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Use of an Ultra-Low Field Intraoperative MRI System for Pediatric Brain Tumor Cases: Initial Experience with 'PoleStar N20'

Pediatrik Beyin Tümörü Olgularında Bir Çok Düşük Alanlı İntraoperatif MRG Sisteminin Kullanımı: PoleStar N20 ile Tecrübeler

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ABSTRACT

AIM: Use of intraoperative MRI (iMRI) is the highest contemporary supportive means for brain tumor surgery. In this article we describe the issues related to iMRI use in pediatric cranial operations.

MATERIAL and METHODS: Pediatric cases operated with the aid of Polestar N20 iMRI system are defined and the pros and cons of the system are emphasized.

RESULTS: Patient positioning is easier and the obtained images are better in pediatric cases, particularly for posterior fossa tumors.

CONCLUSION: iMRI should be used in all pediatric brain tumor operations when possible.

KEYWORDS: Intraoperative, Magnetic resonance imaging, Pediatric, Tumor

ÖZ

AMAÇ: İntraoperatif MR kullanımı günümüz beyin tümörü cerrahisi için en üst destekleyici yöntemdir. Bu yazıda pediatrik kranial operasyonlarda intraoperatif MR kullanımıyla ilgili konulara değinilmiştir.

YÖNTEM ve GEREÇLER: Polestar N20 intraoperatif MR sistemi kullanılarak gerçekleştirilen pediatrik olgular anlatıldı ve bu sistemin olumlu ve olumsuz yönleri belirtildi.

BULGULAR: Özellikle posterior fossa tümörleri için pediatrik olgularda hasta pozisyonlanması daha rahat ve elde edilen görüntü kalitesi daha iyi idi.

SONUÇ: Pediatrik beyin tümörü operasyonlarında iMRI mümkün olduğunca kullanılmalıdır.

ANAHTAR SÖZCÜKLER: İntraoperatif, Manyetik rezonans görüntüleme, Pediatrik, Tümör

INTRODUCTION

Magnetic resonance imaging (MRI) with its multiple and versatile imaging properties is the contemporary means of choice for diagnosis and follow-up of most neurological disorders. Technological development has brought faster and better devices with more diverse images of the nervous system. Following the increasing demand for less or minimally invasive operations, interventional and intraoperative use of this technology has been introduced in the 1990's (4,15). As the name itself implies, the goal of intraoperative magnetic resonance imaging (iMRI) is to supply a real time or near-real time images of the brain during the operation. Although the number of the centers having a chance to use iMRI is increasing, these devices or suites are too difficult to obtain to become widespread for now. As a consequence, there is a slow increase in the number of articles describing the details of the use of iMRI, particularly in the pediatric patient population. In this article, we take the opportunity to describe the efficacy of a low-field iMRI system for pediatric cranial operations by highlighting six pediatric cases.

TECHNIQUE

We use a PoleStar N20 (Medtronic Surgical Navigation Technologies, Louisville, USA), iMRI system with an integrated neuronavigation suite in our operating room. This is a 0.15 T low-field system that approaches the operating table and surrounds the head to obtain images. It consists of a 0.15 T scanning magnet coupled with an optical MRI tracking system. The magnet is formed by two vertical, parallel, medially tapering disk-shaped arms, and the permanent magnet docks under a standard operation table (1,12,19). The aperture between the disk-shaped arms is 27 cm to allow the head of an adult patient to be placed in for imaging of the brain to be accomplished.

Patients are positioned in an MRI–compatible three-pin headholder, to which is attached a passive infrared reference frame for navigational purpose. The magnet is positioned under the table and is approached to the operation field when it is to be used.

After MR imaging is completed, the magnet is lowered beneath the table. Surgery is then continued in the usual way with regular instruments.

