The history of brain retractors throughout the development of neurological surgery

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Early neurosurgical procedures dealt mainly with treatment of head trauma, especially skull fractures. Since the early medical writings by Hippocrates, a great deal of respect was given to the dura mater, and many other surgeons warned against violating the dura. It was not until the 19th century that neurosurgeons started venturing beneath the dura, deep into the brain parenchyma. With this advancement, brain retraction became an essential component of intracranial surgery. Over the years brain retractors have been created pragmatically to provide better visualization, increased articulations and degrees of freedom, greater stability, less brain retraction injury, and less user effort. Brain retractors have evolved from simple handheld retractors to intricate brain-retraction systems with hand-rest stabilizers. This paper will focus on the history of brain retractors, the different types of retractors, and the progression from one form to another.

Handheld Brain Retraction

In 1879, William Macewen (1848–1924) successfully resected the first brain tumor, a frontal meningioma.32 Sir Rickman Godlee (1849–1925) performed the first primary intracranial brain tumor operation, for a glioma, on November 25, 1884. The patient survived the surgery but succumbed to a wound dehiscence and infection a month later. Godlee described using a narrow spatula to separate...

Only the man who is familiar with the art and science of the past is competent to aid in its progress in the future.

Billroth

The earliest operation of which we have written record is trephining,23 which involved drilling a hole in the skull to expose intracranial contents for both medical and mystical purposes.37 The procedure dates back to the Mesolithic period, before the development of written language and use of metal instruments, perhaps as far back as 10,000 BC.22 Handheld retractors were part of the ancient Roman surgical sets and were likely held by assistants to give the surgeon access to the skull while trephining (Fig. 1). It was Hippocrates (460–ca. 370–377 BC) who first mentioned the use, description, and codification of trepanation in his treatise On Injuries of the Head.22 His trepanation tools included the trepan, serrated trepan, raspety, and sound. The sound was a probe that served as a retractor and protector of the dura during the craniotomy as it was placed into the bur hole to determine its depth and the mobility of the underlying bone. With few exceptions, cranial surgery from the era of Hippocrates until the 18th century focused mostly on head trauma, with much respect to the dura and the brain parenchyma, and the only retraction that was needed was of the extraaxial soft tissue. In his book on skull fractures, Jacopo Berengario da Carpi (AD 1460–1530) illustrated an elevator (retractor) used to perform trepanation in the 16th century (Fig. 2).56 Notably, many surgical instruments of the 16th and 17th centuries were decorative, large, and clumsy.4 During the later half of the 19th century, there was a significant change in the field of brain surgery. Advancements in cerebral localization, anesthesia, control of intracranial pressure, antiseptics, and aseptic techniques decreased the morbidity and the mortality associated with neurosurgery, allowing neurosurgeons to become more aggressive in their management of cranial pathology.40 As intracranial surgery became more feasible and neurosurgeons became more comfortable operating deeper into the brain, a great need for brain retraction developed. Initially brain retraction was performed using handheld retractors that required an assistant to hold them. However, in addition to the assistant’s hand obscuring vision and light, assistant error and fatigue led to retractors slipping from their desired placement, causing excessive retraction and injury to the brain parenchyma and other vital structures.38 These challenges ultimately led to the development of other innovative retractors and retraction techniques.

Key Words • brain retraction • brain retractors • neurosurgical history
the tumor from the brain parenchyma. In an 1886 edition of The London Medical Record, Dr. Hughes Bennett and Dr. Godlee discuss the tumor resection:

For shelling out the tumour, the finger and a small spatula, tempered to be easily moulded into any form, were used, so as to avoid the use of the cautery, which was felt likely to obscure the condition of parts.

