

A Cranio/Spinal Positioning Device for the Treatment of Ependymoma

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INTRODUCTION

Ependymomas are glial tumors of the central nervous system which are treated with a combination of surgery and radiation.

Post surgical radiation is a critical procedure because the entire cranio/spinal region is often treated. Such radiation procedures often use a cranio/spinal positioning device for precise reproduction of radiation from cranium through the spinal canal.

This paper addresses the clinical nature and treatment of ependymomas. Finally, the materials and techniques for fabricating a cranio/spinal positioning device will be discussed.

THE CLINICAL NATURE OF EPENDYMOMAS

Ependymomas arise from ependymal cells lining the ventricular cavities and central canal of the spinal cord. Overall they represent approximately five percent of all brain tumors, less than 10 percent of all gliomas, and 24 percent of all intra-spinal tumors. Ependymomas may occur in all age groups, with over one-half occurring in children and young adults.

Approximately one-half of ependymomas arise intra-cranially and the other half intra-spinally. A significant number of cranial tumors protrude into the upper cervical subarachnoid space.

Ependymomas are graded from 1 to 4. Most of the tumors are low grade 1 and 2. Eighty percent of spinal tumors and 60 percent of intra-cranial tumors are low grade. Grades 3 and 4 are considered to be malignant ependymomas.

Ependymomas show several major routes of spread. They are not encapsulated and tend to be locally invasive, extending into ependymal-line spaces. They can seed the cerebral spinal fluid (CSF) and tumor cells can implant and grow anywhere within the CSF pathways, cranially and spinally. In the late stages they may spread to adjacent dura, bone, and scalp. Rarely, extra-central nervous system metastasis can occur, usually after repeated surgical procedures.³

The presenting symptoms relate to the tumor location. Intra-ventricular tumors obstruct the flow of CSF and the patients typically present with signs and symptoms of increased intracranial pressure; i.e. papilledema, headaches, nausea, vomiting, ataxia, and incoordination. Diagnostic studies will include skull x-rays, and head

CT scans. In addition to visualization of the tumor mass, these studies may also show enlargement of and erosion of the sella turcica, separation of the cranial sutures in a young child, and obstructive hydrocephalus. Ventricular shunting may be necessary to relieve the obstruction to the CSF flow before a more definitive procedure is undertaken. Spinal tumors produce spinal cord and nerve root compression and are visualized on myelography.

TREATMENT OF EPENDYMOMAS

The treatment for ependymoma includes surgical resection with removal of as much tumor as is safely possible. These tumors may involve vital structures, and occasionally only decompression and biopsy can be performed. Surgery alone provides a five year survival of 16 percent.² Post operative radiation has been shown to significantly improve local tumor control and survival for these patients.³

The treatment volume and dosage is based on the location of the primary tumor, areas of extension, and occurrence or estimated risk of CSF seeding. For high risk patients, cranio/spinal radiation is given. The entire neuraxis is the target for radiation, higher dosages given to areas of known tumor, and lower dosages given as prophylactic treatment to areas at risk for subclinical disease. This has been shown to virtually eliminate the later development of CSF seeding. The primary tumor site remains the major site for tumor recurrence after this treatment. This may be due to the limitations on the total dosage that can be safely administered to the primary tumor located in the spinal cord (5,000 rads) or posterior fossa (5,500 rads) without excessive risk of development of induced spinal cord radiation myelitis or cerebral necrosis.

The University of Rochester Cancer Center, Rochester, New York, has made recommendations on the postoperative radiotherapeutic treatment of ependymomas based on local tumor control, patterns of spread, and normal tissue tolerance.⁵ Low

grade supratentorial tumors are treated with whole brain radiation. Low grade infratentorial tumors are treated with whole brain fields with cervical cord extension to C-5. High grade tumors at any site, or any tumor with positive CSF for malignant cells and/or subarachnoid seeding on myelography are given cranio/spinal radiation. Low grade spinal cord tumors are given spinal cord fields. The recommended total dosages are 4,500 rads to the whole brain, 5,500 rads to the primary tumor volume if intracranial, and 5,000 rads if intra-spinal, 3,000-4,000 rads to the spinal cord, prophylactic treatment depending on the status of the subarachnoid space.