ILLUSTRATIVE CASES

Case 1

This 2-year-old boy experienced increasing headache for three months before his admission. MR images revealed a cystic mass lesion in the left side of the cerebellum. Surgery was performed in the prone position. The iMR coil was placed outside the operative field to face the operation area to comfortably acquire images. He was slender enough to fit inbetween the magnets, so acquiring high-quality images of the posterior fossa was possible. Navigation was performed during surgery using the iMR images. Step-by-step iMRI images were obtained. Final images showed the complete resection of the lesion. Histopathologic diagnosis was pilocytic astrocytoma (Figures 1 and 2).

Case 2

This three-year-old boy suffered head trauma and the imaging studies for this trauma incidentally revealed a mass lesion in the left temporal lobe. He was operated in the supine position. Navigation with iMRI images supported the total resection of the lesion (Figure 3). Histopathological diagnosis was dysembryoplastic neuroepithelial tumor.

Case 3

This three-year-old boy suffered long lasting vomiting attacks and weight loss with no impairment of consciousness. Following a period of inconclusive gastrointestinal evaluation, cranial computed tomography was performed and showed a posterior fossa tumor. He was operated in prone position. Complete removal of the tumor was accomplished with the

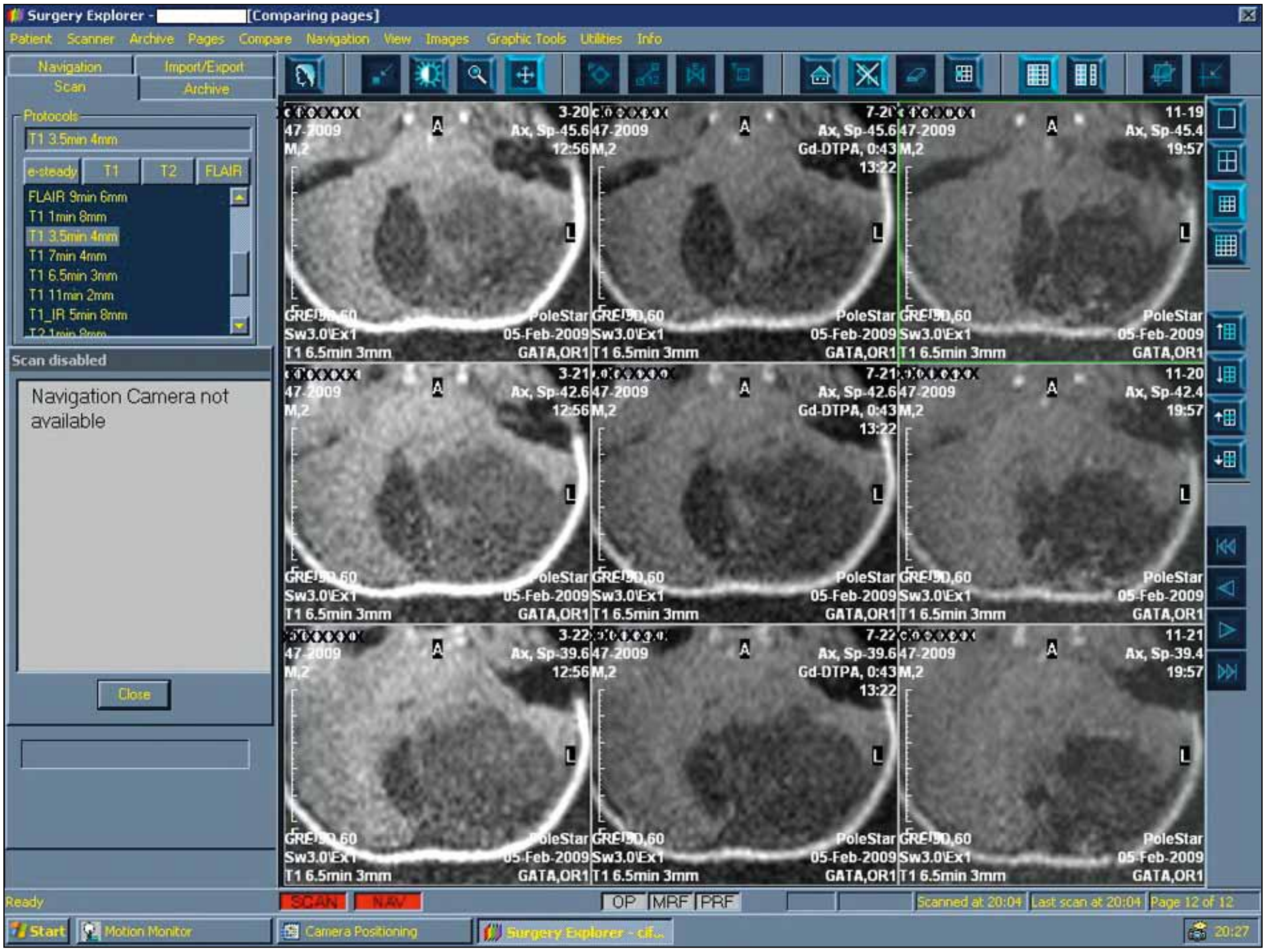

Figure 1: iMRI images showing the complete resection of left cerebellar tumor. Left column: at the beginning, middle column: in the middle, right column: at the end of the operation.

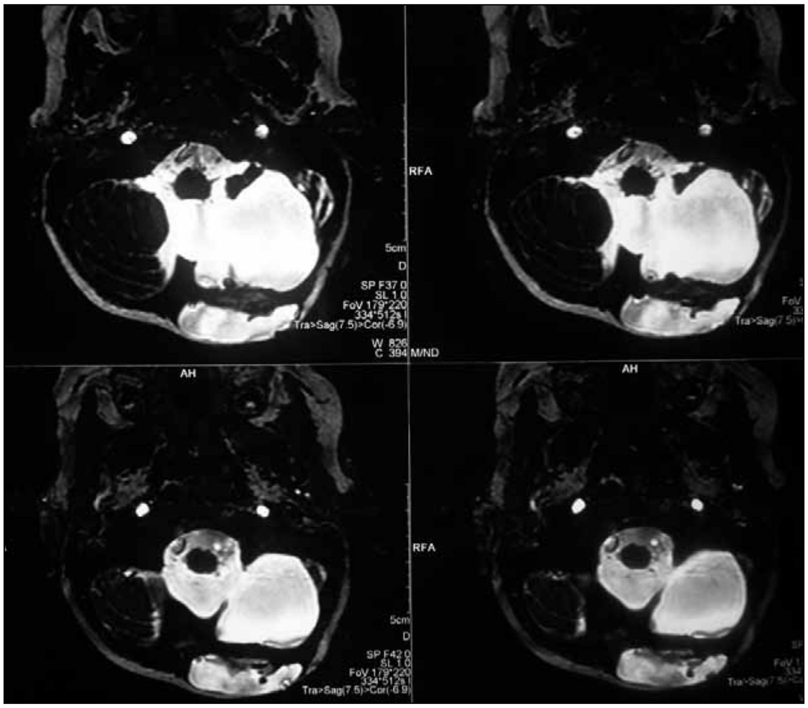

Figure 2: Postoperative MRI images confirming the resection (ninth month follow-up).

Figure 3: iMRI images gradually showing the resection of the left temporal tumor (from left to right).

support of iMR system. Histopathological diagnosis was ependymoma Grade II (WHO) (Figure 4).

Case 4

The family of this four year-old girl noticed her inability to climb down the stairs. Cranial MR revealed a suprasellar mass lesion and she underwent a resection operation via pterional approach. Subtotal excision of the mass lesion was performed with the aid of iMRI. Histopathology was pilomyxoid astrocytoma (Figures 5 and 6).

Figure 4: Complete resection of posterior fossa tumor. Note the brilliant view of all the cervical spine.

