after 20 years of experience, one must admit that at times the selection of patients for surgery is extremely difficult and, as yet, ill-defined. The initial enthusiasm associated with any new surgical procedure is frequently found to be excessive. This was found to be true for stellate ganglion blocks in the treatment of cerebral artery thrombosis. Enthusiasm for ligation of the internal mammary artery for angina pectoris faded under the eye of careful scientific evaluation. The mere presence of a stenosing or ulcerating atherosclerotic plaque in the internal carotid or vertebral artery does not insure that removal of the plaque will benefit the patient. Even the improvement in these patients following removal of an atherosclerotic plaque may not be entirely related to the operative procedure, as some of these patients improve spontaneously. The ability to tolerate obstruction in one or more of the four major arteries that supply the brain is dependent upon the development of collateral circulation. Many transient cerebral ischemic attacks may be due to distal embolization of thrombotic or atherosclerotic material from an ulcerating plaque and may not be related to the degree of stenosis produced by the plaque. Most physicians agree that our present surgical procedures upon the carotid arteries have a place in the management of cerebral vascular insufficiency; however, further study is needed to determine more precise methods of selecting patients for carotid endarterectomy.

Pathology

For all practical purposes, atherosclerosis is the usual cause of obstructive or ulcerative lesions in the extracranial portion of the carotid arteries. The lesion is usually located in the base of the internal carotid artery and/or carotid bifurcation. The lesion extends 2 to 6 cm into the internal carotid artery; however, at times it may extend to the base of the skull or intracranially. On occasion one encounters embolic obstruction of the carotid artery or obstruction due to arteritis, fibromuscular hyperplasia, or kinking. It has been recognized for some time that atherosclerotic lesions will infrequently accumulate where major arteries
branch. Swirling, eddying, and other flow changes have been offered as the explanation for deposition of atherosclerotic material at arterial bifurcations.

DeBakey and associates have described three patterns of involvement in the carotid arteries - proximal, cervical, and intracranial. The proximal portion of the external carotid artery is also frequently involved. Obstruction to the right internal carotid artery may occur at its origin from the brachiocephalic artery or from direct obstruction at the origin of the brachiocephalic artery from the aorta. In the cervical form the atherosclerotic involvement is in the region of the bifurcation of the common carotid artery. Intracranial involvement occurs in the carotid artery at or distal to the foramen lacerum. Finally, a mixed form of obstruction may occur in which the atherosclerotic lesions involve multiple sites or are diffuse.

Practical Anatomic Considerations in Carotid Endarterectomy

Variations in arterial anatomy are frequent and numerous. The common or standard type anatomy pertinent to the carotid arteries will be stressed with the idea that the operating surgeon will familiarize himself with the many possible variations. Exposure of the carotid bifurcation can be made by a short, curved, transverse cervical incision along the lines of Langer. This results in a cosmetically attractive scar. Most surgeons feel an oblique incision along the anterior border of the sternocleidomastoid gives easier and better exposure of the anatomic structures. The thin, quadrangular platysma muscle lies beneath the panicus adiposus and is separated from the external layer of the cervical fascia by loose areolar tissue. The main cutaneous branches of the cervical plexus and the external jugular vein lie beneath this muscle layer. All of these structures must be sectioned; however, no significant functional deficit results. The platysma muscle is supplied by the cervical branch of the facial nerve. Variation in the muscular development of the platysma is frequent. In making the cervical incision one must be certain that the supramandibular and inframandibular branches of the facial nerve are protected from injury in order to avoid drooping of the lower side of the face. A number of the superficial sensory branches of the cervical plexus are necessarily sectioned. This produces varying degrees of numbness medial to the incision, but this problem corrects itself in 3 to 6 months as nerve regeneration occurs.

Variations of the Aortic Arch

The branches of the aortic arch are the brachiocephalic, left common carotid, and left subclavian arteries. The brachiocephalic artery is 3.5 to 5 cm in length and rises to the level of the right sternoclavicular joint to bifurcate into the right common and right subclavian arteries. The left common carotid artery is usually the second branch of the aortic arch, although it may arise from the brachiocephalic (formerly named the innominate) artery.

