From Hippocrates to Palmaz-Schatz,  
The History of Carotid Surgery  

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The extracranial carotid artery is the most common site for peripheral vascular procedures. Although the association of carotid disease and neurologic dysfunction was understood by the ancient Greeks, over 1700 years would pass before the relevant anatomy was described. In the 16th and 17th centuries, attempts at treatment of carotid injury and aneurysm by ligation were met with extremely high rates of stroke and death. It is not until the mid 20th century, with the introduction of carotid angiography and improved vascular surgical techniques, that the era of reconstructive carotid surgery begins. We present a synopsis of the history of carotid surgery from ancient times to present day.  

Key Words: Carotid artery; Carotid surgery; Occlusive carotid disease.  

The impact of carotid artery occlusion on neurologic function has been appreciated for over 2000 years (Table 1). Some of the basic terms for carotid disease come from the ancient Greek medical literature. Hippocrates, about the turn of the fourth century BC, not only used the term ‘apoplexy’ (‘to strike down’) but also gave a faithful and accurate description of strokes, prodromal symptoms, and transient ischemic attacks and knew that lesions of the carotid artery resulted in contralateral hemiplegia.  

According to Rufus of Ephesus, who lived about 100 AD, the term carotid was derived from the Greek word meaning ‘to stun, stupefy, or fall into deep sleep.’ The reason for naming the artery was that compressing it caused loss of consciousness—‘sleep.’ This was also described by Ambroise Paré: ‘... the arteries which they call carotids or soporales, the arteries for sleep.’  

Carotid Artery in the Middle Ages  

The first meaningful description of the cerebral vessels, including the vertebral-basilar system, was given by the noted Swiss physician Johann Jakob Wepfer. In his Treatise de Apoplexiae, printed in Schaffhausen in 1658, he described the hemispheric supply of the brain by the carotid arteries, ‘which proceed intact and not divided,’ and made the first known reference to the association of pathological changes in the cerebral vessels and symptoms of cerebral ischemia.  

Thomas Willis expanded on the work of Wepfer, Casserio, and others and in 1664 published his Cerebri Anatomie. Although he was not the first to describe the vascular ring which now bears his name, it was not until his treatise, with illustrations by Sir Christopher Wren, that its true significance was understood.  

The Diseased Carotid Bifurcation  

In 1809, the noted British surgeon Sir Astley Cooper recognized and discussed the possibility of stroke after carotid ligation. Almost 20 years later, Abercrombie drew an analogy between cerebral ischemia and gangrene of the legs. The relationship between extracranial cerebrovascular disease and stroke was noted by Gull in 1855. A year later, Virchow described carotid thrombosis with ipsilateral blindness.  

The first suggestion to restore blood supply to the brain was made by Gluck in his treatise ‘Die moderne Chirurgie des circulations Apparates,’ published in Germany in 1898. He was also the first to replace a segment of the common carotid artery with a vein graft in experimental animals. Although the clinical picture of internal carotid thrombosis was fairly accurately described as early as 1881 by Penzoldt, the syndrome consisting of temporary hemiparesis,
aphasia, and transient loss of consciousness was first tied conclusively to occlusive disease of the carotid arteries by Chiari, in Prague, in 1905.13

One of the most important individuals in the development of an understanding of extracranial occlusive carotid disease was Ramsey Hunt, who in 1914 described in detail the clinical syndrome of contralateral hemiplegia and ipsilateral amaurosis fugax owing to cervical carotid disease and emphasized that the latter is a common cause of ‘brain softening’ and stroke. He presented a strong case connecting extracranial cerebrovascular disease with stroke, and also urged that ‘in all cases presenting with cerebral symptoms of vascular origin the main arteries of the neck should be carefully examined for a possible diminution or absence of pulsation.’