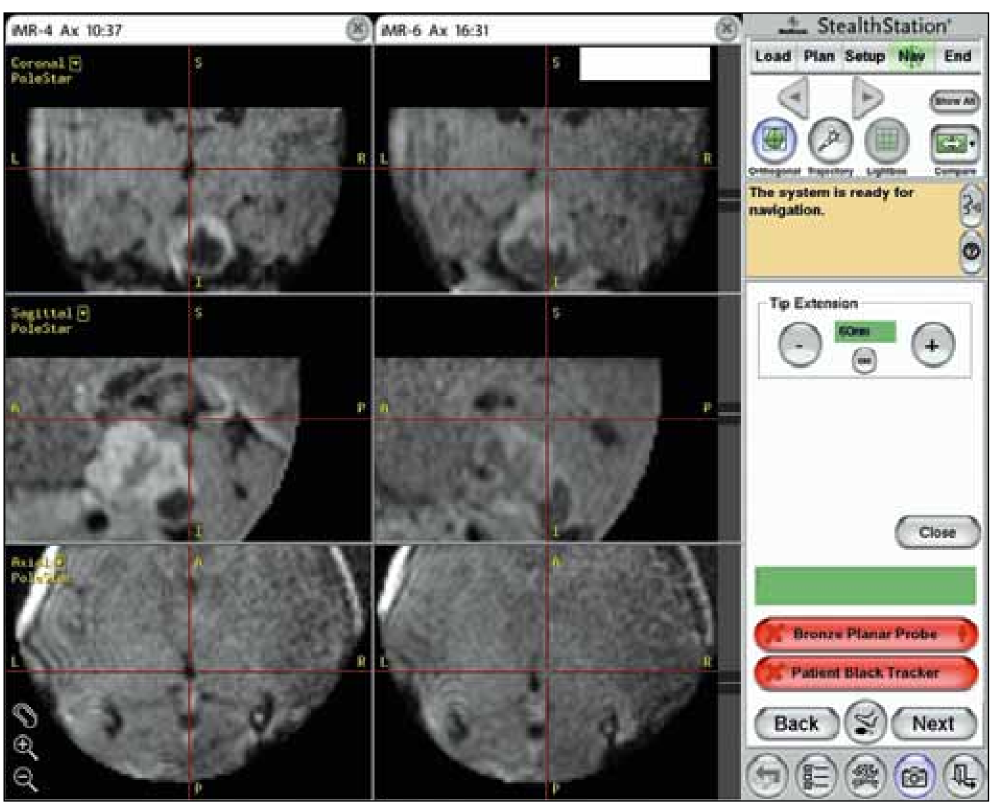

Figure 5: iMRI images transferred to navigation screen. Left column at the beginning, right column at the end of the operation.

Case 5

Radiological evaluation of this three year-old boy with gait and stance disturbance revealed a giant cystic posterior fossa lesion. He was operated via a suboccipital craniotomy and the lesion was totally resected with the aid of iMRI (Figure 7). Histopathology was pilocytic astrocytoma.

Case 6

Another three year-old boy with gait disturbance was admitted and his MR scans showed a solid forth ventricle mass with small cysts. He was operated in the prone position with iMRI. Total resection was accomplished and the histopathological diagnosis was medulloblastoma (Figure 8).

Figure 6: Suprasellar mass lesion.

DISCUSSION

The use of iMRI in cranial procedures provides an immediate control of the operation site. The volume of the residual lesion can be easily assessed especially in deep or eloquent area tumors (3,13,14). Intraoperative MR imaging guidance has also proven to be useful in stereotactic surgery, epilepsy surgery, transsphenoidal surgery and spine surgery (5,6,9,11,21).

Over the years, the application of iMR imaging in the pediatric neurosurgical population has become accepted as an innovative and important neurosurgical technique. Lots of different magnet types in different designs have been used but the majority of studies in pediatric patients have been limited to low-field iMR imaging systems (2,11,16,17,18,20) with the exception of just a few series (7,10).

