Intraoperative magnetic resonance imaging and meningioma surgery

***A. A. Adeolu and G. R. Sutherland**
**Department of Surgery, College of Health Sciences*
Obafemi Awolowo University, Ile Ife, Osun State, Nigeria
e-mail address: adeoluaa@yahoo.com
Seaman Family Magnetic Resonance Imaging Research Center, Division of Neurosurgery,
Department of Clinical Neurosciences, Foothills Hospital/
University of Calgary, Alberta, Canada

Summary
Objective: **To determine if intraoperative magnetic resonance imaging improves surgical resection and postoperative outcome of intracranial meningioma.**
Study design: **Prospective, non-randomized, cohort study**
Method: **Intraoperative Magnetic Resonance Imaging (iMRI) was used to evaluate patients with meningioma undergoing surgery. Images were obtained after induction of anaesthesia and at various stages of tumour resection. Extent of surgical resection was graded using Simpson grading system for meningioma. The images were reviewed together with histopathology and early outcome. Primary outcome measure was determined by finding unexpected tumur in interdissection images. Secondary outcome measures were determined by postoperative complications including infections and mortalities.**
Results: **There were 39 procedures in 38 patients from January 1998 to December 2002. Surgical-planning images helped to optimize craniotomy placement. Interdissection images revealed unexpected residual tumour in only 1 patient. Complete resection (Simpson grades 1-3) was achieved in 33 procedures. The average follow up period was 16.4 months. Tumour recurrence has been observed in three patients. Two of these patients had anaplastic meningioma. There was no mortality in the 30-day postoperative period.**
Conclusion: **Intraoperative MRI was beneficial in siting the craniotomy in addition to providing anatomical relationships between the tumour and adjacent structures in lesions located at the skull base though the full benefit of these is yet to be determined. The low morbidity and zero mortality recorded in the study may be related to all these factors.**

Key-words: ***Intraoperative Magnetic Resonance Imaging, Meningioma, Resection, Outcome.***

Résumé
Objectif: Déterminer si l'imagérie par résonance magnétique provoque une amélioration dans la résection chirurgicale du méningiome intracranien et des résultats postopératoire.
Plan d'étude:- Etude cohorte, en perspective, non-randomiser.
Methode: Imagérie par résonance magnétique intra-opératoire (IRMI) était utilisé afin d'évaluer des patients atteints du meningiome qui suivent un traitement chirurgical. Des images ont été obtenues après le déclenchement d'anesthésie et des diverses étages de la resection de la tumeur. La valeur de la resection chirurgicale était mesuré à travers l'utilisation du système du classement de Simpson pour le méningiome. Les images ont été passé en revue ensemble avec l'histopathologie et un résultat précoce. Des mesures des résultats primaires ont été décidées tout en étudiant la tumeur inattendu dans les images interdissections. Des mesures des résultats secondaires ont été décidées à travers des complications postopératoires y compris des infections et mortalités.
Resultats: Il y avait 39 protocoles à partir du janvier 1998 au décembre 2002. Des images de l'organisation chirurgicale ont beaucoup aidé d'optimiser le placement de la craniotomie. Des images de l'interdissections avaient indiqué le résidu de la tumeur inattendue chez un patient seulement. Résection complète (calibrage de Simpson 1-3) était réalisé dans 33 protocoles. La période moyenne de soins post-hospitalier était 16,4 mois. La fréquence de la tumeur a été notée chez trois patients dont deux avaient eu un méningiome analplastique. Il n'y avait pas une mortalité dans le 30 jours période postopératoire.
Conclusion: IRM Intraoperatoire était bon dans l'emplacement de la craniotomie en plus de la fourniture des rapports anatomiques entre la tumeur et des structures adjacentes dans les lesions siègées dans la base du crane quoique on n'arrive pas encore à étudier leurs avantages en plein fleur. La base de la morbidité et de la mortalité zero notée dans cette étude pourrait ëtre en consequence de tous ces facteurs.

Introduction

Meningioma is the second most common primary intracranial neoplasm occurring at a frequency of 13-22%[1,2]. The majority of the tumours have a benign pathology such that complete surgical resection may be curative[3-7].

