

Neurosurgery and Neuronavigation at Pomona Valley Hospital Medical Center



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Stereotactic Neurosurgery has been refined to an armless and frameless neuronavigational system in recent years. In the past 50 years we have seen a significant advancement in this field from its humble birth to today's CT, MRI and computer application. Stereotactic (from the Greek *stereo*, three dimensions; *tactic*, to probe) is a term to describe procedures done in a precise and defined three-dimensional space.

Historically, burr holes, or trephination, was performed in China approximately 5000 years ago. A well known legend in China describes a doctor, Hua Tuo, to have attempted a craniotomy on King Cao Cao (AD 222 to 280) for headaches caused by a brain tumor.^{1,2}

Incan artifacts (AD 1000 to 1600) have demonstrated early use of trephination instrumentation (Fig. 1) techniques and craniotomy with gold plate. (Fig. 2)



(Fig. 1) Ceremonial gold tumi, decorated with precious turquoise stones (Chimu culture, c. AD 1000 to 1600; Museo del Oro, Lima).



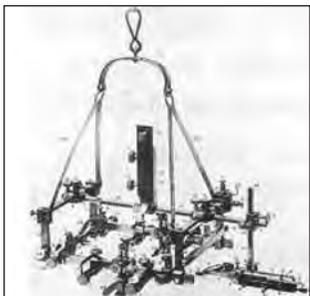
(Fig. 2.) Frontal cranioplasty with a gold plate. (Museo del Oro, Lima).

Surgeon John Collins Warren was the first to use ether anesthesia in surgery, on October 16, 1846. With the advent of general anesthesia, the scope and duration of surgeries were dramatically broadened.

Neuronavigational concepts began early in neurosurgery with the development of the Horsely-Clark stereotactic apparatus. Sir Victor Horsely (Fig. 3) is considered by many as England's father of neurosurgery. Robert Clarke and Victor Horsely kept early animal investigation strictly in the laboratory at Queen Square's Hospital, London England. This knowledge was the roots for the development of today's concepts but never was used on humans despite attempts by Dr. Clarke to persuade neurosurgeons to use it. This unit was patented and kept on the shelf for years. Later different versions were developed for human use.^{6, 10}



(Fig. 3) Sir Victor Horsely



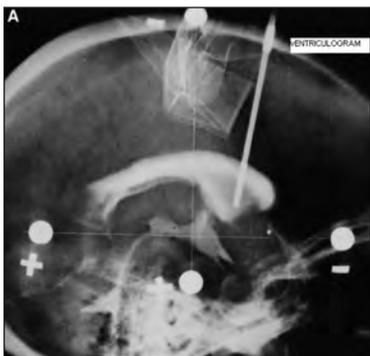
(Fig. 4) *Horsely Clarke stereotactic frame*
From the cybermuseum¹⁴

Harvey Cushing, MD (1869-1939) is considered as the father of neurosurgery in the U.S. Consider the difficulty of the 2000 brain tumor surgeries he performed in his lifetime, during the infancy of neurosurgery where even simple illumination was sparse compared to today's microscopes ability to magnify and illuminate deep crevices of the brain.



(Fig. 5) *Harvey Cushing, M.D.*

Rapid interest in finding ways to probe into the brain resulted in the interest in the treatment for Parkinson's and other disorders. The CT scan quickly replaced the ventriculogram in the 70's and distinctly made improvements in stereotactic surgery. The now outdated ventriculogram was used to delineate the anterior and posterior commissure, aqueduct, and the fourth ventricle, which allowed for accurate placement of an electrode to areas of the thalamus or midbrain.⁵



(Fig. 6)
Ventriculogram

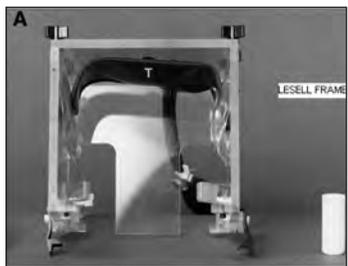
Today's complex computerized applications that are applied to neuronavigation are based on the origins of Cartesian principles developed in the 17th century by French philosopher "Rene Descartes; mathematical principle of locating a point in three dimensional space¹² Neuronavigation has been developed by many giants in the field of neurosurgery. Dr. Philip Gildenberg describes his mentors, Drs. Ernst A. Spiegel and Henry T. Wycis, as the parents of stereotactic surgery. They were the first to apply Cartesian knowledge to humans brains.^{13,14} Many neurosurgeons have contributed and it certainly would not have been possible without the work of Patrick Kelly at the Mayo Clinic.^{8,9} Functional and stereotactic neurosurgery was advanced at the University of Toronto, Ontario Canada by Dr. Ronald R. Tasker.¹¹ There are too many individuals to list in this short article to give it any justice. Clear and thorough details of this history have been precisely elaborated by Dr. Patrick Kelly.¹⁰

