

Stereotactic-Guided Craniotomy for Resection of a Cerebral AVM

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Cerebral arteriovenous malformations (AVM) are abnormal channels of blood between arteries and veins in the brain.

These channels offer less resistance to blood, causing increased blood-flow. When this occurs, the arteries that supply the blood and the veins that drain the AVM grow. Easier flow through the AVM allows blood to be stolen from surrounding tissue. Resultant symptoms range from headaches and blurred vision to transient ischemic attacks (TIAs) and seizures.^{1,2}

Grading AVMs

AVMs are graded according to their size, the importance of the brain tissue in which they lie, and their pattern of venous drainage, with grade I having the least risk for surgical removal and grade V having the greatest risk for surgical removal. Points are assigned to the different categories into which the AVM falls. Total points equal the grade of the AVM (Table 1).¹

Occasionally, grade I or II AVMs pose a problem for surgical localization when they are deep within the parenchyma or in critical areas of brain function. With the use of stereotaxis, these small lesions can be reliably located with less anesthesia time and minimal trauma to the surrounding tissue.^{1,3,4}

Patient Selection

Individuals harboring AVMs normally show symptoms before they reach 30 years of age.⁵ The patient may present with a variety of symptoms including seizures, sudden headache, often with a loss of con-

sciousness, and diplopia (double vision). A lumbar puncture may show blood in the cerebrospinal fluid (CSF), which is indicative of subarachnoid hemorrhage. Preoperative workups include a CT or MRI scan and four-vessel cerebral angiography if the AVM is too small to be detected by CT or MRI. After determining the location, size, and grade of the AVM, a decision is made as to a need for a stereotactic technique for resection.

Development of Stereotaxis

The history of stereotaxis dates back to the early 1900s when it was used primarily for experiments on animals. The first human applications were for the drainage of abscesses and with ventriculography.⁶ It was not until the invention of computed tomography (CT) and magnetic resonance imaging (MRI) that the real capabilities and possibilities of stereotaxis were fully realized. Today, stereotaxis is an indispensable tool in areas such as gamma knife radiosurgery and closed brain biopsies.

Stereotactic principles are based upon using three-dimensional coor-

dinates to provide exact localization within the cranial vault. These three-dimensional coordinates are derived from two-dimensional positions outside the head. The distances are measured from these positions to a specified target within the brain and input into a computer for processing into usable coordinates. These coordinates are then used to determine the path of entry and target location within the skull.^{6,8}

Tools Used in Stereotaxis

Stereotaxis is performed with the following tools:

Head Ring. The head ring provides a stable point of reference by being firmly attached to the patient's skull with four sterile CT or MRI compatible headpins (Figure 1). The pins, which are attached to carbon rods that do not show on CT or MRI, do not hinder imaging or artifact the final copy. A special wrench is used to tighten the pins. The head ring must also be adaptable to the Mayfield bed attachment for skull fixation during craniotomy. Because the patient is usually under general anesthesia for the craniotomy, intubation can be performed before the placement of the head ring. Head rings that allow jaw extension are available so that intubation can be safely carried out without compromising the airway.^{6,8}

Localization Headbox. The localization headbox is placed over the head ring. It contains nine vertical and diagonal rods that resemble a bird cage when in place. When intersected by a CT or MRI scanning plane, the rods show an artifact outside the skull on the final film. This is the basis of determining the dis-

Table 1. Grading Factors for AVMs¹

Size of AVM	
<3 cm:	1 pt
3-6 cm:	2 pts
>6 cm:	3 pts
Eloquence of Brain Tissue	
Eloquence:	1 pt
Less eloquence:	0 pts
Drainage Pattern	
Deep veins:	1 pt
Shallow:	0 pts



Figure 1. The fixated head ring provides an immovable point of reference once applied to the skull.

tance and final stereotaxic position of the lesion and is known as the stereotaxic reference plane.^{6,8}

CT or MRI Scanner Software. CT or MRI scanner software must be compatible with the type of stereotactic system being used. It must provide a roller controller-type cursor to determine the X and Y coordinates by plotting the visual artifact of the CT or MRI scanning plane through the localization head-box.^{6,8}

Computer. A separate computer processes all of the data provided by the scan and turns the figures into usable stereotactic three-dimensional values that can be registered on the arc-quadrant.