Preoperative imaging allows accurate tumour localization, assessment of local mass effect, vascular supply and the degree of peritumoral edema with brain shift[8]. Surgical navigation techniques have resulted in more accurate craniotomy placement[9-11]. In an attempt to further enhance lesion localization and resection, several investigators have introduced intraoperative CT[12] and MR[9, 10, 13-18] imaging.

In this report we analyze 38 patients with meningioma who underwent tumour resection with IMRI to determine if intraoperative imaging augments surgical resection and outcome.

**Correspondence*

Materials and methods

Patients population

This was a prospective study of all the thirty-eight patients who underwent thirty-nine procedures for intracranial meningioma in our iMRI suite from January 1998 to December 2002. The selection criterion for iMRI management was the presence of a lesion whose surgical removal could potentially benefit from iMRI on the basis of lesion localization and resection control (surgical planning and interdissection images), ensuring its complete resection and revealing the presence of complications (quality assurance image).There were 364 procedures in the iMRI suite over the study period.

MRI technique

i) ***Technology***

The intraoperative MRI used in this study has been described in details in earlier reports[9, 18-21]. iMotion, as the system is currently known essentially consists of ceiling mounted, movable, high-field 1.50 T magnet. It is capable of moving in and out of operating room as needed.

ii) ***Imaging sequence***

Surgical planning images were obtained after induction of anaesthesia and positioning of the patients. We performed interdissection study in all the patients to determine extent of resection and further anatomical details. Quality assurance study was done after skin closure. High definition T1 images were obtained in all the patients. Enhancement was performed with gadolinium. Nine patients had T2 images. Neuronavigation was coupled to our IMRI system in 1999 and was used in eight patients. Magnetic resonance angiography was performed in three patients. We analyzed the images obtained. We also reviewed the histology reports of the resected specimen, operation notes, theatre records, and immediate postoperative course. We analyzed the findings and compared the results with previous reports on benefits of intraoperative MRI and outcome in operative management of meningioma. Extent of resection was graded using Simpson grading system for meningioma[22] as follows:

Grade 1: Complete macroscopical tumour removal with its dural attachment and any abnormal bone (including sinus resection if involved)

Grade 2: Complete macroscopical tumour removal with coagulation of its dural attachment

Grade 3: Similar to grade 2 but without coagulation of dural attachment

Grade 4: Subtotal tumour removal

Grade 5: Simple tumour decompression or biopsy

Outcome measures: Primary outcome measure was determined by finding of unexpected tumour in interdissection images. Secondary outcome measures were determined by postoperative complications including infections and mortalities. We also looked for resolution, persistence, worsening and recurrence of the preoperative symptoms and signs in the postoperative period. Postoperative MRI finding of recurrent tumor was taken as evidence of tumor recurrence.

Results

There were 39 procedures in 38 patients over the study period. One patient was operated upon twice because of tumour recurrence. Twenty-six of the patients were women and 12 were men. The female: male ratio was 2.5: 1 The age range of the patients was 24 years to 84 years with a mean of 56 ± 17years.

There were only four infratentorial lesions with the remaining lesions located in the supratentorial compartment. Table 1 gives further details of the lesion distribution. Nearly 62% of the lesions were located in the convexity and parasagittal regions

Table 1 Tumour location

Location	Number of cases	Percentages
Convexity	13	33.3
Parasagittal/falcine	11	28.2
Olfactory groove	5	12.9
Sphenoidal ridge	2	5.1
Tuberculum sellae	4	10.3
Clivius	2	5.1
Cerebellopontine angle	2	5.1
Total	39	100

Extent of resection

Unexpected residual lesion was found in one patient (see figure). There was incomplete excision in six procedures. Table 2 illustrates the extent of resection using the Simpson grading system for meningioma[22].

Table 2 Extent of resection by Simpson grade

Simpson grade	Number of patients
Grade I	5
Grade II/III	28
Grade IV	6
Grade V	0
Total	39

Pathology and outcome

Thirty-three (84%) of the resected tumours had benign pathology. Five (12.9%) lesions were atypical and 1(2.6%) lesion was malignant.

The postoperative hospital stay for the patients was from 2 days to 70 days with a mean of 8.4 days. Table 3 further illustrates this.

Table 3 Postoperative hospital stay

Number of days	Number of patients
1-5	22
6-10	9
11-15	5
16-20	0
>20	2
Total	38

More than half of the patients were discharged within 5 days of operation with only 7 patients being discharged after 10 days.