We could define the optimal iMRI system as providing excellent images in different sequences (may be supplied by a high-field magnet) without the need of interruption of surgery and arrangement of the operation room for imaging. The higher the magnetic field, the lower the usability of incompatible surgical and anesthetic operation room instruments and devices. However, no optimal suite has been developed yet. Despite the fact that high-field systems can supply high-resolution images, the use of these systems are quite complicated and usually requires an MRI operator. Such factors result in longer operation time and correlated risks. The high cost of such a purchase is another handicap.

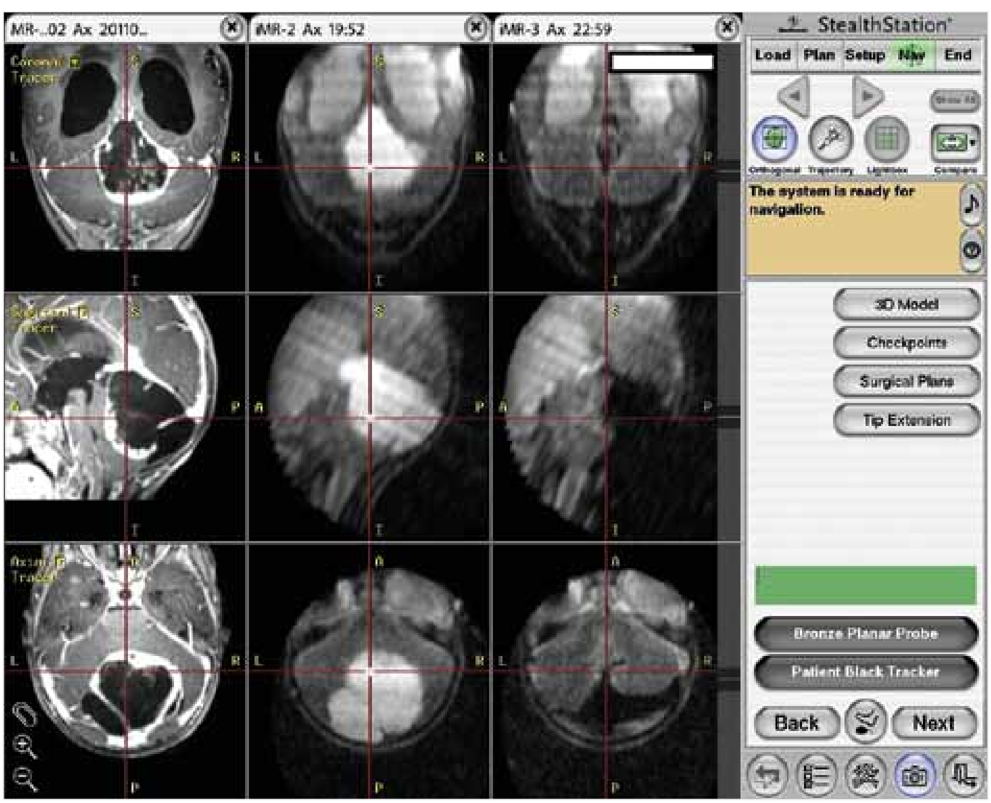

Figure 7: MR images in the navigation screen. The left column shows preoperative images and middle column shows the lesion at the beginning of the operation. The right column confirms the total resection.