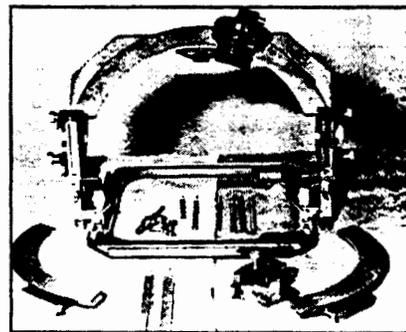


Figure 2. Stereotactic arc-quadrant and components.

The Arc-Quadrant. The arc-quadrant is the device that actually determines what physical route and point of entry the surgeon will use to reach the malformation (Figure 2). The arc consists of a square base that is adaptable to the head ring and an arc that spans the length of the base. It is graduated in millimeters in all dimensions for precise placement of coordinates. The three ranges of motion within the arc include the (1) anteroposterior (AP), (2) lateral, and (3) vertical. Accessories used with the arc include a left half arc, right half arc, guide block, guide tube, and reducer bushing.

Phantom Base. The phantom base allows the surgeons to double-check the coordinates in a three-dimensional stereotactic space before actually beginning the surgery (Figure 3). The base represents the patient's brain with the ability to place the target anywhere within its borders using the vertical, lateral, and AP coordinates of the previously computed target point.

At National Naval Medical Center in Bethesda, Maryland, we use the Cosman-Robert-Wells (CRW) Stereotactic System made by Radionics of Burlington, Massachusetts. This system is extremely accurate and very user-friendly.

Supplies and Instrumentation

At the naval medical center, supplies are ordered from Central Sterile Receiving (CSR) the day before surgery (Table 2).

The operating microscope on a contraves stand is placed in the room with a video camera mounted on the scope. The camera is hooked to a television monitoring system to allow the surgical technologist to view the procedure and anticipate the surgeon's needs. This also enables the rest of the surgical team to observe the procedure. The surgical technologist in the scrub role must be aware of the vasoactive drugs on the field.

The circulator must ensure that extra supplies are available in the room to avoid having to leave the room during the procedure. Appropriate headlights and light sources are available as well as the

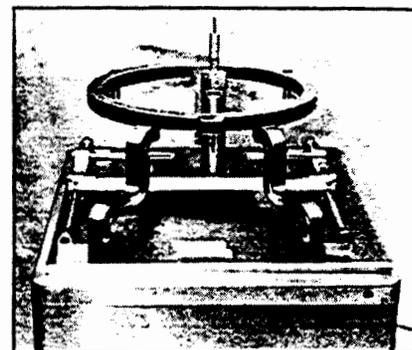


Figure 3. Phantom base.

surgeon's loupes. The circulator must ensure that there is a full tank of nitrogen with the tank attachment turned on and ready for use. Positioning supplies include eggcrate for pressure points, pillows, axillary rolls, and a gelpad for the bed. A warming blanket is laid on the operating room bed before it is made to maintain intraoperative patient temperature control. The Mayfield bed attachment and stereotactic Mayfield adapter for the head ring should be placed near the bed. Items for placing the stereotactic head ring on the patient's head, the stereotactic phantom base, and computer are placed on a separate table or stand in the room.

The Phalen and Mayfield table are positioned to facilitate moving in and over the draped patient. The bipolar machine and electro-surgical unit are positioned where the patient's feet will be when the operating room bed is turned. Three suction wall units are available with suction canisters. The microscope is assembled to provide either an opposing view or a side-by-side view, depending on the patient's position, and balanced with the proper lens size. It is imperative that the neurosurgeon check the microscope before scrubbing his or her hands. If the surgeon may require a separate microbipolar machine, it should be made available to prevent time loss in switching cords.

Patient Preparation

The patient is brought into the room. The neuroanesthesiologist places a radial arterial line for

Table 2. Supplies, Instruments, and Accessories Used for Stereotactic-Guided Craniotomy