POMONA: The beginnings of the neuronavigational program at PVHMC

Stereotactic neurosurgery in private practice can be rewarding by applying these same principles in clinical practice. This idea was initially introduced to Pomona Valley Hospital Medical Centers (PVHMC) by LDR Neurosurgery in the late 80's by Scott Lederhaus, M.D. The initial phase and introduction of this technology was kept simple. He introduced the use of a simple and cost effective device, the Polaris neuronavigational unit. This was an effective tool which adhered to principles of Ockham's razor. Keeping it simple allowed the Polaris system to perform early brain biopsies safely. Under local anesthesia a bedside application of a small skull ring attached to the patient's skull was done in minutes, followed by transporting the patient to the radiology department to obtain a CT scan. The surgeon proceeds in acquisition of computerized coordinates follow by actual applying coordinates to a phantom stereotactic frame. Final steps in the operating room application of similar coordinates to the patient's skull mounted device and finally using an arc-arm instrumentation to obtain the brain biopsy. Difficult stereotactic brain biopsy of

certain brain lesions can best be appreciated when tackling the Pineal region which is surrounded by a moat of vascularity. This was first accomplished at PVHMC by Dr. Lederhaus using the Polaris system. Biopsy of lesions within the Pineal region has been successfully reported in 103 cases as a relatively safe procedure in experienced hands.⁴ Although Polaris had an advantage of a simple system, it did not allow for the use of the intraoperative computerized technology for more advance cases.

Dr. Lederhaus' training in this field was guided by Ron Young, MD at the University of California, Irvine (UCI) with the use of the Leksell stereotactic instrumentation and frame (Elekta).



(Fig. 7. Leksell Frame)

Lew Disney, M.D. had extensive stereotactic training prior to arriving to Pomona while in Canada at the University of Alberta Edmonton, Alberta. My training and experience at UCI and the additional training courses at the Mayfield Clinic in Cincinnati Ohio, mimicked Dr. Lederhaus'.

Neuronavigation at PVHMC Today: BrainLab VectorVision

The field was progressing rapidly and we needed a more advance system that could be used by other specialties at PVHMC including spine, ENT, Radiotherapy and even functional neurosurgery. The program at PVHMC has been developed by LDR Neurosurgery to its current phase with the BrainLab VectorVision neuronavigation system. It has been defined as "an intraoperative, image-guided, frameless, localization system."⁷ Its current components are; computer workstation situated in the operating room used for registration of images and physical spaces, an intraoperative camera localization device, and a computer image display

that allows for passive reflections of infrared flashes. Instantaneous computer reformation provides surgeons with real-time responses regarding the locations of surgical instruments in relationship to the brain and lesion. It's versatile software capacity allows for a computer formatted visual overlay-view of the lesion, within the right eyepiece of the operating microscope, allowing the surgeon to work without looking up onto the monitor. Advanced "Z touch" technology will permit laser facial recording and delete the use of fiducial skin markers for registration. A special pointer tool, equipped with two highly reflective markers, is used for registration of the patient. To achieve real-time imaging of patient head movement during surgery, a star-shaped tool is fastened to the Mayfield headrest as a rigid reference point. To guarantee exact navigation, this so-called "Mayfield adapter" must remain in the same position, with respect to the head of the patient, throughout the operation.⁷

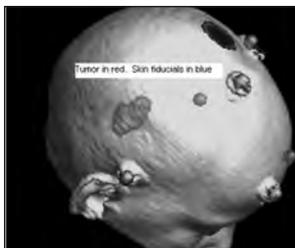
CASE REPORT

PVHMC's first pediatric case

A young child was transferred to PVHMC with seizures and a brain lesion that was considered a possible hemorrhage or brain tumor. MRI and CT scans are done and surgery is rendered without complications. Final diagnosis is cavernous malformation.



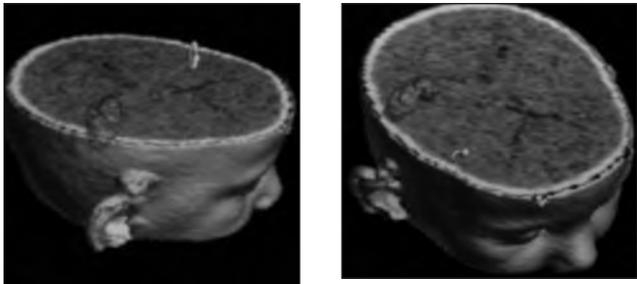
(Fig 8 & 9) Cameras and monitor and scalp fiducials



(Fig. 10 & 11)

Surgical Procedure: The computer images with tumor overlay is rotated to mimic the head position (Fig. 10). The patient is position in the operating room with Mayfield head device applied. The skin is marked with location of tumor and allowing surgeon to minimize surgical entry with extreme accuracy without relying on traditional head landmarks (Fig. 11).

Surgical planning and tumor reconstruction is done at the work station with the use of images formed from a triplanar format and obtained in 2mm slice CT scan, or MRI. The scans can then be seen in three-dimensional reconstruction, and viewed in different planes or angles allowing for improved surgical planning (Fig 12 & 13).



