When persons in good health are suddenly seized with pains in the head, and straightway are laid down speechless, and breathe with stertor, they die in seven days, unless fever come on

—Hippocrates 460–37 BC, Aphorisms on Apoplexy

Since Hippocrates’ dramatic description of the clinical features in a patient, the authors and many others believed to have experienced subarachnoid hemorrhage over 2400 years ago; this illness has remained a mystery up until the 19th century. The review describes the evolution of our understanding of subarachnoid hemorrhage and its treatment originating in first civilizations up to this very day.

Ancient Egypt and Roman times

First descriptions of an arterial aneurysm date back as early as 3000 years BC. Imhotep (2725 BC), the founder of ancient Egyptian medicine, is believed to be an author of a paragraph found in the Ebers Papyrus on the treatment of arterial aneurysms using cautery:

This is a vessel swelling, a disorder I will treat. It is the vessels that cause it. It originates from an injury upon the vessel. Then thou shalt apply to it treatment with the knife; this [the knife] is heated in fire; the bleeding will not be considerable

The progress of our understanding of arterial aneurysms as a cause of subarachnoid hemorrhage was virtually nonexistent for many years due to religious superstitions and reliance of external bodily examination. It was not until 2 millennia later when first pathophysiological mechanisms were recorded. Ephesian physician Faenius Rufus (117 BC), who trained in Alexandria, suggested that arterial dilatation may occur as a result of trauma. Several hundred years later, Greek physician Galen of Pergamon (AD 129–210) coined the term aneurysm (Greek aneurysma, a widening; from anu, across; and eurys, broad) and recognized 2 distinct entities of true and false arterial aneurysms:

An artery having become anastomosed (ie, dilated) the affection is called aneurysm; it also arises from the wound of the same, when the skin lies over it is cicatrized, but the wound in the artery remains, and neither unites nor is blocked by flesh.

From Aneurysm to Subarachnoid Hemorrhage

Over the course of Middle Ages, the recognition and management of peripheral artery aneurysms advanced considerably; however, the discovery and demonstration of intracranial aneurysms did not occur until the late 18th century. Morgagni of Padua (AD 1682–1771) described an unruptured dilatation of the posterior branches of both carotid arteries on autopsy in 1761. Four years later, Francisci Biumi published a postmortem description of a ruptured cavernous carotid artery aneurysm. However, it was John Blackall (AD 1771–1860) who made the link between clinical features of subarachnoid hemorrhage and ruptured intracranial aneurysm. In a report published in 1810, Blackall described anatomic features of a ruptured basilar artery attributing it to the cause of sudden death in the Swedish crown prince Charles August, an event which led to a new royal dynasty existing to this day. Samuel Wilks, a British physician who worked in Guy’s hospital in London, further characterized clinical and pathological features of sanguineous meningeal effusion in 4 case series at autopsy and coined the term spontaneous subarachnoid hemorrhage in 1859. At the time, no diagnostic tools existed, hence the diagnosis of subarachnoid hemorrhage was mostly made postmortem. Occasionally, the signs such as third nerve palsy, pulsation in a patient’s head, or a bruit on auscultation would be recognized as features of an intracranial aneurysm. Unless present, these patients were treated—to the extent treatment existed—as if they had a stroke.

Ligation Era

Peripheral arterial ligation was popularized by John Hunter (AD 1728–1793), who was first to perform the ligation of the proximal neck of a popliteal aneurysm. Despite the first...
ligation of carotid artery performed 200 years before Hunter by Ambroise Pare (1510–1590) on a patient with penetrating neck wound who subsequently developed dysphasia and hemiplegia, it was not until 19th century that cervical carotid ligation became the method of choice to treat carotid and intracranial aneurysms. Jean Louis Petit (1674–1750) made an observation that brain can survive on a single carotid artery supply after following a patient with common carotid artery aneurysm for 7 years, who had a completely occluded carotid artery. Encouraged by Petit hypothesis, Mason Cogswell (AD 1761–1830) pioneered elective carotid ligation for carotid aneurysms. The results were variable, and success of the operation was largely unpredictable. Astley Cooper (AD 1786–1841) recorded a detailed account of 2 cases of carotid aneurysms, which he treated with ligation.8 The first patient who was afflicted by a massive carotid aneurysm occupying two thirds of her neck developed hemiplegia soon after the operation and died shortly afterward. In contrast, the second patient with a considerably smaller aneurysm was treated successfully and returned to employment 8 months after the operation.