William Williams Keen (1837–1932), the first brain surgeon in the United States, used the handles of a teaspoon and tablespoon in his 1882 cranial surgery (Fig. 3). In 1890, Alec Fraser, in his operative text “A Guide to Operations on the Brain,” provided instructions on handheld retractor placement. In 1901, Dr. Lothar Heidenhain (1860–1940) described using thin spatulas of various sizes to delineate tumors under direct vision. Subsequently, in addition to utilizing the handles of spoons for brain retraction (Fig. 4), Dr. Charles Frazier (1870–1936) developed an elevator that could be used in operations at the base of the brain (Fig. 5A and B). Frazier’s retractor was unique in shape and thickness; the angle of the handle relative to the retractor blade was situated such that the hand holding the retractor would not interfere with the surgeon’s view of the operative field, and the blade was thin enough to yield uniformly under pressure. In some situations, Dr. Frazier would use both his elevator and spoon retractor to facilitate tumor resection (Fig. 5C). Sir Victor Alexander Haden Horsley (1857–1916), often recognized for being the first surgeon to successfully remove a spinal cord tumor in 1887, performed many intracranial surgeries in which he used brain retraction (Fig. 6 left). In his 1906 address to the British Medical Association on “The technique of operations on the central nervous system,” Horsley included one of the first written accounts of brain retraction, in which he discusses brain retractors, retraction technique, and retraction injury:

The hemisphere can be readily compressed upwards by inserting a flat spatula cautiously beneath it and between the veins just described. The next question, of course, is, “What happens to the hemisphere compressed?” This entirely depends on the mode of compression. If the compression is, as it should be, gradual, the soft nerve tissues soon mold, with very little internal derangement; but it is easy to produce, with too much and too rapid application of pressure, laceration of and ecchymotic oozing between the fibers of the corona radiata. Such compression contusions of the basal portions of the hemisphere are relatively unimportant, because they relate to portions of the cortex of which the function is either readily compensated when lost or of very wide representation. The inspection of the deep parts of the skull by displacement of portions of the brain entails trouble to the assistant, because it is certainly disadvantageous to move the retractor when once properly in position. So far I have spoken of the cerebrum. I think that precisely the same principles should prevail in the case of the cerebellum.

With this procedure properly applied to the temporal lobe it is remarkable how much can be seen and correctly examined. With a good illumination the crura cerebi, the circle of Willis, the pituitary body and internal carotid, the second and third

**Fig. 1.** Illustration of the variations in size and shape of handheld retractors used as part of ancient Roman surgical sets. The most famous surgeon in Rome was Galen, who was surgeon to the Roman emperor. In Galen’s time, tools became more varied and more sophisticated than they were in prior eras. Illustration from 1898 surgical text by Ernst Julius Gurlt.
nerves come into view. I have in two cases after removal of a pituitary tumour inspected the base of the brain further by means of a small rhinoscopic mirror placed in the sella turcica; and it is very easy by continued but gentle pressure with a copper spatula, or with a spatula of suitable size, and with a strong headlight, to inspect the lateral region of the cerebellum and medulla oblongata with the issuing nerves. For these reasons I venture to take exception to the step of removing portions and lobes of the encephalon if these impede the approach to the lesion.24

A critical yet most subtle comment, Horsley began describing a paradigm shift in neurosurgery at that time. He also went on to describe that he preferred retracting the lateral lobe of the cerebellum rather than excising it, as proposed by Dr. Frazier, when removing a cerebellar le-

FIG. 2. Left: Berengario da Carpi on Fracture of the Skull or Cranium, from the 1629 edition. Its publication was critical to the development of cranial surgery. The text includes illustrations of surgical instruments for performing cranial surgery along with instructions for the procedure of craniotomy for management of skull fractures. Right: Illustration of brain elevators used by Berengario da Carpi in his surgical techniques. Courtesy of the Boston Medical Library.