The spinal cord is the most radiosensitive structure treated with the cranio/spinal radiation. It cannot repair radiation induced damage. Underdosage of parts of the spinal cord could lead to tumor recurrence, while overdosage could lead to radionecrosis and permanent neurological deficits. With cranio/spinal radiation, the spinal cord is treated with several radiation beams with different angles of divergence. To optimize the dosage at the field junction regions, several measures are taken. The collimator angle for the brain field is rotated to match the angle of divergence from the beam to the upper spinal field. Field junction gapping is performed. Small calculated gaps, usually one or two centimeters, are located on the skin between consecutive fields. As the radiation beams hit the skin, a "cold" or low dose region will occur on the skin, but the beams will diverge to intersect at the spinal cord region in the body. The skin gap position is moved inferiorly with each daily treatment, in cycles of three or four. This is known as "feathering" and is done to smooth out the inhomogeneity of dosage at the spinal cord at the gap regions. Areas of significant under or overdosage are to be avoided. Computer dosimetry is often used to aid in treatment planning.⁷

The quality of life in long term survivors tends to be good. The majority of patients lead active and useful lives. The side effects from the treatment can be divided into acute and chronic. The acute side effects occur during or just after treatment and are

usually transient. These include hair loss, skin erythema, mucositis of the upper respiratory and digestive tract, nausea, and myelosuppression. Chronic side effects occur months to years following treatment and may be permanent. They are more severe the younger the patient is at treatment. They often do not occur at all in the adult patient. These include neuropsychiatric and intellectual impairment, endocrine dysfunction (especially growth hormone deficiency), growth disturbance secondary to spine radiation, and carcinogenesis, especially a small risk of induction of thyroid neoplasia.⁸

In summary, multiple separate radiation treatments are necessary for maximum radiation benefit, and different angles of divergence and sectors of radiation are also required during different treatment sessions. To increase the assurance of even radiation throughout the above process, minimizing the possibility of cold and hot spots, a cranio/spinal positioning device may be constructed (Figure 1). Cold spots will, as mentioned, increase the possibility of recurring tumors. Hot spots, particularly of the spinal cord, may cause permanent paralysis.

CONSTRUCTION OF A CRANIO/SPINAL POSITIONING DEVICE

Materials

- One box extra fast-setting 4" plaster
- One box extra fast-setting 6" plaster
- One bag 4" webril
- Six foot length 6" or 8" stockinette
- Two foot length 4" stockinette
- One bandage scissor
- Two indelible pencils

Procedure

Six or eight inch stockinette (whichever is appropriate) is applied to the patient with arms inside the stockinette (fleshy or obese patients should be cast with arms out of the negative impression). The patient is then placed on the simulator in the supine position. A nine centimeter hole is cut in the four inch stockinette approximately 12

centimeters from one end. The short end is pulled over the patient's head until the hole frees the nose and mouth area (Figure 2). The eyes, chin, and other facial tissue surrounding the nose and mouth must be covered with stockinette and later included in the negative impression.

The oncology technician now positions the patient's head in a flexed position, reducing the cervical curve and aligning the torso visually using an anterior laser reference which bisects the sagittal plane (Figures 2 and 3). When visual alignment is achieved, the patient is fluoroscoped from the sacrum through the cranium to assure linear progression of the spinal column and head.

Lateral lasers are now set to bisect both the right and left frontal planes. A second set of lateral lasers perpendicular to those above create a cross reference. This cross reference should initially be located just distal to the acromion; then the perpendicular reference is moved superiorly to the skull (Figure 3). If a clear reference is not attainable, just proximal to the ear, adjust the mid frontal plane reference to attain maximum reference coordinates at both the skull and the acromion area. Once this common plane is located, start superiorly to transfer the bisecting reference lines, first to the skull, just above the ear, then to the acromion area, and finally to a point at the mid thoracic level. To do so, cut small holes in the stockinette and apply a cross to the skin at the laser intersections. These

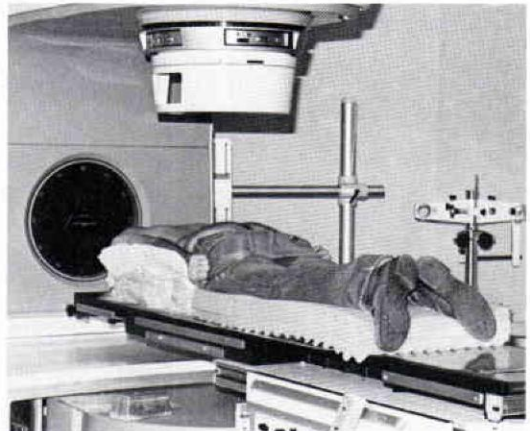


Figure 1. Patient positioned for treatment with arms inside the negative impression.