Also in 1914, Matas described his compression test, which challenged the efficiency of collateral circulation.14 Bailliart in 1917 investigated the behavior of the arterial pressure in the retinal arteries. His studies were the precursors of ophthalmodynamometry.15

The first report on cerebral angiography was presented by Egas Moniz, of Lisbon, on July 7, 1927 session of the Societe de Neurologie in Paris. He presented satisfactory angiograms in five patients using intra-carotid injection of strontium bromide and sodium iodide. Babinski, the doyen of French neurology, congratulated Moniz, saying that the radiograms presented by Moniz were ‘remarkable.’17

A carotid occlusion (presumably a thrombosed aneurysm) was first diagnosed by angiography by Sjöqvist in 1936.18 One year later, Moniz presented four patients in whom the diagnosis of internal carotid artery occlusion was made by angiography and concluded that whenever the clinical symptoms suggest internal carotid artery occlusion, ‘cerebral angiography will always provide diagnostic certainty.’19 From 1944 to 1948, it gradually became clear that the symptoms of carotid disease may be caused not only by complete occlusion but also in a rather sizable group of patients by stenosis of the vessel at one or several points. In 1944, Krayenbuhl recommended that determination of the retinal artery pressure described by Bailliart in 191715 should be applied in the diagnosis of internal carotid artery occlusion.20

During the 1950s, arteriosclerotic occlusion emerged as a frequently occurring and clinically recognizable entity. In 1955, Millikan and associates described the syndrome of ‘intermittent insufficiency of the carotid arterial system,’21 whose characteristics were similar to the ‘cerebral intermittent claudication’ described by Hunt in 1914.22 They emphasized the relationship of these attacks to the state of the
collateral circulation and to changes in blood pressure. This was also demonstrated in the clinical observations of Meyer and associates in 1956, who were able to reproduce the attacks in patients with carotid artery disease by changing their position on a tilt table. 23

During the fourth and fifth decades of our century, Carl Fisher, 19, 24, 25 along with Ramsey Hunt, 22 made what were probably the most important advances in clarifying and defining the clinical picture of carotid stenosis. Fisher revived Chiari’s theory that ulcerative plaques of the carotid bifurcation may cause cerebral embolism. Fisher also called attention to the bifurcation atheroma as a frequent cause of contralateral transient and permanent motor dysfunction, and went so far as to predict that ‘vascular surgery will find a way to bypass the occluded portion of the artery during the period of ominous fleeting symptoms.’ 24

The effectiveness of collateral channels from the external to the internal carotid artery was emphasized by Hutchinson and Yates who in 1957, showed that these collaterals are even more effective than those of the vertebral artery. 26

### Nonreconstructive Carotid Surgery

The first operations on the carotid artery were limited to ligation of the vessel. According to Cutter (1920), it was Jean Louis Petit who first noted that occlusion of the carotid artery is a condition compatible with life. He made his observation in a patient with an aneurysm of the common carotid artery whom he had followed for 7 years and who at autopsy proved to have the lumen of the vessel completely occluded by thrombi. 29

The first report of operative ligation of the common carotid artery was that of Ambroise Paré in 1552. His patient, however, developed aphasia and hemiplegia. 3 The elective ligation of the common carotid artery with survival was performed by Hebenstreit and reported in 1793. 30 The first case published in the English literature was that of John Abernathy in 1811. 31, 32 Abernathy, a pupil of John Hunter, operated on a man whose carotid artery was gored by the horns of a cow. The patient survived the operation without any immediate undue consequences but suffered hemiplegia and died the following day. While the procedure is believed to have taken place in 1798, it was not reported until 1804. Twitchell in 1843 reported carotid artery ligation for penetrating trauma with survival. 33

The first operations for carotid aneurysms consisted primarily of proximal but occasionally also of distal ligations. Such procedures were performed by Cogswell in 1803, 34 and by Sir Astley Paston Cooper in 1809. 35 Cooper’s first patient died of hemorrhage; his second, of infection. On June 22, 1809, Cooper repeated the operation, this time successfully, and the patient lived 13 years thereafter. 35

Ligation remained the treatment of choice for the management of carotid artery aneurysms until the middle of this century. The first carotid ligation for carotid corpus cavernosum fistula was performed by Benjamin Travers in 1809, and the first for intracranial aneurysm by Victor Horsley in 1885. 2 Ligation was performed with increasing frequency, not only for aneurysms and injury but also for tumorous involvement, arteriovenous communications, etc., until the dangers of the procedure became generally known.