FIG. 3. The spoon-spatula from Dr. William Sharpe (1882–1960), probably similar to that used by William Williams Keen and colleagues in the late 19th and early 20th centuries. It was described as a very useful surgical tool for protecting the underlying brain tissue when incising the dura, as well as in exploration of brain tissue during procedures. Reproduced with permission from Sharpe and Sharpe: Neurosurgery: Principles, Diagnosis, and Treatment, J.B. Lippincott, 1928.
sion. He did, however, admit that “in the process of removing a large tumour in that region the cerebellum is considerably bruised when so pushed aside.”24 In 1909, William Harvey Cushing (1869–1939), the father of American neurosurgery, subsequently used a spoon-shaped, rounded retractor that caused less damage to the cortical vessels compared with the flat, sharply edged retractors.5

Cushing and Horsley both introduced handheld retractors designed as rectangular ribbons that could be shaped based on need (Fig. 6 right).10 Cushing describes use of handheld retraction in the removal of olfactory groove meningiomas, commenting how the under surface of the frontal lobe must be elevated and moved aside so as to expose enough of the tumor:

A sufficiently deep furrow was thus made to let the spatula-elevator be inserted under its upper edge as to overcome the tendency of the tense brain to extrude into the wound. The growth was then excavated still further until the shell of that portion…could be collapsed and withdrawn in the manner shown.6 (See Fig. 7).

In 1913, Dr. Thierry de Martel (1875–1940), one of the founders of neurosurgery in France, introduced a malleable retractor that he attached to the edge of the cranial defect.8 Around this same time, Fedor Krause (1857–1937), the father of German neurosurgery, was employing, in addition to the hand-held rounded edge retractors, a suction-retraction technique to help steady, expose, and remove gliomas (Fig. 8).33 Dr. Walter E. Dandy (1886–1946) highlighted the importance of careful brain elevation with handheld retractors in his 1925 discussion, “An operation for the total removal of cerebellopontine (acoustic) tumors.”7 In 1926, Hans Brun (1874–1947) recommended the careful injection of saline around a lesion to help separate (retract) the tumor from normal brain parenchyma.3
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While Dr. Temple Fay (1895–1963) is often credited with the development of the first lighted retractor in 1927 to help facilitate operative exposure, there is evidence that his mentor, Dr. Charles Frazier, was utilizing the device before 1927. In *Annals of Surgery* in 1921, Frazier describes a new approach to the sphenopalatine ganglion, highlighting the use of his lighted retractor:

> The space in which one works is comparable in size to that in the approach to the Gasserian ganglion and I have found my illuminated retractor—so satisfactory in the Gasserian ganglion operation—amply illuminates the field.

Furthermore, in the 1922 text *Surgery: Its Principles and Practice*, Dr. Frazier describes using his lighted retractor in surgeries of the trigeminal nerve (Fig. 9A).

However, even earlier than Frazier and Fay, in 1920, Dr. Alfred Washington Adson (1887–1951) was utilizing a lighted retractor for elevation of the temporal lobe during surgery along the trigeminal ganglion (Fig. 9B and C).

**Self-Retaining Retraction**

The early self-retaining retractors were screw driven. As late as 1895, screw mechanisms were used to open retractors and the Broz wound-dilator was a widely used example. These retractors were cumbersome to handle, required two hands to place, were difficult to clean, and the screw mechanism was often inaccessible once placed (Fig. 10). To address these shortcomings, Franz Weitlaner, (1872–1944) an Italian-born physician working as a community doctor in Ottenthal, Austria, developed the Weitlaner retractor in 1905. With regard to self-retaining retractors specific to cranial neurosurgery, there are four categories of self-retaining retractors: skull mounted, which are directly attached to the skull or indirectly attached with a skull clamp; soft tissue mounted, which are secured by the tension in the muscles and soft tissue; table mounted, which are attached to the operating table; and headrest mounted, which are attached to the skull clamp.