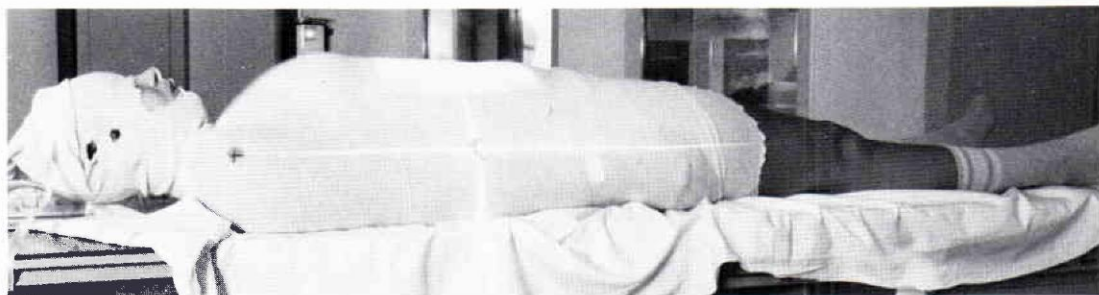


Figure 2. Patient positioned on simulator ready for the taking of a negative impression (note laser intersection at mid-thoracic level).

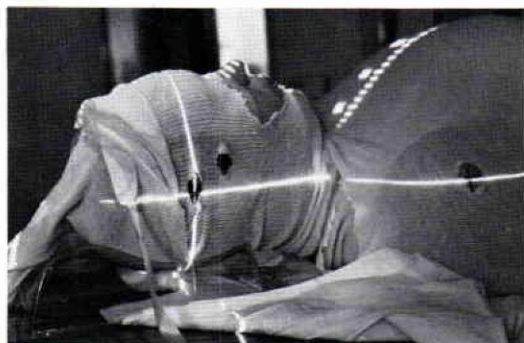


Figure 3. Patient being aligned with lasers at the cranium (above the ear) and at the acromion. Note the anterior reference grid to help determine the length and feather points of radiation. Also note the plastic head cup used to reduce cervical curve.



Figure 4. Application of plaster to neck area after applying webril.

reference lines help assure the established alignment prior, during, and after casting. After alignment is complete, webril is applied, two to three layers, over the entire anterior head and neck to mid frontal plane (Figure 4). Continue applying webril over the entire anterior torso to a point 10 centimeters distal to the perineum. The medial and lateral edges of the webril for the negative impression of the torso should radiate well past the mid frontal line to the positioning table.

Rapidly apply 4" plaster strips of two layers thickness to the head, neck, and superior shoulder level while leaving access to the nose, mouth, and alignment holes. The chin, forehead, and eyes must be cast. Continue casting by applying two layers of six inch plaster from right to left as far posteriorly as possible on both sides. Cover the torso completely—encompassing the arms, which are at the patient's side—and casting to 10 centimeters below the perineum. Leave reference holes open. Then apply two layers of six inch plaster over the entire anterior surface from superior to inferior. Finally, reinforce the neck and shoulder area with two additional layers of plaster bandage.

Realign the laser reference coordinates and re-examine the final position. If these visual coordinates align within satisfactory parameters, the patient is fluoroscoped as a secondary alignment check.

Finally, transfer the mid-frontal laser mark onto the negative mold with an indelible pencil (Figure 5). This line must be scribed from superior cranial to the distal aspect of the negative mold. After the line is completed, lift the mold off the patient, leaving the stockinette in place.