In 1902, Jâboulay suggested to Carrel that carotido-jugular-vein anastomosis might help revascularize the brain when there is insufficient blood supply owing to thrombosis. 36 In 1911, Matas modified the technique of proximal carotid ligation for aneurysms by applying metal bands in lieu of ligatures. 14

In the later 1930s, the operation most frequently performed for carotid artery occlusion was excision of the occluded segment according to the principles of Leriche. 37 The first such intervention was performed by Chao and associates in 1938 at the Medical College of Peking in 1935 on a 48 year-old Russian who ‘seemed to be constantly worried’ and ‘appeared to be emotional with rather frequent exhibitions of tears.’ Their second patient was a 27-year-old student, the only patient recorded in the annals of carotid surgery who after having collapsed ‘was taken by rickshaw to his residence.’ To the surprise of the surgeons, the mental conditions of both patients improved after the operation and they concluded that in such cases ‘excision of the thrombosed artery should be carried out.’ 38

Throughout the 1940s, the treatment of choice for cervical internal carotid occlusion remained excision and ligation to ‘prevent the propagation of the clot and release vasospasm.’ 39 In a few cases in which the symptoms seemingly improved, the beneficial effect may have been the cessation of repeated embolization from the occluded site.

To present a complete history of the development of extracranial carotid surgery, the procedure introduced by Sciaroni in 1948 must be mentioned; he named it ‘reversal of the circulation of the brain.’ It consisted of creating side-to-side anastomosis between the common carotid artery and the internal jugular vein. The resulting arteriovenous fistula was expected to increase cerebral blood flow, alleviate symptoms of paralysis and epileptic seizures, and cure hypertension. 40 Sciaroni’s example was soon followed by others.
describing excellent results. Because of such enthusiastic reports, the operation was performed for several years before it fell into disrepute.

The Age of Reconstructive Carotid Surgery—Non-occlusive Carotid Disease

The feasibility of restoring flow through the interrupted carotid artery by anastomosis and vein grafts was proven experimentally by Gluck in Germany in 1898,11 by Jâboulay in France in 1902,36 and by Carrel and Guthrie in the United States in 1902.41–43

The earliest successful carotid reconstructions were performed in patients with aneurysms long before similar operations were performed for occlusive disease. The reason for this is simple: surgeons who operated on aneurysms were able to do so because of the ease of diagnosis of the lesion. They did not have to wait for the development of angiography, without which the presence of carotid occlusion or stenosis can hardly be established.

The first surgeon to restore carotid continuity after resection for aneurysm, or, as a matter of fact, for any kind of carotid lesion, was von Parczewski, who in 1916 resected an arteriovenous aneurysm of the common carotid artery and restored continuity by performing an end-to-end anastomosis.44 His example was soon followed by von Haberer, who in 1918 successfully applied resection and lateral suture as well as resection and end-to-end anastomosis in soldiers of the German army wounded in World War I.45 In the same year Lexer and Denck also gave reports of successful resection of the common carotid with end-to-end anastomosis for war-inflicted aneurysms.45

It is not generally recognized what an important role surgical oncologists played in the development of carotid artery surgery. Their involvement with surgical restoration of the carotid artery stems from the frequent involvement of the carotid artery during radical neck dissections for malignancy. Similarly, breakdown of the common carotid artery sometimes occurs after intensive radiation treatment of the neck. Complete excision of the tumor may also necessitate the resection of the invaded vessel. While initially such cases were handled by ligation, it was soon realized that ligation of the carotid artery bears an unacceptable mortality and stroke rate.