**Fig. 6.** Left: The Horsley retractor, described as a combined blunt dissector and spatula that is designed for protecting the dura mater under a saw or for separating growths from brain parenchyma. Illustration from the 1915 text, *The Operations of Surgery by Jacobson*. Right: Brain spatulas. Cushing and Horsley introduced the earliest brain retractors, with varying sizes and shapes to allow for handheld manipulation and modification according to surgical need. From Dujovny et al.: *Neur Res* 22:675–683, 2010; http://www.maneyonline.com/doi/abs/10.1179/016164110x12644252260439. Reprinted with permission from Maney Publishing.

**Fig. 7.** Cushing’s postoperative sketches demonstrating the technique of removing a large olfactory groove meningioma. Note the use of a spatula-elevator in retraction of the frontal lobe. Reprinted with permission from the *Journal of the American College of Surgeons* (formerly *Surgery, Gynecology and Obstetrics*).
Skull-Mounted Retractors

In 1930, Thierry de Martel developed the first skull-mounted retractor, which consisted of a metallic cylindrical post that was inserted into the skull on one end and a rectangular retractor on the other. However, limitations of this retractor were that each retraction blade required its own drill hole and the varying thickness and strength of the skull did not permit placement of the posts in all craniotomy locations. Dr. Norman Dott (1897–1973), often described as the “engineering surgeon,” developed a skull-mounted retractor that he described as “the nice little machine we use to hold the brain out of the way when we are dealing with tumours of difficult access.” The Dott-Gillingham retractor addressed one of these limitations by attaching multiple retractors to one rod. In 1937, Wallace Hamby (1903–1999) developed a clamp that attached retractors to the edge of the craniotomy and thus obviated the need to drill additional holes into the skull (Fig. 11). However, this too was dependent on the thickness of the skull and could not be used in all locations.

Subsequently, the first neurosurgical use of the operating microscope in 1957 by Theodore Kurze and the development of microneurosurgery in the 1960s and 1970s led to the creation of many new microneurosurgical instruments and improvement of existing instruments, including brain retractors. The retractor blades remained fairly similar, but the major changes occurred at the level of the blade fixation; it was no longer acceptable to have any movement of the retractor blade or head during surgery. To this end, the Malis and Heifetz retractors were developed in the late 1970s, which allowed multiple retractor blades to attach to one fixation point, either in a drill hole or edge of the skull. Additionally, these retractors provided surgeons more individualized options; they included various rod lengths and multiple blade fixation points along each rod. Mahmut Gazi Yaşargil (1925–), a Turkish neurosurgeon, developed another flexible self-retaining retractor in 1968, known as the Leyla retractor (Fig. 12), which was initially attached to the edge of the craniotomy. However, difficulty achieving adequate tightening of the arm leading to retractor blade drift, shift of the mounting device during use, lengthy arm interfering with surgeon’s hands, and damage to the dura and soft tissue around the craniotomy clamp resulted in the Leyla...
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Fig. 10. A self-retaining retractor similar to the Broz wound-dilator. This retractor consists of a strong steel spring; the tension of which may be regulated by a screw mechanism. Illustration from the International Record of Medicine and General Practice Clinics, Vol 62.1

Fig. 11. Illustration of Dr. Hamby’s skull-mounted clamp and lighted retractor for exposure of the gasserian ganglion. From Hamby WB: Am J Surg 36:732–733, 1937. Reprinted with permission from Elsevier.

retractor being attached to the operating table rather than the craniotomy edge.47