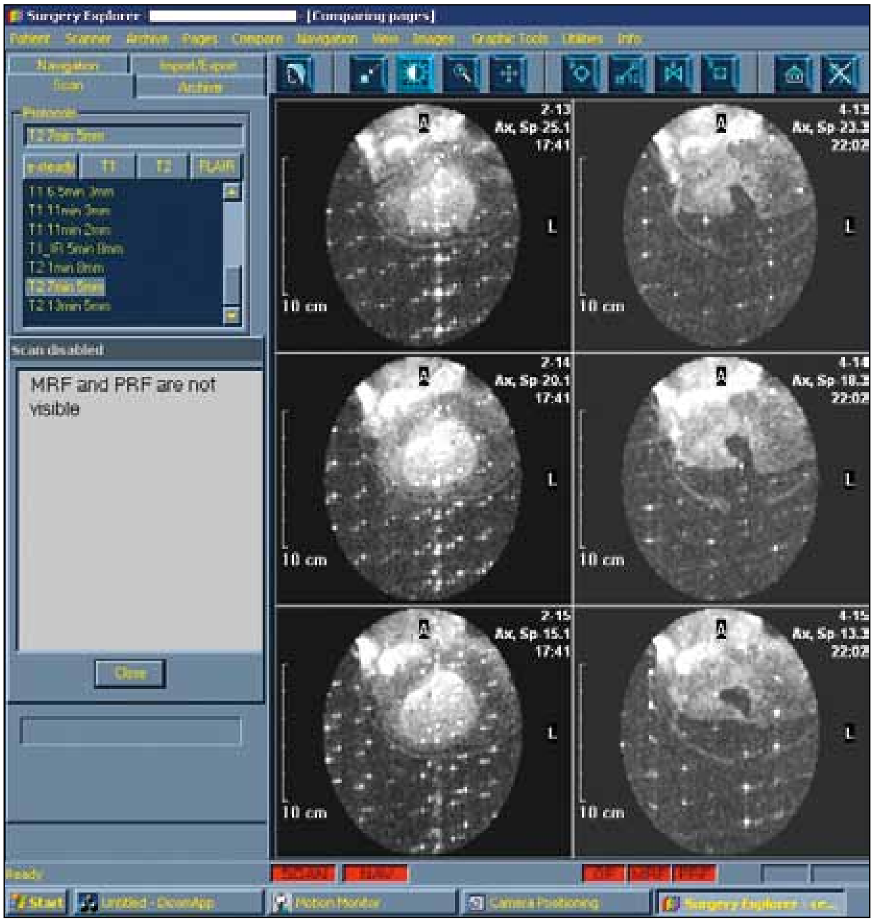

Figure 8: Intraoperative MR images of the forth ventricle mass lesion. Left column at the beginning of the operation and right column at the end with total resection**.**

Figure 9: Slender body structure of the child fits inbetween the magnets.

Our low-field iMRI system has the advantages of its low-field magnetic strength. It can be used in a standard operating room with MRI incompatible instruments. It provides more patient access since scanning and navigation are directly under the control of the neurosurgeon and thus eliminates the need of the simultaneous presence of a neuroradiologist or an MRI operator. Precision and accuracy acquired by N20 system are comparable to other systems particularly in tumor surgery and biopsies. (8,19).

The width of the patient's shoulders and the field of view of the magnet are two major restrictions for obtaining certain images. Only the supratentorial area of an adult can fit into the aperture of the magnets in the prone or supine positions. The infratentorial area of an adult can be partially seen only in the three quarter prone position. However, a slender pediatric patient can easily fit into the magnet and supratentorial, infratentorial and even the whole cervical spinal region can be viewed clearly in pediatric patients in the prone, supine or Concorde positions (Figures 4 and 9).

The field of view is 16x20 cm (Figure 10). The head circumference of a pediatric patient up to 4 years old is 47-54 cm (mean 51 cm). This means a diameter of about 16 cm. The field of view is big enough to cover almost the whole brain of a pediatric patient up to four years old (Figure 11).