The first description of the treatment of an intracranial aneurysm was documented by Victor Horsley (AD 1857–1916) in 1885, who discovered by chance a massive aneurysm in the middle cranial fossa while operating on a patient with suspected brain tumor. Horsley successfully performed ligation of a cervical carotid artery, and according to the later report by Keen,9 the patient was in good health 5 years after.

Not everyone believed that carotid ligation was a safe and reliable technique to treat intracranial aneurysms. In his description of a clinical syndrome of subarachnoid hemorrhage, Harvey Cushing (AD 1869–1939) expressed his reservations about the surgical treatment of cerebral aneurysms:

How it is that a surgeon comes to write a note upon a lesion having such remote surgical bearings may be told

In his Little black book, Harvey Cushing documented operative details and clinical course of 9 patients with suspected brain tumors, who were found to harbor cerebral aneurysms during Cushing renowned exploratory craniotomies (Figure 1).10 Using a lumbar needle, Cushing would puncture the pulsating mass, and the gush of blood would confirm the diagnosis of an aneurysm. He would then wrap the aneurysm with strands of muscle to control the bleeding and promote clot formation. On several occasions, Cushing reluctantly performed carotid ligation, the step he called foolish and futile due to the high incidence of postoperative hemiparesis.

In order to address this problem associated with carotid ligation, the idea of graduated carotid occlusion was born. The invention of the Selverstone clamp enabled gradual carotid artery clamping over the course of 72 hours, which would in turn promote thrombosis within the aneurysm sac while allowing the development of collateral cerebral circulation. The clamp, whose stem protruded through the skin, was expected to have a quarter turn a day, presumably gradually reducing the flow to the point of final carotid occlusion. This approach led to the reduction in the incidence of ischemic complications compared with the traditional carotid ligation and is still practiced in under-resourced settings in the developing world.

Emergence of Direct Approach to Cerebral Aneurysms

Although carotid ligation remained the mainstay treatment of cerebral aneurysms until 1930s, many recognized that different approach was needed to treat this delicate, but often fatal pathology. Norman Dott (AD 1897–1973), one of the Cushing’s residents, learned the technique of wrapping the aneurysm with muscle during his residency and was the first to successfully treat a ruptured internal carotid aneurysm. Dott took one step further and perfected a highly technical and hazardous technique of suture ligation of the neck of an aneurysm. Suture was notoriously difficult to secure and could easily rupture friable aneurysm wall. In 1911, Cushing designed a silver clip to control deep and inaccessible blood vessels during brain tumor resection. Despite inventing the clip, Cushing never used it to secure cerebral aneurysms; instead, it was his competitor Walter Dandy (AD 1886–1946), who successfully performed first clipping of an intracranial aneurysm in 1937 using the Cushing clip after small modifications were made by McKenzie.11 This operation date marks the birth of modern vascular neurosurgery, which basic principles remain the backbones of cerebral aneurysm surgery practiced today. In the years to follow, the practice of aneurysm clipping spread across the world as the notion of treatment of subarachnoid hemorrhage shifted from having remote surgical bearings to largely curable condition. However, intracranial surgery was not without risks. Due to suboptimal instruments, lack of magnification, and primitive neuroanesthesia, many surgeons continued to practice bed rest or carotid ligation up until 1970s. During this time, significant advancements were made to make the clips removable, more easily adjustable, and safer to deploy. The introduction of operative microscope by Kenichiro Sugita (AD 1932–1994), who also developed a widely used aneurysm clip opened new opportunities to access parts of the cranium previously thought to be inconceivable.12

![Figure 1. Cushing's drawing of an internal carotid aneurysm found on craniotomy. Reprinted from Cohen-Gadol and Spencer with permission of the publisher. Copyright ©2004, American Association of Neurological Surgeons.](http://stroke.ahajournals.org/Downloaded-from)
Theodore Kurze (AD 1923–2002) was the first neurosurgeon to use operative microscope to clip an aneurysm in 1957.\(^{13}\) The microscope and bifrontal craniotomy to expose the aneurysm was part of the extensive experience of Pool.\(^{14}\) Finally, in 1969, the results of the cooperative study of *Intracranial Aneurysms and Subarachnoid Hemorrhage* showed significantly reduced mortality with clipping over conservative management and carotid ligation, which provided justification for intracranial intervention.\(^{15}\)