Thirty-one patients remained the same or had improved

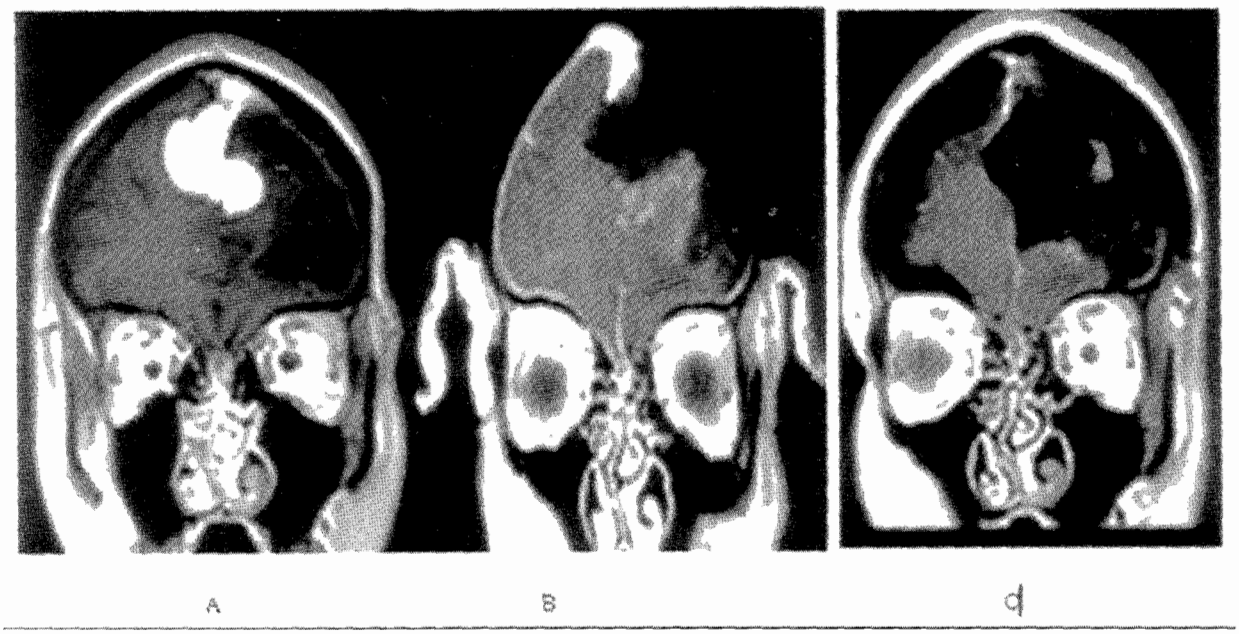

Figure: *Contrast enhanced T1 intraoperative MRI images (Coronal views). A. Surgical planning images showing recurrent falcine meningioma B. Interdissection images showing unexpected residual tumour C. Quality assurance images showing complete tumour resection*

at the time of discharge following surgery. Eight patients were worse. None of the patients developed wound infection. There was no mortality.

Thirty-six charts were available for follow up review. Three of these patients were referred to other hospitals. They were not doing well at the time of discharge and were not available for follow up. The follow up period was from 1 month to 54 months with a mean of 16.4 months. The status at the last follow up is as shown in Table 4.

Table 4 Status at postoperative follow up

Status	Number of patients
Improved	19
Stable	5
Residual	6
Recurrence:	
Stable	1
Reoperated	2
Total	33

Only 1 out of the six patients with residual tumour showed evidence of radiological progression at the last clinic attendance, the other patients were stable.

One patient was readmitted one month after discharge because of deteriorating level of consciousness. He died few days after from hyperglycemic coma.

Discussion

The female preponderance and distribution of the lesions in our series follow known pattern for meningioma[3, 6, 7].

Only 4% of our series were malignant. This finding is in keeping with other reports[2-7]. In view of the benign nature of these lesions, meningioma constitutes a rewarding lesion to treat if complete resection can be achieved at surgery. To achieve this goal, good perioperative planning is very important.

Our IMRI systems allowed us to take immediate preoperative and intraoperative images without compromise of the standard anesthetic and surgical techniques and principles. We obtained good quality images that gave the surgeons good anatomical definition of the tumours as well as their relationship to adjoining structures (see Figure). These images gave better details compared to the images from systems of lower field strength[17, 19, 23] and CT. T1 axial and coronal views were used in most of the cases and these were found to be adequate to make good judgment and appropriate decisions in these cases.