Supplies	2 18-gal Angiocaths	Papaverine
2 Split sheets	Microscope drape	5F Malleable suction catheter
Footdrape	Absorbable gelatin sponge (Gelfoam)	
Phalen and Mayfield table drapes	Bone wax	Instrumentation
Large basin for emesis and square basins	2 x 14 Oxidized cellulose (Surgicel)	Craniotomy set with rongeurs and Raney clip applicators
Magnetic needle pad	Microfibrillar collagen hemostat (Avitene)	Stereotactic arc (Cosman-Robert-Wells)
Marking pen	21-gal Needle	Greenburg retractor with (Sugita) malleables
Arachnoid beaver blades	Dural hook	Aneurysm clip tray (Sugita)
2 No. 10 Blades, 3 No. 15 blades, and 3 No. 11 blades	Uncoated monofilament polyglactin 910 suture: size 0, 2-0, 3-0 on CT-1, 4-0 on dura needle	Leyla bar retractor with bed attachment
3 Packs of radiopaque sponges	2 35-Wide staplers	Rhoton dissector set
Sterile handtowels	Dermahooks	Rhoton and Frazier suction tips
Gowns and gloves	Bicollagen sponge	Insulated bipolars with nonstick tips and cord
3 Suction tubings	3 Packs of Raney clips	Drill (Midas Rex)
Instrument pouches	Thrombin	Drill attachments B-1, 0, C (Midas Rex)
16-F Catheter, 5-cc balloon Foley catheter, and insertion kit with urimeter	Bacitracin	Drill bits B-1, 0-2, C-1 (Midas Rex)
2 Asepto bulb syringes	0.25% Bupivacaine hydrochloride 1:200,000 epinephrine	Microscissors, curved and straight
Prep tray	Ventricular catheter	Cushing silver clip applicators
4 Extra Mayo stand covers	Stereotactic stockinette	Fine needle drivers
2 Saline cans	Cushing clip boats	Micro bayonets and bipolars
	Cottonoid (sizes: 1/8 x 1/8; 1/4 x 1/4; 1/2 x 1/2; 3/4 x 3/4; 3 x 6)	2 Adjustable suction regulators
Accessory supplies	Radiopaque cottonballs	Operating microscope (Zeiss)
3 20-cc Syringes		

drawing blood gas and monitoring intraoperative blood pressure in addition to the standard blood pressure cuff. A central line is also placed in the patient's right atrium for central venous pressure monitoring. A pulse oximetry probe is placed on the patient's finger for monitoring blood oxygen saturation. Two large-bore IVs are placed in case mass volume replacement is necessary. An electroencephalograph (EEG) technician places EEG leads on the patient's scalp to monitor brain wave activity. This may be necessary if the neurosurgeon requests burst suppression.

Burst suppression decreases the brain's need for oxygen by decreasing the amount of electrical activity. This allows the neurosurgeon to cross-clip major arteries in the brain while decreasing the risk of ischemia or infarction. This is accomplished by giving the patient massive amounts of barbiturates.

The neuroanesthesiologist induces the patient with an IV anesthetic such as thiopental sodium. The patient is then intubated as the nurse anesthetist inserts a Foley catheter into the bladder to monitor

urine production.

After the endotracheal tube is secured, the neurosurgeon places the head ring on the patient. The rods and pins on the head ring are sterile. Povidone-iodine ointment is placed on the tips of the pins to stem infection and prevent air emboli from entering the venous system. For supratentorial AVMs, the ring is placed with the base even at the level of the nose and parallel to the orbitomeatal and intercanthal lines. This varies widely with lesions that are infratentorial or temporal. The head ring can be tilted to compensate for lateral lesions and this is best achieved with the patient in a sitting position. With the patient under general anesthesia, the circulator must help support the patient's head. Care must be taken not to harm the patient's cervical spine during application.⁶⁹

After application of the head ring, the patient is transported to MRI for radiographic examination. The localization headbox is placed over the head ring, and the patient is transferred into the MRI chamber. No metal objects are allowed

around or near the chamber. The neuroanesthesiologist maintains the patient's anesthesia with an MRI-compatible anesthesia machine. Images of the patient's brain are taken at 1.5-mm intervals with the localizer headbox attached and the neurosurgeon measures the distance from the artifacted headbox rods outside the skull to the targeted AVM within the brain. This is accomplished with a roller controller trackball cursor. When the cursor is placed on each of the nine artifacted rods, the MRI scanner produces an XY coordinate that is then processed into usable stereotactic coordinates by the computer.⁶⁴

In the operating room, the surgical technologist readies the field (Figure 4). The craniotomy set is opened and set up to facilitate keeping open whatever side of the Phalen table will be facing the surgeon. Raney clips are loaded onto the applicators, absorbable gelatin sponge is cut to size and soaked in thrombin, and oxidized cellulose is cut to size. Preoperative local injection should be available, such as 0.25% bupivacaine hydrochloride with 1:200,000 epinephrine. A