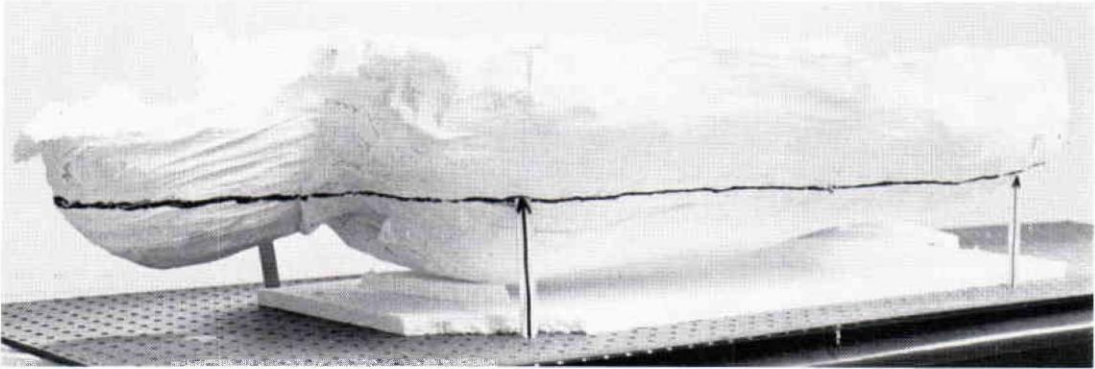


Figure 5. Mid-frontal plane line on mold is parallel to the pressed board base.



Figure 6. Unfinished mouth/nose well and drilling of the lateral breathing holes.

Materials for Mounting of the Negative Mold

- Plaster bandage, six inch
- ¼" perforated pressed board, 21" × 6'
- One roll masking tape, two inch
- Heavy brown paper (90 lb.)
- ½ gallon Kingsley foam
- 10 cans insulation foam
- One inch thick styrofoam sheets
- Stockinette, eight inch and four inch spray glue
- 4 cm. hole saw w/ power drill
- Skiving knife
- Utility knife
- Large scissors
- Cast cutter

With cast cutters and large scissors, trim and smooth all edges. Those of the torso should be left as high as possible. However, the head and neck trim lines will be determined by the physicist (we have radiated through the negative mold and maintained accurate depth of penetration). Fi-

nally, trim the nose and mouth opening to a symmetrical square opening and apply masking tape over the outside of this opening.

Prepare the quarter inch pressed board by applying masking tape over the holes on the rough side of the board (Figure 4). Place the board on a flat level work area which has been covered with paper.

Locate the negative mold, head down, on the board, so that the head portion is at one end of the board. Put styrofoam blocks under the torso, lifting the mold high enough so that the nose will be well clear of the baseboard upon completion. Carefully align the transcribed laser reference line on the mold with the pressed board base, assuring these references are parallel from superior to inferior aspects (Figure 5). Then the parallel references are secured with styrofoam or wood blocks, and the nose clearance is re-examined.

Construct a brown paper form around the head, neck, and upper shoulder area. Secure this form to the board with masking tape. Mix one-half to one quart of Kingsley foam and pour it into the molded area, and let cure (Figure 8). Once the head, neck, and shoulder area is secure, use styrofoam blocks to fill the large gaps between the cast and base, and pour one-half to one quart of Kingsley foam down the mid-line of the negative mold in three intervals. When this has cured, inject insulation foam in the gaps of the styrofoam. Prepare a paper form to surround the circumference of the negative mold and inject foam to fill the

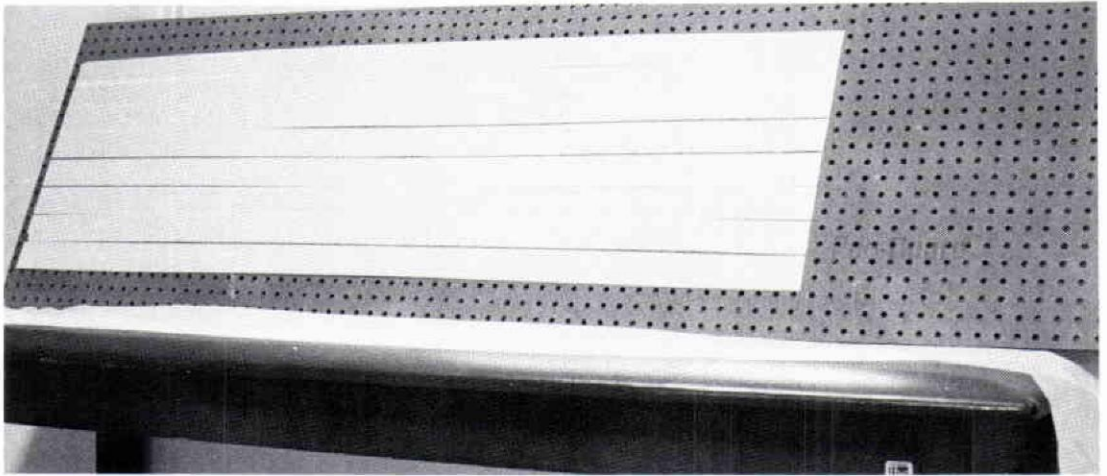


Figure 7. Masking tape applied to pressed board.