**Soft Tissue–Mounted Retractors**

Soft tissue–mounted retractors, like the Weitlaner retractor, were among some of the first retractors in neurosurgery to provide access to the skull by keeping the soft tissues out of the surgical field. In 1961, the House-Urban retractor was developed, described as a modified Weitlaner retractor that provided extradural elevation of the temporal lobe (Fig. 13A).9 Subsequent modified versions of the House-Urban retractor include the Fisch (Fig. 13B and C), Garcia-Ibanez, and others (Fig. 13D). Dr. Peter J. Jannetta (1932–) modified Weitlaner’s soft-tissue retractor in 1973 by attaching two posts on each arm of the retractor, which allowed for the attachment of rods and intracranial retractor blades to provide cerebellar retraction (Fig. 14A and B).27 Dr. Jannetta eliminated some of the intrinsic instability of the soft tissue–mounted retractor by securing it to the surgical drapes. In the early 1980s, Apfelbaum and Glibach developed the Apfelbaum retractor, which contained a flexible rod and rounded retraction blades to minimize excessive cerebellar compression (Fig. 14C).34 Subsequently, the Miskimon cerebellar retractor, Cloward brain retractor, and Enker brain retractor were developed; these are all soft-tissue retractors that use malleable retraction blades. While useful and pragmatically developed at the time, a common limitation that soft-tissue retractors share is that the support system for retraction is very close to the operative site, and, therefore, the articulations provided by the retractor arms, rods, and blades are too few to provide retraction from all angles.34

**Table-Mounted Retractors**

Table-mounted retractors helped solve the aforementioned limitations by attaching the base of the retractor to the operating table. In 1974, Yaşargil and Fox attached the Leyla retractor to an Aesculap retractor–holding bar.51 Subsequently, in 1976, Dr. Jose Kanshepolsky developed a U-shaped frame that served as an attachment point for the base of retractors and slid onto the side of the operating table (Fig. 15).28 The disadvantages of these systems were the possibility of independent head or retractor arm movement causing uncontrolled movement at the brain.
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**Fig. 14.** A: Intraoperative use of Dr. Jannetta’s modification of the Weitlaner retractor. The retractor is self-retained and angulated with posts and attached microneurosurgical retractor in place. Reprinted with permission from JNSPG. B: A 1973 modification of the Weitlaner retractor by Jannetta, who introduced the ratchet holder for the brain retractor, which allowed the blade to remain in place independently. From Dujovny et al.: Neurol Res 32:675–683, 2010; http://www.maneyonline.com/doi/abs/10.1179/016164110xt1264252260439. Reprinted with permission from Maney Publishing. C: Use of the Apfelbaum retractor to support a malleable blade over the lateral aspect of the cerebellum. The malleable blade is supported by a flexible arm attached to the self-retaining retractor. Copyright RK Jackler. From Atlas of Skull Base Surgery and Neurotology, Ed 2, 2009.

retractor interface and amplification of any movements along the length of the retractor arms.

**Headrest-Mounted Retractors**

In 1967, Dr. Frank Mayfield (1908–1991) and George Kees (1925–2010) developed the Mayfield Horseshoe and General Purpose headrests (Fig. 16A) to better support and stabilize the head during operations. With the advent of microneurosurgery and the resultant smaller craniotomies with better head stabilization, Mayfield and Kees developed the Mayfield 3-pin skull clamp in 1973 (Fig. 16B). Dr. Kenichiro Sugita (1932–1994), a neurosurgeon from Japan, also developed a 4-pin fixation head holder in 1978 (Fig. 16C). The pin skull clamps, such as “the Mayfield” and “the Sugita” are firmly attached to the skull and then attached to the operating table, theoretically eliminating any possibility of head movement. Therefore, the increased distance from the craniotomy site and their rigid attachment to the table made these 3- and 4-point headrests ideal for supporting the base of self-retaining retractors. Drs. Mark S. Greenberg, Kenichiro Sugita, Takanori Fukushima, and Keiji Sano all developed self-retaining retraction systems that attach to skull clamps. The Greenberg self-retaining retractor and hand-rest system was developed in 1975 and consists of primary clamps, secondary clamps, flexible rod holders, retractor blades and hand rests for stabilization, as well as a structural and functional staircase organization (Fig. 17). The Greenberg system could be used with a variety of skull clamps. The Sugita multipurpose microneurosurgical head frame system was developed in 1977 and could only be used with the special skull clamp included in the system (Fig. 17). The Sugita system consists of a head holder with a frame attached to it to hold flexible self-retaining retractors, hand rests, microsurgical instrument holders, a plate for cotton patties, and skin-flap spring retractors. In 1981, Richard Budde and Jim Day developed the Budde Halo Brain Retractor System (Fig. 18). This system was designed to attach to the Mayfield skull clamp.