The exact incidence of aortic arch variations is not known, but in view of the radical modifications which the original symmetric arrangement of the aortic arches undergo during embryologic development, it is not surprising that variations from the usual adult plan frequently occur. In the adult, the aortic arch measures approximately 28 mm in diameter and, after giving off its three main branches, the diameter averages 23 mm. Opposite the origin of the left subclavian artery is a ligament, the ligamentum arteriosum, that connects the concavity of the arch to the proximal portion of the left pulmonary artery. Between the left subclavian artery and the ligamentum arteriosum there is, always in the newborn infant and
occasionally persisting in the adult, a constriction of the arch - the isthmus aortae. This may be succeeded by a dilatation named the aortic spindle. Extreme narrowing of the arch at the isthmus is known as coarctation of the aorta. Many variations in branching of the aortic arch occur. At one extreme, the usual three separate origins from the aortic arch occur and, at the other extreme, all branches arise from a single main stem called the brachiocephalic artery. All sorts of combinations may occur. The right dorsal aortic root may persist so that the supply to the descending aorta is double. One arch may differ from the other in caliber. A double aortic arch may form a ringlike constriction around the trachea and esophagus necessitating surgical intervention. The left aortic root may disappear leaving a right aortic arch and this may or may not be associated with situs inversus. On occasions there may be persistence of the right aortic arch resulting in complete reversal of the arch branches. In these instances, the right subclavian artery passes dorsal to the trachea and may result in esophageal compression. Abnormalities of partitioning of the primitive ventral aortic trunk may occur with resulting various degrees of aortic and pulmonary artery narrowing. This may go so far as complete obstruction to the lumen of either the ascending aorta or the pulmonary artery. A persistent ductus arteriosus may permit these infants to survive. This is in distinct contrast to the persistence of an unclosed ductus arteriosus in an individual with an otherwise normal vascular system. Surgical intervention for this condition, with ligation of the ductus arteriosus, was successfully carried out for the first time by Gross and Hubbard in 1938. Vascular surgeons operating upon the carotid arteries must be familiar with and prepared to interpret any of these anatomic variations. The exact vascular anatomy for each individual is usually first brought to light by the arteriographic studies performed upon patients with symptoms suggestive of cerebral vascular insufficiency. Insufficient knowledge of anatomy and embryology may lead to erroneous interpretation of arteriograms and a possible catastrophic surgical end result.

**Common Carotid Arteries**

The common carotid arteries are paired vessels that lie within the anterior cervical triangle on the prevertebral fascia. They are from 8 to 12 cm in length and extend from the sternoclavicular articulation to the superior border of the thyroid cartilage where they divide into the external and internal carotid arteries. The point of bifurcation varies, but in 85 percent of individuals it occurs within 2.5 cm of the top of the thyroid cartilage. The common carotid arteries are contained in the carotid sheath which houses the internal jugular vein and the vagus nerve. The jugular vein may lie ventro- or dorsolateral to the common carotid artery while the vagus nerve lies dorsal and between the two vessels. The ansa cervicalis, with its superior and inferior rami along with the branches to the strap muscles, is located in the anterior part of the carotid sheath and should be protected from injury. At times one or more of the branches to the strap muscles may hinder exposure and these branches can be sacrificed without significant residual. In exposing the common carotid arteries the crossing middle thyroid veins are tied and sectioned.