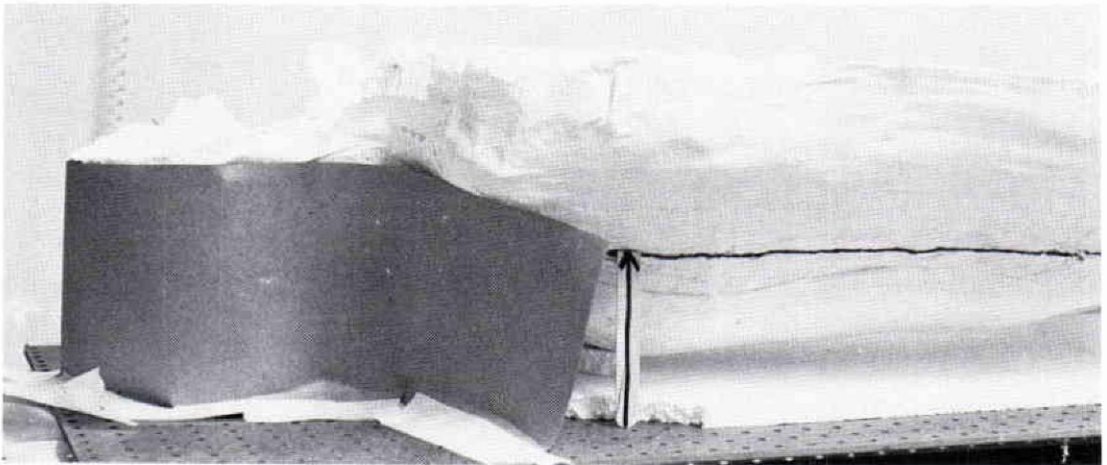


Figure 8. Head/neck area formed to pour Kingsley Foam. Be certain that the parallel alignment between the mold and base board is maintained during this procedure.

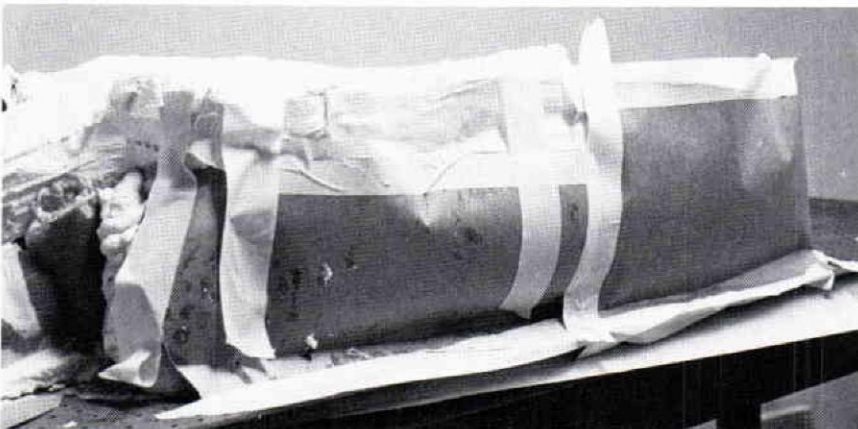


Figure 9. Entire mold formed with paper, and foamed.



Figure 10. Lateral breathing hole must be clear to mouth/nose well at the level of the base board.

form (Figure 9). Let this foam cure overnight. If the patient is heavy or large, a final layer of Kingsley foam should be formed over the outer surface to insure rigidity.

Trim the side walls of foam flat with a large skiving knife. The foam should extend no higher than the mid-frontal plane of the head, cervical, and superior shoulder level. Trim the foam as high as the plaster trim line for the torso.

Cut through the masking tape and foam of the nose/mouth area by removing all foam material down to the pressed board base (Figure 6). This constructs a well within which the nose and mouth fit. Using the 4 centimeter hole saw, drill medial and lateral breathing holes perpendicular and centered in the transverse plane with the nose/mouth relief at the level of the pressed board (Figures 6 and 10).

Cut a length of stockinette which will cover the inside surface of the negative mold, and drape over the sides, two inches past the pressed board. Then cut this piece of stockinette length wise.