Surgical oncologists, like their colleagues operating on carotid aneurysms, were not hampered by a lack of sophisticated technology in establishing the diagnosis. This gave them a considerable edge over those involved in the treatment of occlusive disease. The latter were for the most part general surgeons caught in desperate situations that called for bold responses. And some of them did indeed respond with measures that were far ahead of their time. The first report of carotid reconstruction in English is that of Harry G. Sloan, who in July 1920 operated on a patient with recurrent carcinoma of the lip with cervical metastases. He wrote: ‘We nicked the common carotid as it lay in a mass of scar tissue…. Before the bleeding was controlled by finger compression above and below the bleeding, the vessel wall was badly damaged by hemostats for about three-fourth of a centimeter…. We decided to excise the damaged area of the vessel and make an end-to-end anastomosis. Using a mosquito hemostat for a needle holder, we succeeded in placing the sutures. We employed Carrel’s original method of suture, i.e., three guy sutures through all the coats of the vessel.’46 Sloan’s patient fully recovered without neurological deficit and was noted to have good temporal pulses after the operation. Enderlen, in an article on carotid body tumors published in 1938, described a similar case in which he had operated 20 years previously.47 A most important but not very well known figure in carotid surgery is John J. Conley (Fig. 1), who practiced at Saint Vincent’s Hospital in New York City in the early 1950s. Conley’s special expertise was oncological surgery of the neck, in the course of which he often removed portions of the internal and common carotid arteries. Realizing the ‘gravity of sudden impairment of blood supply to the brain’ and ‘in the hope of salvaging some patients who would otherwise die of cancer and fatal carotid hemorrhage,’ Conley designed an appropriate operation. It consisted of end-to-end anastomosis between the distal stumps of the internal and external carotid arteries, which permitted the blood to flow through the anastomotic connections of the external carotid artery from the contralateral side into the external carotid artery. In describing this ingenious technique in 1952, Conley mentioned that vascular transplants of autogenous veins would be even more advantageous to maintain adequate blood supply to the brain. A year later, he reported for the first time in the surgical literature, a case in which a portion of the common carotid artery that had ruptured owing to irradiation was replaced with a segment of autogenous saphenous vein.48

In the same report, Conley published a series of case histories describing the clinical course of patients operated upon for tumors of the carotid body or for extensive cancerous invasion of the neck in whom carotid artery excision had become a necessity. With a technique and planning that would withstand the scrutiny of modern times, Conley successfully replaced the common and/or internal carotid arteries.
in 11 patients. He operated on his first patient in March 1951 and corrected the deficiency in the internal and common carotid arteries by the ‘immediate anastomosis of a segment of the great saphenous vein into this area.’ With his impressive series of patients, Conley proved to be a surgeon far ahead of his time.

Reconstruction for Occlusive Carotid Disease

Like many other surgical advances, surgery for carotid occlusion has developed over an unnecessarily long period of time from its conception to its wide general application today. This is especially true when we consider that sophisticated operations on the carotid artery, including resection and end-to-end anastomosis as well as replacement with autogenous vein grafts for tumors and aneurysms, were performed 30 years before the first such operation was done for carotid occlusion. In seeking to chart an accurate history of surgery for occlusive carotid disease, difficulties are encountered in establishing the chronology of the first interventions. For example, the first carotid reconstruction by resection and anastomosis was performed in 1951 but was not reported until 1954. Similarly, the first successful carotid endarterectomy was performed in 1953 but was not fully described until 19 years later. Moreover, in trying to identify the priority of surgical procedures and those who performed the initial operations to restore blood flow through the interrupted cervical carotid, several factors must be considered: the type of pathology, the type of procedure, the outcome of the operation, and the date of surgery versus the date of publication.

Surgery to restore patency in occlusive carotid disease began in the early 1950s with somewhat desperate attempts to salvage patients with acute strokes. As diagnostic methods, primarily angiography, evolved and became refined, a plethora of methods to restore carotid flow were developed but later gave way to endarterectomy with or without patch arterioplasty as the procedure of choice for most cases of occlusive carotid artery disease. This development was slow, however, and the confused state-of-the-art in 1953 is clearly reflected in the summary of Gurdjian and Webster:

Following diagnosis, the management may include: (1) bilateral stellate block; (2) excision of the cervical sympathetic on one or both sides; (3) the use of anticoagulants; (4) excision of the freshly formed clot to reestablish circulation through the thrombosed area; (5) carotid artery ligation and excision of a portion of the thrombosed vessel; (6) ligation of the carotid siphon intracranially.

