Frameless, pinless stereotactic neurosurgery in children

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Objective. Frameless neuronavigation has been established as a useful adjunct to intracranial surgery; however, the procedure is limited in young children by the need for rigid skull fixation with pins. Pin fixation is difficult and hazardous for patients younger than 2 years of age. Minor risks have been associated with pin fixation in older patients also, including scalp laceration, skull fracture, and epidural hematoma.

Methods. The authors adapted a pinless head fixation system, consisting of a beanbag device, for use with frameless neuronavigation. This system was used to perform intracranial neurosurgical procedures in nine patients.

Conclusions. This pinless, frameless method provides a new option for children who are unable to sustain rigid head fixation. It is also an alternative to rigid pin fixation for patients of any age.

Key Words • third ventriculostomy • neuronavigation • frameless stereotaxy • neuroendoscopy • pediatric neurosurgery

In the past few decades, frame-based stereotaxy has enabled additional precision in neurosurgery; however, the method is cumbersome, lengthens operating time, and interferes with freedom of movement of instruments. The development of computerized frameless neuronavigation has enabled freehand movement and real-time control of the approach trajectory. In addition, frameless neuronavigation is beneficial in cases in which distorted anatomical features hinder localization of landmarks in the body. One current limitation of neuronavigation is the necessity of rigid head fixation with pins. Pin fixation is not routinely performed in children younger than 3 years of age due to the thinness of the skull and the risk of intracranial injury. In addition, pin fixation in older children carries a small risk of scalp laceration, skull fracture, and epidural hematoma. Vacuum beanbag devices are often used to immobilize and position patients for surgery or radiation therapy. We tested the hypothesis that pinless head fixation using a beanbag headholder would make frameless, pinless intracranial neurosurgery available to patients who are vulnerable to the risks of rigid head fixation, particularly the very young.

Clinical Material and Methods

An adaptor to the Mayfield headholder was constructed (Fig. 1) consisting of a plastic plate coupled to the operating room table with an attachment point for the frameless stereotactic localizer. The 50 × 60-cm beanbag device (Vac-Fix; Soule Medical, Inc., Lutz, FL) was fastened to the platform with Velcro (Fig. 2). The senior surgeon (D.W.P.) selected patients suitable for head fixation using the beanbag apparatus. Initially, the headholder was used on young children and eventually, beanbag fixation was also used in older patients undergoing straightforward endoscopic procedures. Preoperatively, patients underwent volumetric CT or MR imaging of the head. The trajectory of the operative approach was planned with the aid of the Stealth neuronavigational system (Medtronic Surgical Navigation Technologies, Louisville, CO). After induction of general anesthesia and the attainment of paralysis, patients were placed in the beanbag headholder. The desired head position was obtained, and vacuum suction was applied to the beanbag to immobilize the patient’s head. Stereotactic head registration was performed using the standard method. An entry point and trajectory were planned, and the neurosurgical procedure was then performed. For endoscopic procedures, the endoscope introducer sheath and endoscope were registered with the neuronavigational system as a stereotactic probe. The endoscope was then tracked in real time. Because the head fixation is not as stable using this method as it is when pin immobilization is used, it is critical for the anesthesiologist to maintain paralysis until the navigational portion of the surgery is completed.

The primary end point for assessing the usefulness of this system was accurate navigation during the procedure. The accuracy of the stereotactic beanbag was evaluated independently by using a model head and the neuronavigational system. The system accuracy, assessed by comparing registered landmarks on the patient’s head to MR images
and calculated as a root mean square error, was less than 3 mm. Outcomes were assessed postoperatively by performing clinical and neuroimaging examinations in the usual fashion.

**Results**

Between January 2002 and January 2003, nine patients underwent frameless, pinless intracranial procedures. The three male and six female patients ranged in age from 2 months to 41 years of age (Table 1). Six of the nine patients were younger than 2 years of age. The patients can be separated into three groups according to the type of operation performed: 1) four patients underwent stereotactic endoscopy and ventricular cyst fenestration; 2) three patients underwent stereotactic third ventriculostomy; and 3) two patients underwent craniotomies. In eight of the patients the operation was performed successfully. Eight of the nine patients experienced improvement in their presurgical symptoms and neuroimaging findings. In one patient (Case 7), the retained ventricular catheter was successfully removed; however, the third ventriculostomy was aborted because of unsuitable anatomical features. This patient died of necrotizing cholecystitis and sepsis.

**Discussion**

Neuronavigation has contributed an added degree of accuracy, reliability, and control in the operating room. The use of prototypical frame-based applications limited access to the surgical field and lengthened operating time, but the subsequent generation of frameless neuronavigation offered real-time control and broadened access to the surgical field. Neuronavigation is a particularly useful adjunct to intracranial endoscopic neurosurgery. Neuronavigation adds an additional dimension of safety to neuroendoscopy by maximizing the accuracy of the approach and minimizing brain trauma. Image guidance is particularly useful for neuroendoscopic treatment of ventricular cysts and multiloculated hydrocephalus because these conditions obscure normal anatomical landmarks. In addition, image guidance can be very useful in endoscopic neurosurgery involving small ventricles, biopsy sampling of intraventricular tumors, third ventriculostomy, and ventriculoperitoneal shunt placement. The utility of neuronavigation also extends to general cranial applications such as tumor resection in the eloquent cortex, locating lesions not identifiable at the cortical surface, and defining probable borders of tumors.

The need for rigid head fixation has limited the use of neuronavigation in young children. Previously, attempts at head stabilization involved taping a small child’s head to the bed, using multiple pin fixation systems (Sugita multipurpose headframe; Mizuho America, Inc., Beverly, MA) or dynamic reference frames directly attached to the patient’s head (StealthStation; Medtronic). Clearly, tape fixation has
We did not procedures.

Alternatively, intraoperative CT or MR imaging eliminates dynamic referencing, remains in the developmental stage. Station AXIEM; Medtronic), with its more sophisticated surgical applications. Electromagnetic technology (Stealth—corp., Plainsboro, NJ), pin fixation remains hazardous in pin devices that have limited the use of rigid head fixation in children younger than 2 years of age. We now routinely use this technique for head fixation in image-guided endoscopic procedures as well as craniotomies in the very young.

**Conclusions**

In the young pediatric population, neuronavigation with rigid head fixation remains a challenge. The beanbag headholder provides a safe, easy, and reliable alternative for head immobilization. The use of the stereotactic beanbag headholder eliminates the risks of rigid head fixation—including scalp laceration, skull fracture, and intracranial hematoma—that have limited the use of rigid head fixation in children younger than 2 years of age. We now routinely use this technique for head fixation in image-guided endoscopic procedures as well as craniotomies in the very young.

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