The ability of iMRI to give good quality and up-to-date images helped in siting the surgical opening over the lesions. This will avoid unnecessary brain retraction and traction on delicate tissues. Neuronavigation has now been incorporated into our system. This further helped with incision placement and tumour location. The former was found to be accurate in this study though we did not ascertain if this gave smaller openings compared to conventional surgical procedure. Again the advantages of the images thus acquired cannot be overemphasized compared

to preoperatively acquired images. The latter is prone to brain shift and distortion from both physiological and physical factors[15, 24]. Change in tumour size at the time of surgery compared to preoperative evaluation can also be determined at the time of surgery.

Complete excision is the surest way of preventing recurrence in meningioma. Simpson reported recurrence rate of 9% after grade 1 excision, 19% for grade II excision and 40% following grade IV excision[22]. Chan and Thompson reported similar recurrence rates in their study[6]. The overall recurrence rate in our patients was 10.3% in 29 patients who had complete excision (Simpson grades I-III) and were available for follow up. Two of the three patients with recurrence had atypical lesions. This has potential for recurrence[2, 3]. Only 1(4.5%) patient out of the 20 patients with benign lesions had recurrence following grade II/III excision.

Perhaps of greater significance is the 30-day postoperative mortality in the excision of meningioma. Adegbite et al in their series reported a mortality rate of 7 %[7]. The mortality rate in Chan and Thompson's series was 4 %[6]. There were 16 deaths in the series reported by Mirimanoff[4]. There was no mortality in our series. Even though our study population is small and the follow up period is short, we believe that the adequate perioperative anatomy provided by our system helped to achieve the lower recurrence rates with no mortality. Furthermore, we did not record any postoperative infection in our series. Even though the operative time is prolonged when using our system as earlier reported[25], adequate precaution is taken to prevent contamination. This finding is different from other series in which a different iMRI system is used. Such series reported postoperative infection related to the use of the iMRI, though the incidence of this was low[23]

Meningiomas are often extraaxial and encapsulated making dissection from adjoining structures relatively safe. In this study we found out that interdissection studies showed complete excision in 32 procedures and further excision to remove residual lesion was performed in only 1 patient (see Figure). This may suggest that operating these patients in the iMRI environment was not helpful. We cannot however, exclude the influence of the surgical planning imaging and, probably, neuronavigation on our outcome. We believe that the zero mortality in this study was the result of combination of these factors. The fresh memory of the structural relationship of the tumors allowed us to avoid injury to delicate structures and prevented overaggressive tumor removal when this was not safe. Moreover, at least the technology can be used for appropriate surgical planning; after surgical planning images, the procedure can be continued as in regular operating suites. Perhaps the two-room concept as described by Sutherland and Kaibara may be more appropriate for this [9]. It will avoid unnecessary patient transfer to the radiology department on the day of surgery as being done for stereotactic surgery including frameless stereotactic procedures.

The experience from this study also suggests that meningioma can be used for optimizing skill in iMRI techniques. It is appropriate for teaching the staff and improving IMRI technology.

Conclusion

Intraoperative MRI was found to be helpful for appropriate surgical planning and incision placement. It was also beneficial in providing anatomical relationships between the tumor and adjacent structures especially in lesions located at the skull base. The full benefit of this remains to be determined. We think the low morbidity and zero mortality recorded in the study may be related to all these factors. Larger and prospective, randomized series with a longer follow up period is recommended to confirm our findings.

References

1. Sutherland GR, Florell R, Louw D, Choi NW, Sima AAF. Epidemiology of intracranial Neoplasms in Manitoba, Canada. Can. J. Neurol.Sci. 1987; 14: 586-592.

2. DeAngelis LM. Primary brain tumors (Intracranial neoplasms). N Eng. J. Med. 2001; 344:

3. Rohringer M, Surtherland GR, Louw DF, Sima AAF. Incidence and clinicopathological features of meningioma. . J Neurosurgery 1989; 71: 665-672.

4. Mirimanoff RO, Dosoretz DE, Linggood RM, Ojemann RG, Martuza RL. Meningioma: analysis of recurrence and progression following neurosurgical resection. . J Neurosurgery 1985; 62: 18-24.