Dorsal and medial to the common and internal carotid arteries are the retropharyngeal space and the prevertebral fascia with its enclosed cervical sympathetic trunk and ganglia. Some surgeons feel that the superior cervical sympathetic ganglia should be removed at the time carotid artery surgery is performed. The superior ganglion is easy to expose and requires only a few minutes to remove. Removal of the ganglion produces Horner's syndrome, which causes the patient minimal problems, or none at all.
External Carotid Artery. The external carotid artery is the smaller (in adults it is of equal size) of the two branches into which the common carotid divides. Eight independent branches usually arise from the external carotid artery before it divides into its two terminal branches - the maxillary and superficial temporal arteries. Terminal branching occurs posterior to the neck of the mandible. One usually ligates the superior thyroid artery permanently or temporarily when performing a carotid endarterectomy, as this provides better exposure. The ascending pharyngeal artery is described as the second branch of the external carotid artery but it may be the first branch and, at times, it may actually arise from the carotid crotch or from the proximal portion of the internal carotid artery. This vessel may be ligated to gain exposure. Better exposure can also be obtained by tying and cutting the facial and lingual veins. The hypoglossal nerve is located beneath the facial vein, on the surface of the external carotid artery, and one must protect this nerve from injury or hemi-atrophy of the tongue will ensue. The sternocleidomastoid artery arises from the posterior side of the external carotid artery and then hooks over the loop formed by the hypoglossal nerve and follows the accessory nerve into the sternocleidomastoid muscle. By ligating and sectioning the sternocleidomastoid artery one can push the hypoglossal nerve superiorly and protect it from injury.

Internal Carotid Artery. The internal carotid artery originates from the common carotid artery opposite the superior border of the thyroid cartilage and, as mentioned above, in adults the external and internal carotid arteries are of equal size. The proximal portion of the internal carotid artery is dilated to form the carotid sinus which is innervated by the carotid sinus nerve. This nerve arises from the glossopharyngeal nerve at the base of the skull and descends between the internal and external carotid arteries to innervate the carotid sinus. Blockage of the sinus nerve with a local anesthetic prior to any dissection or manipulation of the carotid bulb region is essential in order to prevent unwanted baroreceptor reflexes. We have not noted any permanent elevation in blood pressure from dividing one or both carotid sinus nerves. It is felt that numerous other baroreceptor nerves resume the function of the carotid sinus nerves. The carotid body, a chemoreceptor, is 2 to 3 mm in diameter and can be seen in the region of carotid bifurcation. If necessary this structure can be removed without producing any known permanent effects. The internal carotid artery is usually located dorsolaterally to the external carotid artery and this may cause some confusion due to nomenclature - internal and external. The internal carotid artery ascends vertically lying on the prevertebral fascia, with the internal jugular vein lying laterally. When the carotid bifurcation is high, exposure can be gained by sectioning the ligamentous portion of the stylohyoid muscle and the ligamentous portion of the posterior belly of the digastric muscle. With low carotid bifurcation, exposure may be helped by cutting the superior belly of the omohyoid muscle. At times the internal carotid artery becomes elongated and tortuous and may actually buckle or kink upon itself and interfere with blood flow. The kinking may be congenital or acquired and surgical correction for kinking may at times be necessary. The vagus nerve descends dorsolaterally to the internal carotid artery. Medial to the artery, the superior laryngeal nerve courses in a medial and inferior direction to the larynx and may be injured if careful dissection is not carried out. It is felt that injury to the superior laryngeal nerve is the most common and serious nerve injury produced by surgeons performing carotid endarterectomies. The cervical portion of the internal carotid artery has no named branches, although the ascending pharyngeal artery has frequently been noted to arise from this vessel. At the base of the skull the glossopharyngeal, vagus, accessory, and hypoglossal nerves exist just dorsal to the artery. As the internal carotid leaves the cavernous sinus it gives of the
ophthalmic artery, then the anterior cerebral, middle cerebral, posterior communicating, and chorioid arteries.

Summary

Patients with cerebral vascular insufficiency can frequently be treated and benefitted by carotid endarterectomy. Experience has now been accumulated which shows that approximately 60 to 70 per cent of patients with cerebral vascular insufficiency have stenotic, ulcerative, or occlusive lesions in the extracranial portion of one or more of the four major arteries that supply the brain. Careful diagnostic studies must be performed in order to properly select patients for surgery. As with any operative procedure it is essential that the operating surgeon have a thorough knowledge of the embryology and anatomy along with an understanding of the anatomic variations that may be encountered in the operative field. At Piedmont Hospital we refuse to accept the old adage which propose that "It is futile to write anything new anatomically because it has all been said before." New operations, new approaches, and new knowledge keep anatomy in a live and dynamic state.