In Toronto, Gordon Murray performed what was probably the first successful operation to restore blood flow in an occluded common carotid artery in 1950. The first reconstruction of an occluded internal carotid artery was performed in Buenos Aires in 1951 on a 41-year-old man who had been admitted to the Institute de Medicina Experimental with symptoms of convulsions, loss of consciousness, aphasia, blindness in the left eye, and right hemiparesis. Percutaneous left carotid angiography revealed a severe stricture of the internal carotid just above the bifurcation. The patient was operated upon by Carrea, Molina, and Murphy. During the course of the operation, ‘the internal carotid artery was cut about 5 mm above the abnormal area, the external carotid was also cut at the same level and the proximal carotid was anastomosed end-to-end to the distal portion of the internal carotid.’ The patient fully recovered from the hemiparesis and aphasia; however, he remained blind in the left eye. The patency of the vessel was confirmed by angiography. The case was reported 4 years later.

Although the technique of endarterectomy was introduced into the treatment of atherosclerotic
occlusion of the aortoiliac system as early as 1947 by dos Santos,53 15 years elapsed before it was first attempted in carotid disease by Strully, Hurwitt, and Blankenberg on January 28, 1953 at the Montefiore Hospital in New York City. Their patient, a 52-year-old man; had a completely occluded internal carotid artery owing to arteriosclerotic stricture with superimposed thrombosis. During the operation, ‘a piece of clot with adherent intima was removed… but retrograde flow of blood could not be obtained.’ The procedure was finally terminated by resection of the carotid artery, but the continuity of the carotid circulation was not restored. The authors concluded that ‘if the diagnosis in this case had been made earlier it might have been possible to remove the clot completely.’54

The first successful carotid endarterectomy was performed by DeBakey (Figs 2 and 3) on August 7, 1953, in a 53-year-old man with transient ischemic attacks. The diagnosis was made without the benefit of angiography on the basis that ‘published reports had indicated that such lesions may be well localized at the bifurcation of the common carotid artery.’ The left carotid bifurcation was explored, and a ‘well-localized atheromatous plaque (which) produced severe stenosis at the origin of the internal, as well as the external carotid artery’ and a ‘partially organized fresh clot partially filling the lumen of the common carotid artery’ were removed.55,56

The operation which gave great impetus to the early development of surgery for carotid occlusion was that performed by Eastcott, Pickering, and Rob on May 19, 1954 and reported in the November issue of the *Lancet* in the same year.57 Their patient was a woman with transient ischemic attacks whose left carotid bifurcation was severely narrowed by an arteriosclerotic plaque. In the course of surgery, which was performed in moderate total-body-immersion hypothermia, the external carotid artery was divided and ligated, and the carotid bifurcation containing the occlusive atheroma was resected. The continuity of the carotid circulation was restored by direct anastomosis between the common carotid artery and the stump of the internal carotid artery. The patient fully recovered from the operation, and had no further attacks of cerebral ischemia.56 In the following years, DeBakey, Eastcott, Rob, Thompson, Moore, Baker, and Wylie exerted the primary influence on the development of carotid artery surgery.55,56,58

On July 7, 1954, Denman, Ehni, and Duty performed an operation that included carotid artery resection and replacement of the removed segments
with lyophilized homografts. Their case is noteworthy not only because the procedure was staged bilaterally but also because, while on one side the circulation to the internal carotid could not be restored, the external carotid was patent and an arterial graft was inserted between it at the common carotid. Restoration of the external carotid circulation was considered desirable primarily because of its communication through the ophthalmic artery with the circle of Willis.\(^6^9\)

In August 1956, Lyons and Galbraith used the method of subclavian-to-common carotid graft to bypass a proximal common carotid occlusion employing a vascular prosthesis manufactured of nylon.\(^6^2\) Side-to-side anastomosis between the external and internal carotid arteries to relieve occlusion of blood flow was performed by Wagner in 1958. In the same year, replacement of the carotid was performed with Dacron by Fields, Crawford, and DeBakey\(^6^3,6^4\) and with homograft by Roberts and associates in 1958\(^6^5\) and by Van Allen and associates a year later.\(^6^6\) In 1959, Bahnson performed the first bypass operation from the aortic arch to the carotid artery using homologous aorta as a graft.\(^6^7\) Transposition of the subclavian to the common carotid artery was described by Parrott in 1964.\(^6^8\)

The internal carotid artery ‘stump pressure’ (the pressure measured in the internal carotid artery after proximal crossclamping) as a hemodynamic indicator of collateral cerebral blood flow was described by Crawford and associates in 1960.\(^6^3\)

Indwelling temporary bypass shunting was first applied during carotid reconstruction by Mical, Hejnal, Heinol, and First at the Institute for Experimental Surgery, in Prague, in 1966.\(^6^9\) They used small plastic tubes inserted through the arteriotomy incision to maintain cerebral perfusion.