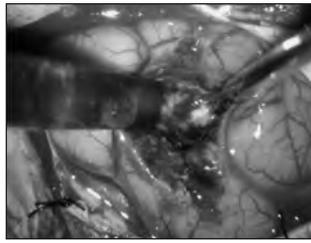
(Fig. 12 & 13) Three-dimensional computer reconstruction

BrainLab surgical planning allows for improved surgical positioning and use of smaller linear incisions and smaller craniotomy opening. This has decreased the risk to patients undergoing elective craniotomy (Fig. 14).



(Fig. 14) Small linear incision

The surgeon will proceed with microsurgical techniques to remove the lesion. The magnified surgical view of this patient's lesion is seen after it was excised without injury to surrounding structures of the brain (Fig. 15).



(Fig 15) Intraoperative microscope view.

This patient did very well and did not have any neurological deficits as seen in his first post op visit (Fig. 15). The final post-operative MRI of the brain with contrast reveals complete resolution of the lesion with a final diagnosis consistent with familial cavernous hemangioma (Fig. 16)



(Fig. 16) Post-op MRI



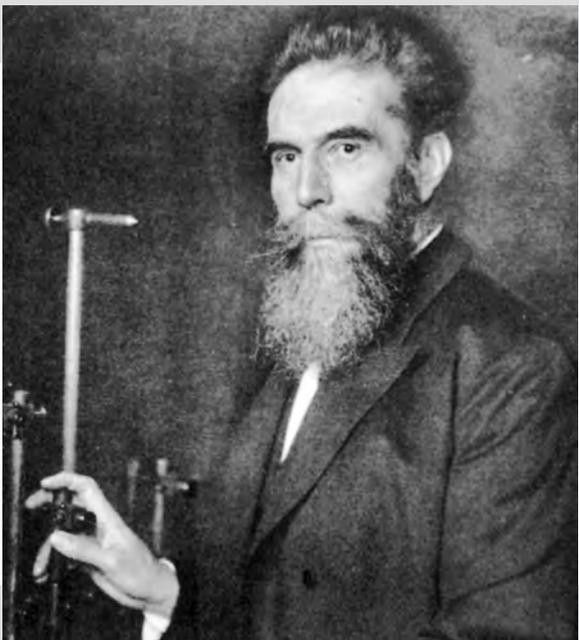
(Fig. 16) First post-op visit with patient Simon Grumbine and parents.

Neuronavigation with BrainLab VectorVision has the ability to get assist surgeons to operate safely in deep seated brain tumors or lesions in eloquent brain structures with improve safety and accuracy. It has been devised as a tool to assist the doctor in navigating through the brain when traditional surface landmarks were not sufficient to perform complex brain surgery.

REFERENCES

1. Wu, Cheng-Yuan M.D.; Wang, Ye-Han M.D.; Meng, Fan-Gang Ph.D.; Liu, Yu-Guang Ph.D. Neurosurgery: Volume 56(4) April 2005 pp 851-860
2. Zhao YD, Zhao YL: Neurosurgery in the People's Republic of China: A century's review. Neurosurgery 51:468-477, 2002.
3. Xiao AP, Chang Y, Chen YY, Chen GZ, Zhou YJ: Stereotactic therapy for epilepsy. Chin J Stereotact Funct Neurosurg 7:21-22, 1994.
4. Kreth, Friedrich W. M.D.; Schatz, Christoph R. M.D.; Pagenstecher, Axel M.D.; Faist, Michael M.D. Stereotactic Management of Lesions of the Pineal Region. Neurosurgery. 39(2):280-291, August 1996
5. Heimburger, Robert F. M.D. Neurosurgery: Volume 56(6) June 2005 pp 1367-1374
6. Horsley V, Clarke RH: The structure and the function of the cerebellum examined by a new method. Brain 31:45-124, 1908.
7. BrainLab VectorVision Neuronavigation System: Technology and Clinical Experiences in 131 Cases Gumprecht, Hartmut K. MD; Widenka, Darius C. MD; Lumenta, Christ B. MD. Neurosurgery: Volume 44(1) January 1999 pp 97-104
8. Kelly PJ: Computer assisted stereotaxis: A new approach for the management of intracranial intra-axial tumors. Neurology 36:535-541, 1986.
9. Kelly PJ: Volumetric stereotactic surgical resection in intra-axial brain mass lesions. Mayo Clin Proc 63:1186-1198, 1988.
10. Kelly, Patrick J. M.D. Stereotactic Surgery: What Is Past Is Prologue. Neurosurgery: Volume 46(1) January 2000 p 16
11. Ron R. Tasker, MD: One Man's Recollection of 50 years of functional and stereotactic neurosurgery. Neurosurgery 55:968-976, October 2004
12. Blaine S. Nashold, Jr. Stereotactic Vignettes 54: 198, Jan 2004
13. Philip Gildenberg, MD: The Birth of Stereotactic Surgery: A Personal Retrospective. Neurosurgery: 54: 1; 199-207 January 2004
14. Spiegel EA, Wycis HT, Marks M, Lee AJ: Stereotaxic apparatus for operations on the human brain. Science 106:349-350, 1947

<http://www.neurosurgery.org/cybermuseum/stereotactichall/stereoarticle.html>



Question: Who Is He?

Hint: His name became the unit to measure the amount of radiation.

Answer on Page 47.