5. De Monte F. Current management of meningioma. Oncology 1996; 9: 83-100.

6. Chan RC and Thompson GB. Morbidity, mortality and quality of life following surgery for intracranial meningiomas. . J Neurosurgery 1984; 60: 52-60.

7. Adegbite AB, Khan MI, Paine KWE, Tan LK. The recurrence of intracranial meningiomas after surgical treatment. J Neurosurgery 1983; 58: 51-56.

8. Gold HI, Lavi E, Atlas SW: Extraaxial Brain tumors. In: Atlas SW, ed. Magnetic resonance of the brain and spine, 2nd edition. Philadelphia: Lippincott-Raven; 1996: 423-487.

9. Sutherland GR and Kaibara T. Neurosurgical suite of the future III. Neuroimaging Clinics of North America 2001; 4: 593-609.

10. Rubino GJ, Farahani K, McGill D, Van de Wiele B, Villablanca JP, Wang-Mathieson A. Magnetic resonance imaging-guided neurosurgery in the magnetic fringe fields: the next step in neuronavigation. Neurosurgery 2000; 46: 643-654

11. Gansandt O, Behari S, Gralla J Fahlbusch, Nimsky C. Neuronavigation: Concept, Techniques and applications. Neurology India 2002; 50: 244-255.

12. Lunsford LD, Parrish R, Albright L. Intraoperative Imaging with a therapeutic Computed tomographic scanner. Neurosurgery 1984; 15: 559-561.

13. Hall WA. High–field MRI in intracranial interventions. Medica mundi 2000; 44: 10-15.

14. Tronnier VM, Wirtz CR, Knauth M, Lenz G, Pastyr O, Bonsanto MM, et al. Intraoperative diagnostic and evaluational magnetic resonance imaging in neurosurgery. Neurosurgery 1997; 40: 891-902.

15. Wirtz CR, Knauth M, Staubert A, Bonsanto MM, Sartor K, Kunze S, Tronnier VM. Clinical evaluation and follow-up results for intraoperative magnetic resonance imaging in neurosurgery. Neurosurgery 2000; 46: 1112-1120.

16. Steinmeier R, Fahlbusch R, Ganslandt O, Nimsky C, Buchfelder M, Kaus M, et al. Intraoperative Magnetic resonance imaging with the magnetom open scanner: concepts, neurosurgical indications, and procedures: a preliminary report. Neurosurgery 1998; 43: 739-748.

17. Hall WA, Martin AJ, Liu H, Nussbaum ES, Maxwell RE, Truwit CL. Brain biopsy using high-field strength interventional magnetic resonance imaging. Neurosurgery 1999; 44: 807-814.

18. Dort JC, Sutherland GR. Intraoperative magnetic resonance imaging for skull base surgery. Laryngoscope 2001; 111: 1570-1575.

19. Kaibara T, Saunders JK, Sutherland GR. Advances in mobile intraoperative magnetic resonance imaging. Neurosurgery 2000; 47: 131-138.

20. Kaibara T, Myles ST, Lee MA, Sutherland GR. Optimizing epilepsy surgery with intraoperative MR imaging. Epilpsia 2002; 43: 425-429.

21. Sutherland GR, Kaibara T, Wallace C, Tomanek B, Richter M. Intraoperative assessment of aneurysm clipping using magnetic resonance angiography and diffusion-weighted imaging: Technical case report. Neurosurgery 2002; 50: 893 - 898.

22. Simpson D. The recurrence of intracranial meningioma after surgical treatment. J. Neurol Neurosurg Psychiatry 1957; 20: 22-39.

23. Hall WA, Liu H, Martin AJ, Pozza CH, Maxwell RE, Truwit CL. Safety, efficacy and functionality of high-field strength interventional magnetic resonance imaging for neurosurgery. Neurosurgery 2000; 46: 632-642.

24. Dorward NL, Alberti O, Velani B, Gerritsen FA, Harkness WFJ, Kitchen ND, Thomas DGT. Postimaging brain distortion: magnitude,correlates, and impact on neuronavigation. J. neurosurgery 1998; 88: 656-662.

25. Archer AP, McTaggart Cowan RA, Falkenstein RJ, Sutherland GR. Intraoperative mobile magnetic imaging for craniotomy lengthens the procedure but does not increase morbidity. Can J Anesth 2002; 49: 420-426.