In the early 1960s, elective application of temporary shunting was advocated by Thompson and associates.\(^7^0,7^1\) Selective application of the shunt on the basis of the measurement of the stump pressure was recommended by Moore and associates in 1969\(^7^2\) and on the basis of electroencephalographic monitoring by Callow in 1980.\(^7^3\)

The late 20th century saw a marked increase in the surgical treatment of carotid artery occlusive disease not as a result of evolving technique, but rather due to the results of several large prospectively randomized trials in the US and Europe. The largest of these, the European Carotid Surgery Trial (1996)\(^7^4\) and the North American Symptomatic Carotid Endarterectomy Trial (1991)\(^7^5\) demonstrated improved outcomes for symptomatic patients with high grade (70–99%) stenosis when compared to medical treatment. Initial discrepancies between the outcomes of the two studies in moderate stenosis (50–69%) likely resulted from differences in lesion measurement techniques. Both NASCET and a recent reanalysis of the ECST data using NASCET criteria,\(^7^6\) demonstrate a small but statistically significant reduction in stroke or surgical death at 5 years for symptomatic patients with moderate (50–69%) stenosis. Treatment of carotid disease was given further impetus by the results of the Asymptomatic Carotid Atherosclerosis Study in 1995, although gains were more modest and highly dependent on excellent surgical outcomes.\(^7^7\)

### Carotid Angioplasty

Internal carotid artery angioplasty was first described by Morris, Lechter and DeBakey in 1967, as a treatment for fibromuscular dysplasia. An open technique was utilized with gradual dilatation of the lesions using biliary dilators. There were no neurologic complications in the 12 patients thus treated.\(^7^8\)

Percutaneous transluminal angioplasty of the internal carotid artery was reported by Mathias in 1977.\(^7^9\) In 1994, Marks and his associates at Stanford University published their experience using Palmaz stents in the internal carotid arteries of two patients who had failed medical treatment for spontaneous dissection. Based on the favorable outcomes, the authors suggested that stents might be used in conjunction with angioplasty in the cerebrovascular circulation to avoid the complications of acute dissection and prolonged balloon inflation.\(^8^0\)

Diethrich, Ndiaye and Reid treated 117 arteries in 110 patients with primary angioplasty and stenting between 1993 and 1995.\(^8^1\) Clinical success at 30 days was 89.1%, however, the authors felt that the rate of neurologic complications—10.9% combined stroke and TIA—was too high to recommend the widespread application of this procedure. This risk was further
demonstrated in a randomized trial between endarterectomy and angioplasty with stent at Leicester Royal Infirmary, UK. After enrolling 17 patients, the trial was halted due to the occurrence of significant neurologic events in five of the seven patients (70%) undergoing angioplasty.82

Refinement of patient selection criteria and standardization of techniques continue to improve the results of internal carotid artery stenting. To further reduce the incidence of embolic stroke, several cerebral protection devices are now being tested. The current devices utilize a filter or balloon placed distal to the lesion, or proximal balloon occlusion with or without flow reversal through the internal carotid artery. Although early results are encouraging, pending the outcome of these trials, the consensus remains that carotid artery stenting should be restricted to high-risk patients in experienced centers where advanced neuroradiology skills are available.83,84

Conclusion

We have attempted to trace, in a complete but concise manner, the evolution of our current understanding of carotid disease and its treatment from antiquity to the present day. No history, however, is truly ‘complete’, and we offer our apologies to those we may have slighted by omission.

That the treatment of carotid disease continues to evolve should come as no surprise. Procedures that would have been unthinkable 50 years ago are commonplace today. Endovascular therapies are promising and it seems likely that this trend will radically alter the surgical terrain of tomorrow. Long held surgical precepts of ‘wide exposure’ and ‘durability’ are giving way to ‘minimally invasive’ and ‘assisted primary patency’. As each succeeding generation makes its contribution, the previous ‘truths’ will be questioned and new technologies will challenge the status quo.

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