**Endovascular Era**

Until the late 1920s, the diagnosis of an aneurysm was often made on clinical history and physical signs. From his observations of air in the ventricular system from war wounds in World War I, Walter Dandy developed a pneumoventriculogram in 1918. It was a risky and painful investigation, which could indirectly display brain tumors and occasionally aneurysms due distortions of the ventricles. In 1927, Egas Moniz (1874–1955), professor of neurology at the University of Lisbon, injected radioactive contrast medium thorium dioxide into the carotid artery and took 3 x-rays of the skull producing first cerebral angiography.\(^{16}\) Initially, many physicians were skeptical of the benefits cerebral angiogram, who feared the risk of stroke. Even Walter Dandy went as far to state, “I can see little if any reason for its employment if the history and localizing neurological evidence is so convincing.” The real use of Moniz invention was not appreciated until 1933 when Norman Dott established a laboratory in Edinburgh and started to use routine cerebral angiograms to aid surgical planning for intracranial aneurysms.\(^{17}\)

The development of cerebral angiogram prompted the search for ways to access and treat aneurysms without opening the skull. A century earlier Alfred Velpeau (AD 1795–1867) made an observation that insertion of foreign bodies such as needles, muscle, or paraffin into an aneurysm causes thrombosis, thus excluding it from the systemic circulation. In 1930, Barney Brooks (AD 1884–1952) introduced a strap of muscle into internal carotid artery and successfully thrombosed carotid-cavernous fistula. During the next 30 years, various methods were developed to directly introduce thrombotic material including even horse hair and copper wires into an aneurysm.\(^{18}\) However, it was becoming clear that thrombosis of an aneurysm provided a suboptimal solution due to acceptably high rate of distal embolization and rebleeding.

In the second half of the 20th century, 2 significant inventions arrived which revolutionized endovascular treatment of intracranial aneurysms (Figure 2). In 1974, Serbinenko (AD 1928) published the results on 300 patients with arteriovenous malformations and cerebral aneurysms treated with microcatheter balloons.\(^{19}\) This publication marked the start of the balloon era during which detachable balloons were deployed to occlude the neck of an aneurysm. Although the outcomes using balloon-based approach were markedly improved compared with the previous methods, due to the fact that most aneurysms were not spherical—unlike conventional—balloons, the recurrence by recanalization of an aneurysm was as high as 20%. Although balloon technology was being perfected, Guido Guglielmi (AD 1948) in his laboratory at the University of Rome during the experiments on electrothrombosis noticed that the stainless steel wire would get eroded when the current was passed, a phenomenon known as electrolysis.\(^{20}\) By attaching an electrolysis-resistant platinum coil to the stainless steel wire, Guglielmi invented the concept of the detachable coil and successfully treated his first patient in 1990. Coiling enabled more complete occlusion of the aneurysm neck and minimized the risk of distal embolization. Although the technique quickly gained popularity, the intense debate between the advocates of coiling and clipping

---

**Figure 2.** Major events in the historical timeline of subarachnoid hemorrhage. ISAT indicates International Subarachnoid Aneurysm Trial; and SAH, subarachnoid hemorrhage.
emerged. This debate prompted a large European collaboration to launch the International Subarachnoid Aneurysm Trial, which results published in 2002 showed that coiling was associated with reduced mortality and morbidity compared with clipping. In recent years, the concept of vascular reconstruction for the complex cerebral aneurysms using flow diverter stents has emerged. Whether this or other technology is going to supersede coiling and clipping altogether only time will tell.

Conclusions

The journey toward the understanding and treating subarachnoid hemorrhage is a perfect example of ingenuity, bravery, and perseverance that both patients and their physicians displayed. Although significant progress has been made in less than 100 years, subarachnoid hemorrhage places a considerable burden on the society. Even the basic questions on the development, natural history, and the role of preventative strategies in subarachnoid hemorrhage remain to be answered.

Disclosures

None.

References

6. Wilks S. Sanguineous Meningeal Effusion (Apoplexy); Spontaneous and From Injury. Guy’s Hospital reports, London, UK; 1859.

Key Words: autopsy ■ dilatation ■ intracranial aneurysm ■ ligation ■ stroke
History of Aneurysmal Spontaneous Subarachnoid Hemorrhage
Kristijonas Milinis, Ankur Thapar, Kevin O'Neill and Alun Huw Davies

Stroke. 2017;48:e280-e283; originally published online August 14, 2017;
doi: 10.1161/STROKEAHA.117.017282
Stroke is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 2017 American Heart Association, Inc. All rights reserved.
Print ISSN: 0039-2499. Online ISSN: 1524-4628

The online version of this article, along with updated information and services, is located on the
World Wide Web at:
http://stroke.ahajournals.org/content/48/10/e280

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in Stroke can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to Stroke is online at:
http://stroke.ahajournals.org//subscriptions/