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Original Article

Intraoperative MRI in trans-sphenoidal surgery using frameless stereotaxis

Mitchell Stanton, Joyce Antony, Teresa Withers

Department of Neurosurgery, Gold Coast University Hospital, Southport, Queensland, Australia.

E-mail: *Mitchell Stanton - mitchellstanton86@gmail.com; Joyce Antony - joyce.antony@uq.connect.edu.au; Teresa Withers - Teresa.Withers@health.qld.gov.au.

***Corresponding author:**
Mitchell Stanton,
Department of Neurosurgery,
Gold Coast University
Hospital, 1 Hospital Boulevard,
Southport - 4215, Queensland,
Australia.

mitchellstanton86@gmail.com

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ABSTRACT

Background: Intraoperative magnetic resonance imaging (iMRI) has been used for pituitary surgery for approximately 20 years. The introduction of frameless stereotaxis allows efficient navigation for both the ENT and neurosurgeon. This allows flexibility in placement of the patients head to facilitate resection, efficient use of theater time and improves the safety profile of the operation. This is the first study to describe and investigate the use of frameless stereotaxis in conjunction with iMRI.

Methods: Consecutive patients who underwent iMRI guided trans-sphenoidal debulking using frameless stereotaxis over a 3-year period, from January 2016 to June 2019, were included in this case series and reviewed retrospectively. The use of AxiEM (Medtronic, USA) tracker facilitated frameless stereotaxis in conjunction with iMRI for trans-sphenoidal debulking of sellar lesions based on the "twin-operating" model.

Results: The cohort of 47 patients had a mean age of 55 years with a slight female predilection. The average lesion size measured 20 mm (3–46 mm) in maximal diameter with objective evidence of visual deterioration being the most common indication to consider surgery. The use of iMRI identified two patients with suboptimal decompression facilitating further resection in the same anesthetic and one hemorrhagic complication requiring evacuation and hemostasis to reduce postoperative morbidity.

Conclusion: This study describes the procedural nuances in the use of frameless stereotaxis for iMRI in trans-sphenoidal surgery to further reduce morbidity and improve outcomes, as well as improving theater utilization and reducing cost.

Keywords: Frameless stereotaxis, Intraoperative magnetic resonance imaging, Pituitary, Trans-sphenoidal

INTRODUCTION

The trans-sphenoidal approach to a pituitary adenoma was introduced by Hermann Schloffer at the University of Innsbruck in 1907. It was later popularized by prominent neurosurgeons such as Oskar Hirsch and Harvey Cushing between 1909 and 1929 and has endured though the generations to remain the preferred approach for sellar lesions.[11] The aim of the procedure is to adequately decompress the optic apparatus or to achieve endocrinological cure while reducing inadvertent damage to surrounding neurovascular structures to minimize morbidity and mortality. The introduction of the operating microscope followed by nasal endoscopy for improved visualization, together with stereotactic guidance improved the safety profile.[5,10]

With increasing availability, magnetic resonance imaging (MRI) was quickly established as the gold standard diagnostic modality for pre- and post-operative imaging of sellar lesions given its superior soft-tissue contrast, free orientation of slices, and elimination of ionizing radiation.[3] The prototype of the first intra-operative MRI (iMRI) was built at the Brigham and Women's Hospital, Boston, in 1994 and was first utilized for trans-sphenoidal debulking of a pituitary adenoma in October 1995.[1,13] The "double doughnut" design of the 0.5T scanner allowed the surgeon to stand between the two magnets to facilitate real time imaging.[13] Operating close to the magnet required new instruments with the very real risk to the surgeon and patient from non-compatible equipment. The concept of the "twin operating theater," consisting of a conventional operating theater and a radiofrequency-shielded operating room with a 0.2T scanner requiring the patient to be transported intra-operatively from one room to the other, was introduced in 1996.[12] Operating outside the magnet affords the use of conventional navigation and instrumentation, but requires transfer and re-registration of navigation.

Frameless stereotaxis avoids the use of cranial fixation while facilitating safe navigation toward the sella. It allows the surgeon to be able to move the head if required for access without losing the benefit of navigation. Frameless stereotaxis also allows for safe and efficient transferring of the patient into the iMRI and back into theater where the images can be merged and further resection is possible without requiring re-registration.