Apply spray glue to the inside of the negative mold to which the above stockinette is to be applied. At this time, smooth webril and add additional webril where necessary to fill gaps. Immediately apply flat stockinette at the center of the negative mold and work the fabric smoothly to the edges. Continue applying stockinette until the entire mold is lined (Figure 11). Strips of stockinette should be applied to the nose/mouth relief before the head is lined (Figure 12). Additionally, allow extra



Figure 11. Completed negative mold covered with stockinette.

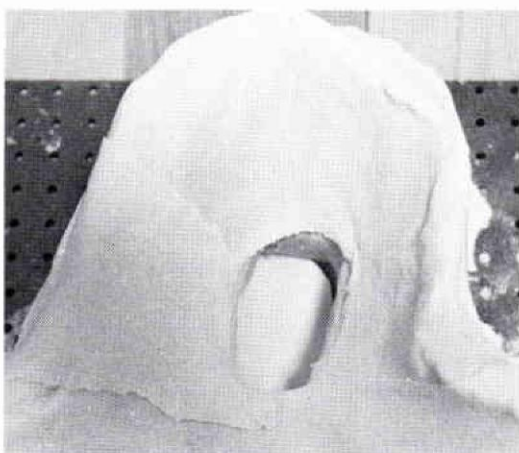


Figure 12. Nose/mouth well finished.

stockinette to drape over the distal edge of the torso. Glue perimeter flaps to side walls and to the underside of the board (Figure 11). All glue must dry well before use of the mold by the patient.

A foam pad is placed at the bottom of the nose/mouth relief (Figure 12). Foam sheets or blocks are cut to support the lower extremities.



Figure 13. Patient in arm-out position being visually aligned.

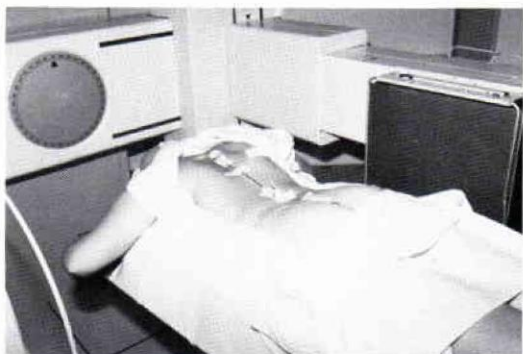


Figure 14. Patient in arm-out position with lead strip taped over spine for fluoroscopic alignment.



Figure 15. Patient ready for treatment (arms in position). Note the three feather lines at the lower thoracic region and reference marks on the posterior and lateral skull.

The completed appliance is placed on the simulator for final patient alignment. The patient should be instructed to lie straight down into the device, as this will achieve the best reproducible alignment. If the patient enters by sliding up into the mold, displacement of soft tissue impedes proper alignment of the patient into appliance reliefs, resulting in poor reproducible alignment.

A light reference is then placed along the posterior mid-sagittal. Palpate the vertebrae to ensure the laser is centered on the vertebrae. Shift the patient slightly to achieve a visual alignment (Figure 13).

Next, medial/lateral laser quadrants are applied to the skull, usually on the ears, if the quadrants are similarly located on both ears. The patient's head is now visually aligned.

Finally, the patient is fluoroscoped to substantiate vertebral and cranial linearity (Figure 14). If the fluoroscopic examination is satisfactory, the laser marks are transferred to the patient's skin as future reference coordinates.

DISCUSSION

Reproducible alignment could not be achieved on one obese female patient with the standard procedure of incorporating her arms into the negative impression. Subsequently the procedure was modified by putting her arms outside the impression, elbows flexed and hands resting near the area of her ears (Figures 13 and 14). This allowed construction of the side walls to contact her thoracic and pelvic areas, increasing control of her flesh and achieving satisfactory, reproducible alignment.

CONCLUSION

Cranio/spinal positioning devices are not new to the radiological treatment of ependymomas. However, such devices are not used in all facilities. Given the difficulty of radiating such a large area while holding to precise parameters, it is suspected that the limitation of adequate construction technology precludes the use of

positioning devices in some radiation facilities. Additionally, by taking the negative impression on a simulator and using a laser alignment procedure, an improved alignment technique has been incorporated into the present molding procedure. Segmenting the mounting procedure from the molding sequence is unique, allowing for a desirably shorter patient casting time, while giving the orthotist the latitude to more precisely mount the negative mold.

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