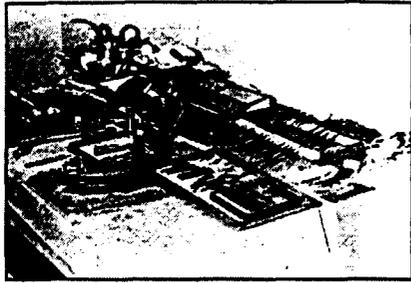


Figure 4. Instrumentation for craniotomy.

vasodilator such as papaverine should also be on the field. All drugs are labeled to prevent an accidental mix-up. The dermahooks are loaded on hemostats to retract the scalp. An inventory is done for the microinstruments and the Greenburg retractor to ensure that all pieces are present. Two suction tubings are precut and placed on the suction regulators. A wide selection of micro AVM and aneurysm clips, ranging in size from 1 mm to 7 mm, are placed on the field (Figure 5). The CRW arc is then assembled. The sterile phantom target probe is placed in the phantom base. All drapes, surgical gowns, and gloves are readied.

Once the patient is removed from the scanner, the localization headbox is removed and the patient is wheeled into the operating room and transferred to the operating table. All pressure points are padded with attention to bony prominences and nerve plexuses and an electrosurgical grounding pad is applied. The bed is then turned to whichever direction the neurosurgeon desires, dependent on the approach to the AVM. The patient's head is marked, then prepped with a povidone-iodine



Figure 5. Aneurysm and AVM clips.

scrub and paint solution. The scrub person then does a needle and sponge count with the circulator.

The gowned and gloved neurosurgeons take the CRW arc and place it on the phantom base to confirm the entry points that were pre-calculated on the Radionics computer. The bottom of the CRW is unsterile and must be treated as such. The target points are then set on the phantom base (Figure 6). After confirmation of the entry points in a simulated stereotactic space, the patient is draped.

A footdrape is laid and a piece of iodine-impregnated incision drape (loban) is placed over the top of the intended incision site on the head. A sterile segment of 6-in. stockinette is rolled over the top of the head ring until it covers the entire field from the top of the patient's head to the base of the ring. Scissors are used to cut holes in the stockinette where the CRW foot pieces will rest on the base of the ring. A new sterile scissor cuts a hole in the stockinette where the incision will be made, exposing the loban underneath. Another layer of loban is applied over the incision site to hold down the stockinette and prevent fragments from entering the wound. Split sheets are then laid just under the base of the ring to prevent interference with the CRW's foot placement. After draping, the electrosurgical cord, bipolar cord, microbipolar cord, and two suctions attached to suction regulators are passed to the circulators. Light handles are applied (Figure 7).

The CRW arc is then locked into place over the patient's head. The coordinates are set and the incision site is determined. The arc is lowered and the scalp is infiltrated with a solution of 0.25% bupivacaine hydrochloride with 1:200,000 epinephrine. A No. 10 blade on a No. 3 handle is used to make the scalp incision. Raney clip applicators are placed at the edges of the scalp for hemostasis. Periosteal elevators dissect the periosteum away from the bone. A Leyla bar is attached to the operating table opposite the reflection of the scalp flap. A radiopaque sponge is placed over the scalp and

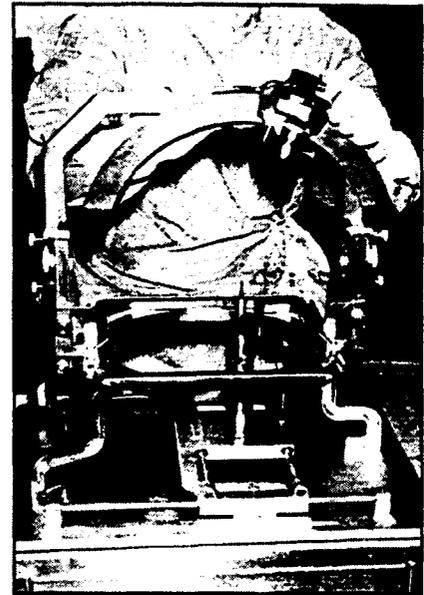


Figure 6. Surgeon checks and confirms figures on phantom base before beginning procedure.

dermahooks are pierced into the galea and attached to the Leyla bar. The bar is then tightened, retracting the flap.