It is well known that the lesion should be centered in the coil field of view in order to get better image quality. It is very difficult to center the lesion in the field of view as in posterior fossa lesions, especially in acromegalic adult patients. With a small head, circumference positioning of the coil becomes

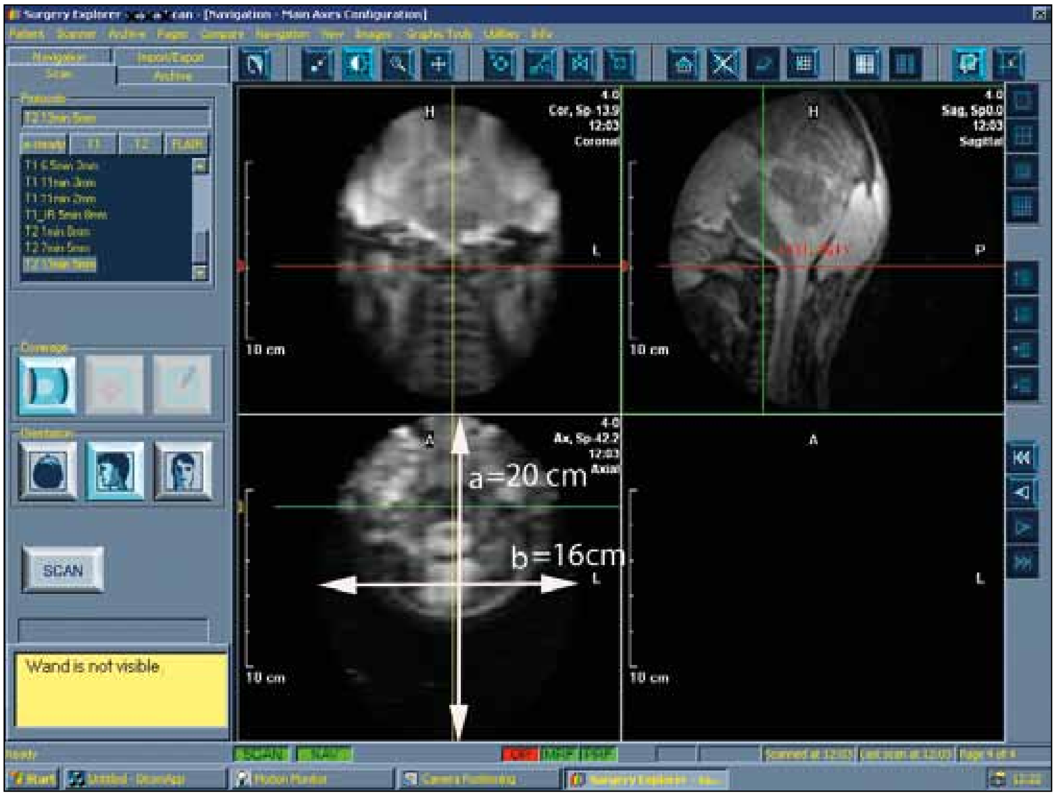

Figure 10: Lower left image shows the field of view. The field of view is 16 x 20 cm.

Figure 11: The hole in the middle of the apparatus mimicking the magnet aperture represents the field of view. Almost whole cranium is inside the field. The coil is placed to obtain images of the posterior fossa.

easier even in posterior fossa lesions as seen in case 3 (Figure 11).

Restricted surgical field may also be a problem in some adult brain operations due to the limited area allowed by the coil.

Preoperative patient positioning and head holder positioning is also a time-consuming procedure in adult patients. In comparison with an adult patient, almost half the time is required for positioning a pediatric patient. The three quarter prone position is needed for a posterior fossa lesion in an adult to fit the patient's head inbetween the magnet arms. Achieving this position as well as the head holder positioning is quite time consuming. The Concorde position can be used for a similar lesion in a pediatric patient less than four years old, but if the three quarter prone position is especially needed the head holder positioning and coil field of view centering is less time consuming.

CONCLUSION

We recommend using iMRI in all pediatric brain tumor operations due to easier patient, coil and head holder preparation, for navigation purposes, and for peroperative and intraoperative evaluation of the surgical success. iMRI is also less time consuming in pediatric patients than adults. Even cervical images can be obtained by the Polestar N20 iMRI if needed.

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