**Other Retraction Techniques**

Today in the 21st century, surgeons and scholars are still searching for ways to improve the visualization of the brain during surgery, while making sure that the brain parenchyma remains unharmed. Spoon retractors were introduced in 2000 as a tool to assist in retracting and removing soft-tissue masses. They are designed with...
an eggshell-like, concave shape to enable retraction upward. This allows creation of enough space to dissect the soft masses from surrounding tissues in the operative field (Fig. 19A). In 2006, Serarslan et al. designed a device of air-filled microballoons and cotton to be used between metallic retractors and the brain surface to minimize operative damage to brain parenchyma. They noted that their materials helped to minimize tissue damage and aid in the separation of sulcal and cisternal walls during surgery. Giannantonio Spena and Pietro Versari have reported usage of balloon tips of Fogarty catheters for gentle brain retraction in cases involving aneurysms of the anterior circulation, as well as for skull base and midline brain tumors (Fig. 19B). Described as a less traumatic and more dynamic method to assist in the operative view, they suggest that their method can act as an alternative to the use of self-retaining retractors. Furthermore, tubular retractors have been used in neurosurgery to access deep-seated lesions of the brain and decrease the effects of retraction on parenchyma. The ViewSite tubular retractor system has demonstrated success in retraction for both adults and children when removing tumors in deep locations (Fig. 19C and D).

**Conclusions**

The retraction of the brain to achieve the necessary corridors for safe and effective treatment has come full circle. In an attempt to minimize indirect damage to tissue, pioneers elected to resect “noneloquent” parenchyma to create that corridor. Necessity brought forth the innovation that resulted in several different types of retractors with a critical look at the different forms of mounting them in a secure and safe fashion. Initially using handheld retractors and their assistants, the early neurosurgeons utilized retraction primarily for soft-tissue retraction. As neurosurgical practice advanced, brain retractors were pragmatically developed to address the functional needs of the time while improving on the limitations of prior retractors. They evolved from simple handheld retractor systems to more complex and ergonomically designed systems that maximize stability and minimize slippage of retractor blades, excessive retraction, and user tremor and
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Fatigue. With this advance we now enter the era of “minimal retraction” neurosurgery where natural planes of dissection are used as our corridors for treatment, with a minimum of retraction applied only when necessary, thus minimizing the neurosurgical footprint and its sequelae at the close of surgery. Much has been learned in the development of retractor systems with regard to the tissue’s behavior and response to retraction. Consequently, modern devices will build upon the current state of the art to improve visualization while minimizing potential harm.

Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

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References

3. Brun H: Zur Technik der osteoplastischen Resektion des Scha-

4. Clowes W: A Profitable and Necessary Booke of Observations, for all Those That Are Burned With the Flame of Gun Powder, &c.: and Also For Curing of Wounds Made With Musket and Caliber Shot, and Other Weapons of War . . . Augmented in the Yeere of our Lorde 1596. London: Bollifant, 1596


8. de Martel MT: La technique opératoire en chirurgie nerveuse. Gaz Hop Paris 86:2045–2048, 1913


23. The history and development of neurological surgery. By Ernest Sachs, A.B., M.D., Research Associate in Physiology, Yale University, New Haven; formerly Professor of Clinical Neurological Surgery, Washington University School of Medicine, St. Louis. 5 1/2 x 8 in. Pp. 158, with 50 illustrations, as plates. 1953, London: Cassell & Co. 30s.


29. Keen W: The later histories of four surgical cases. 1. My first case of brain tumor (1887). 2. Two patients with rectal cancer surviving many years; describing also a simple and successful method of dressing an inguinal anus. 3. Traumatic rupture of middle meningeal artery without skull fracture (1902). JAMA 60:1418–1420, 1913


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