The drill is loaded with the B-1 bit on the B attachment to make an initial hole for placement of the footplate on the B-1 attachment. The B-1 bit on the B-1 attachment is then used to turn a bone flap. The bone flap is dissected away from the dura mater with a No. 3 Penfield dissector, then removed and soaked in a concentrated bacitracin solution. The C-1 bit on the C attachment is then used to drill dural tacking holes around the edge of the craniotomy. The bone flap is drilled in a similar manner to facilitate suturing of the bone flap back to the skull at the end of the case.

Before entering the dura, four fresh wound towels are placed around the incision and the attachments for the Greenburg retractor are placed in position on the head ring. Two primary and floating secondary arms with flexible snake retractors are positioned. A 4-0 uncoated monofilament polyglactin 910 suture on a dura needle is used to tent the dura to the skull to avoid slippage of the dura beneath the skull and to prevent an epidural



Figure 7. Completed draping procedure.

hematoma from developing. A dural hook is used to elevate the dura away from the arachnoid and a No. 15 blade on a No. 7 handle is used to make a durotomy. A Penfield No. 4 dissector is used to probe the subdural space. With toothed Gerald pickups and DeMartel dural scissors, an elliptical shape is cut in the dura. The dural flap is reflected away from the now exposed brain, and 4-0 suture is used to tack the dura to the galea, holding the dura out of the way.

The CRW arc is again raised over the brain and the coordinates set. A ventricular catheter is passed through the reducing bushing to indicate where the cortical incision will be made in the arachnoid matter (Figure 8). From this point on, only warm lactated Ringer's solution is used to irrigate the brain. This solution more closely matches the brain's natural pH level.

The surgical technologist drapes the microscope, which is then swung into place over the patient's brain. If possible, the natural sulci overlying the AVM is opened with a beaver blade and bipolar cautery, and the underlying gyri is incised in the same manner. At times, it may be necessary to remove part of the gyrus to get exposure to the AVM; exposure is accomplished with bipolar and suction. All brain tissue not currently in the neurosurgeon's site is covered with a wet bicollagen sponge or nonadherent polytetrafluoroethylene (polytef). At intervals during the brain dissection, the CRW arc is raised and the ventricular catheter is passed to show the direct route. This minimizes unnecessary damage and resection of normal brain tissue. A tape tag such as a sterile tape strip at the end of the

catheter acts as a depth gauge and tells the neurosurgeon how much further to dissect.

The Greenburg retractor is moved into position with Sugita malleables at the working ends. A padding buffer such as wet polytef is used to line the surface of the malleable retractor to allay unnecessary pressure during retraction. Once the part of gyrus overlying the AVM is removed and the retractors are in place, the CRW arc is again raised. The coordinates are set and the catheter is passed to confirm that the surgeons have located the correct place. Once the AVM is visualized, the dissection of the lesion begins.

At this point, the surgical technologist must be alert to everything that is happening under the microscope. The AVM may rupture or bleed at any time. Rhoton dissectors and microscissors should be readily accessible. Avoid giving the surgeon oxidized cellulose unless it is specifically requested as it will adhere to the vessels and the nidus of the AVM and could rip the walls when removed. The aneurysm clips are brought to the Phalen table so they are quickly available.

The neurosurgeon begins dissecting the arachnoid away from the AVM with a beaver eye blade and microscissors. Hemostasis is maintained with a microbipolar, absorbable gelatin sponge, and cottonoids. The AVM is gently dissected away from the parenchyma with Rhoton dissectors. Microcottonoids are placed to develop a plane between the AVM and the brain. The feeding arteries are clipped with aneurysm clips and cut. The clip must be wet before application to prevent adherence to the vessel if removal is necessary. Deep draining veins may cause sudden bleeding and access to them is sometimes a problem. The surgical technologist should be aware of this danger and prepare for the worst. A large supply of absorbable gelatin sponge, oxidized cellulose, and cottonoids should be available.

Irrigation must be kept normothermic to prevent vasospasm and injury to the brain. A temperature slightly above 110°F is usually suffi-



Figure 8. Arc is raised to confirm durotomy entry point with a ventricular catheter.

cient. Once all feeding arteries and draining veins are clipped or cauterized, the AVM is then removed en bloc. The surgical technologist in the scrub role must always record the number and type of clips implanted. If any major parent arteries seem to be in spasm, drops of papaverine are applied to alleviate the problem.