We retrospectively analyzed 47 consecutive patients who underwent trans-sphenoidal debulking of sellar lesions guided by iMRI in combination with frameless stereotaxis to evaluate safety and efficacy while describing the procedural nuances of our technique. This is the first study describing and investigating the use of frameless stereotaxis in combination with iMRI in trans-sphenoidal debulking of sellar lesions.

MATERIALS AND METHODS

This novel technique was developed at a single tertiary academic hospital by a senior Neurosurgeon. Consecutive patients who underwent trans-sphenoidal debulking using frameless stereotaxis and iMRI over a 3-year period, from January 2016 to June 2019, were included in this case series and reviewed retrospectively. In accordance with the Helsinki Declaration, ethical approval was sought from the local Human Research and Ethics Committee. The study was categorized as a quality activity and deemed exempt from a review.

Validation of the AxiEM (Medtronic, USA) Electromagnetic Navigation system with MRI was completed by the manufacturer. This technique was trialed and validated without complication or image degradation using the Gold Coast University Hospital intraoperative MR system (1.5T Siemens Magnetom Skyra). The MRI room based on the "twin operating theater" is located adjacent to the neurosurgical operating theater allowing direct access intraoperatively as demonstrated in [Figure 1]. An extensive checklist was developed to ensure MRI-compatible equipment only is used by surgical and anesthetic teams when being transferred into magnet area [Figure 2]. However, this orientation still allows use of routine neurosurgical equipment for the operation which is cost saving.

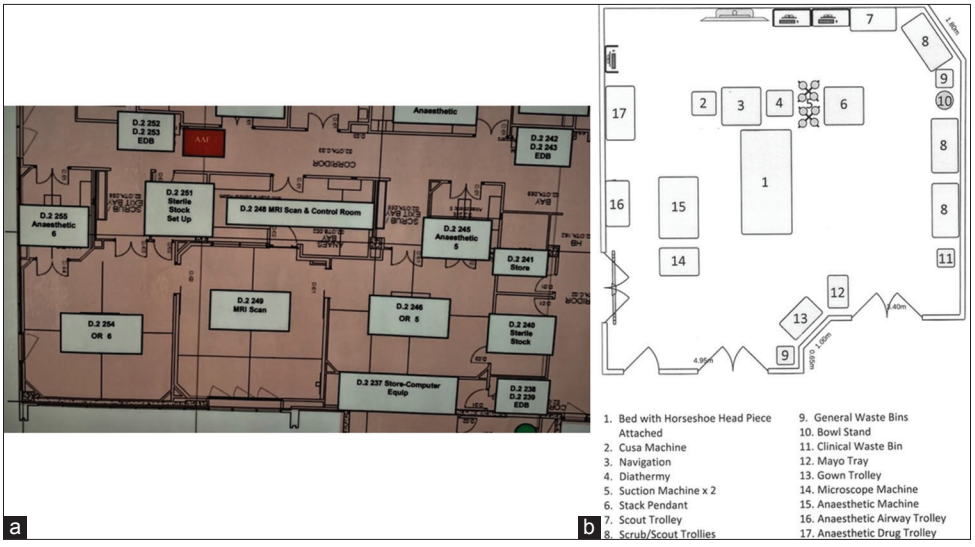


Figure 1: Theater room set up: (a) the intraoperative magnetic resonance imaging is set up between Theater 6, neurosurgical theater and theater 5, hybrid trauma theatre based on the "twin operating theater" model allowing direct access intraoperatively. (b) demonstrates the standardized theatre setup to minimize preoperative set up time.

DRAPES:	
GOWNS X 5	
SPLIT DRAPE SET	
TROLLEY COVER	**PREP** - HALF STRENGTH BETADINE
LARGE BOWL SET	
	EXTRAS
INSTRUMENTS:	MEDIUM CLEAR TEGADERM (FOR DRAPING)
0 DEGREE 4MM FESS SCOPE	LARGE PLASTIC (FOR DRAPING)
BLACK UPCUTTERS	18 G DRAWING UP NEEDLE
NEURO MICRO INSTS (FOR FINE DECKERS)	20ml SYRINGE
LIGHT LEAD AND CAMERA INTEGRATED	CATHETER EXTRAS & HRLY IDC BAG
SEPTOPLASTY(SMR) TRAY	14FR CATHETER **(NOT TEMP PROBE - MRI INCOMPATIBLE)**
STRAIGHT SHOT M4	GELFOAM [SMALL]
TRANSPHENOIDAL TRAY	MEDIUM SPONGES
FESS TRAY (FOR FREER SUCKER & GRASPERS)	NEURO PATTIES - ½" x ½"
NASAL PACKING TRAY (FOR PRE-OP LOCAL)	NEURO PATTIES 1/2" X 3 " (X4 FOR PRE-OP LOCAL)
STRAIGHT MAYO SCISSORS	RAYTEC X 1 PKT
ENT NASAL SPECULUM COTTLE (DNO - ON SMR TRAY)	SOFT SUCTION TUBING x 2
DECKERS MICRO PITUITARY (DNO - ON MICRO TRAY)	SPUTUM TRAP
PITUITARY RONGEURS (DNO)	SUCTION MONOPOLAR DIATHERMY (8FR - NEURO STORES)
30 DEGREE 4MM FESS SCOPE (DNO)	MONOPOLAR DIATHERMY
CRANIOTOMY TRAY (DNO)	SUCTION TUBING CONNECTOR
FESS EXTRAS TRAY(DNO)	QUIVER X 1
NASAL PUNCH TRAY (DNO)	SURGICEL FIBRILLAR
WORMALD FRONTAL SINUS TRAY (DNO)	5 ML SYRINGE [DNO]
FRONTAL SINUS TRAY (DNO)	22G SPINAL NEEDLE [DNO]
MINI TREPHINE TRAY (DNO)	1MM SILASTIC SHEETING [DNO]
	NEEDLE MAT [DNO]
DISPOSABLES FROM MEDTRONIC (neuro store):	15 BLADE (DNO)
TRICUT BLADE 4mm (1884004)	23g NEEDLE (DNO)
0 DEGREE ENDO SCRUB (1912000)	2 ML SYRINGE (DNO)
30 DEGREE ENDO SCRUB (1912010 - DNO)	3/0 CHROMIC G182 (DNO)
HIGH SPEED CURVED DIAMOND	3-0 VICRYL RAPIDE (DNO)
1883274HSE (DNO) ASK FIRST	BULB SYRINGES (DNO)
1885061HS 5mm (DNO) ASK FIRST	DUPLOCATH 25 (NEURO TROLLEY) - DNO
HIGH SPEED CUTTING BUR (1884075HSE - DNO)	LONG NEEDLE POINT ENT DIATHERMY TIP (NEURO STORES)
CURVED 40 RAD BLADE (DNO)	NEURO PATTIES - ½" x 1" (DNO)
NON-INVASIVE PATIENT TRACKER(9734887)	PREP BALLS X 1 (ASK IF PREPPING)
MALLEABLE SUCTION MEDIUM STANDARD(9735016)	STAPLES (DNO)
MIDAS REX CLEARVIEW (SP12MH30T)	XYLOCAINE 2% WITH ADRENALINE (DNO)
EQUIPMENT NEEDED IN THEATRE	NASOPORE X 2 (ANAESTHETIC FRIDGE - NEURO) DNO
SUCTION UNITS x2	SURGIFLO (HAVE AVAILABLE)
ELASTOPLAST COVERED HEAD SUPPORT(IN PLASTIC BAG)	
DIATHERMY MACHINE (AT FOOT OF THE BED)	**PRE OP PACKING**
MEDTRONIC NAVIGATION SYSTEM	1 AMP OF ADRENALINE 1:1000
STACK & SWING MONITOR AT HEAD OF TABLE	1/2" X 3" NEURO PATTIES (X4)
1 X BAG SALINE (WARM)	COPHENYLCAINE FORTE NASAL SPRAY + NOZZLE
MOUNT MEDTRONIC CONSOLE ON A POLE	DENTAL NEEDLE
MRI COMPATIBLE J-BOARDS	LIGNOSPAN SPECIAL CARTRIDGES X 4
	NASAL PACKING TRAY
FlexL COILS X 2 STORED IN MRI CONTROL ROOM	
BOTTOM COIL COVERED WITH PLASTIC BAG	
MEASURING TEMPLATES X 2 STORED IN MRI CONTROL ROOM	
MRI OPERATING TABLE	MAY NEED TISSEEL 4CC (CARDIAC FRIDGE) + DUPLOCATH
COUNT TO BE DONE BEFORE POST-OP TRANSFER TO MRI	
MRI CHECKLIST DONE BEFORE POST-OP TRANSFER TO MRI	
KEEP SETUP STERILE UNTIL POST-OP MRI COMPLETE	