Once excision of the AVM is complete, the cottonoids are removed and a powdered microfibrillar collagen hemostat is applied to the wound and left to sit for 5 minutes. The microfibrillar collagen hemostat is then irrigated and the wound is examined for any further bleeding. The retractors are removed from the brain and the edges of the brain that were in contact with the malleables are examined.

Closure of the dura is carried out with 4-0 uncoated monofilament polyglactin 910 suture on a dura needle. Toward the end of dural closure, a small durotomy is left open and microirrigation is introduced. If the irrigation returns with a high amount of blood, the dura must be reopened and examined for possible bleeding. The microscope must remain sterile until this is completed or until it is determined that the

AVM space has not re-bleed. The durotomy is then closed and the bone flap is replaced using 0 uncoated monofilament polyglactin 910 sutures passed through the original holes drilled at the beginning of the case. The galea is reapproximated with 3-0 uncoated monofilament polyglactin 910 suture. Staples are applied to the skin and a nonadherent dressing with a petroleum gauze and 4 x 8 plain sponges are taped into place with a headwrap consisting of two self-adherent bandages (Kling), two gauze bandages (Kerlex), and tape.

The patient is transported to the neurosurgical intensive care unit for postoperative observation.

Postoperative Results and Complications

Postoperative results are related to the size and location of the AVM. Mortality is less than 5% and morbidity is less than 10% following this procedure.⁵

Typically, the patient will undergo cerebral angiography postoperatively to confirm total eradication of the AVM. Care is taken to avoid raising the patient's blood pressure above 140 systolic to prevent cerebral perfusion breakthrough.² With an uncomplicated postoperative period, the patient may be released in 1 week following surgery. Δ

Acknowledgements

The author would like to thank Ronald Hargraves, MD, LaVerne Lovell, MD, Teri Tripp, RN, MSN, CNOR, and the Bethesda Naval Hospital neurosurgical team for their assistance and editorship of this paper.

References

1. Spetzler RF, Zabromski JM. Grading and resection of cerebral arteriovenous malformations. *Clinical Neurosurgery*. 1990; 36:318-337.
2. Stein, BM. Supratentorial arteriovenous malformations. In: Fein JM, ed. *Cerebrovascular Surgery*. New York, NY: Springer-Verlag; 1985; 4.
3. Heros RC, Kazuyosh K. Deep parenchymatous lesions. In: Apuzzo ML, ed. *Brain Surgery: Complication Avoidance and Management*. New York, NY: Churchill-Livingstone; 1993.
4. Davis DH, Kelly PJ. Stereotaxic resection of occult vascular malformations.

Journal of Neurosurgery. May 1990; 72(5):698-702.

5. Hoff JT, Boland MF. Neurosurgery. In: Schwartz SI, Shires GI, Spencer FC, eds. *Principles of Surgery*. 6th ed. New York, NY: McGraw-Hill; 1994:1848.
6. Arbour RB. Stereotaxic localization and resection of intracranial tumors. *Journal of Neuroscience Nursing*. Feb. 1993; 25 (1):14-21.
7. Chin LS, Zee C, Apuzzo ML. Special considerations in point stereotactic procedures. In: Apuzzo ML, ed. *Brain Surgery: Complication Avoidance and Management*. New York, NY: Churchill-Livingstone; 1993.
8. Heilburn MP, Brockmeyer D, Sunderland P. Stereotactic surgery for mass lesions of the cranial vault. In: Apuzzo ML, ed. *Brain Surgery: Complication Avoidance and Management*. New York, NY: Churchill-Livingstone; 1993.
9. Steen SN, Zelman V, Gruen P, Bayat A, Apuzzo, ML. Techniques and refine-

ments of anesthesia for stereotaxy. In: Apuzzo ML, ed. *Brain Surgery: Complication Avoidance and Management*. New York, NY: Churchill-Livingstone; 1993.

Bibliography

- Hassenbusch SJ, Anderson JS, Pillay PK. Brain tumor resection aided with markers placed using stereotaxis guided by magnetic resonance imaging and computed tomography. *Neurosurgery*. June 1991; 28(6):801-805.
- Young RF. Intracranial procedures for pain management. In: Apuzzo ML, ed. *Brain Surgery: Complication Avoidance and Management*. New York, NY: Churchill-Livingstone; 1993.

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