Figure 2: Equipment and instrument checklist: An extensive checklist was developed to ensure only magnetic resonance imaging compatible equipment was used by surgical and anesthetic teams.

Preoperatively, patients were reviewed in the outpatient clinic setting after being referred by their general practitioner. A thorough history and examination was documented by a neurosurgical registrar. An Ophthalmologist assessed visual acuity, formal perimetry, and fundoscopy and an endocrinologist reviewed a complete pituitary blood panel. Finally, the collected information and images were reviewed by the senior neurosurgeon to determine surgical candidacy. Indications for surgical intervention include radiological progression in size, radiological, or clinical evidence of compression of the optic apparatus or an endocrinopathy not amenable to medical management. Contra-indications for surgical intervention include but are not limited to advanced age, severe medical co-morbidities, cognitive impairment requiring assistance with activities of daily living, or inability to cease anticoagulation.

In the operating theater, the preoperative CT and MRI stealth sequences are loaded on the StealthStation™ S8 surgical navigation system using the cranial mode and merged. The patient is positioned supine on a Maquet table (Maquet, Rastatt, Germany), an AxiEM tracker was applied to middle of forehead of patient and covered with an Opsite™ dressing as extra security and registration performed using the tracer. The patient is appropriately draped to facilitate preservation of tracker positioning for

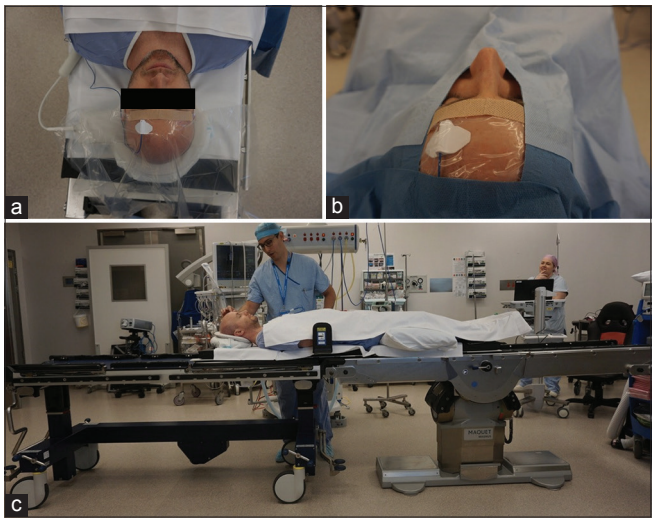


Figure 3: Patient positioning and transfer: (a) patient positioned on the Maquet table with tracker on forehead to facilitate frameless stereotaxis. (b) surgical draping to facilitate the Pittsburgh model of a combined otorhinolaryngologist and neurosurgeon working as a team. (c) Railroading patient onto the magnetic resonance imaging transfer trolley.

iMRI as demonstrated in [Figure 3]. Care is taken to ensure that the clear non-adhesive drape is applied to cover the tracker before applying the adhesive surgical drapes over the eyebrows, to reduce any chance of pulling off the tracker when the drape was removed as this would compromise the accuracy of its use if surgery needed to continue post iMRI. We utilized the Pittsburgh model of a combined otorhinolaryngologist and neurosurgeon working as a team. The approach to the floor of the sella was performed by a senior ENT surgeon and the debulking of the sellar lesion undertaken by the senior neurosurgeon. The objective of surgery is for safe maximal resection.

The patient is undraped, leaving the AxiEM tracker in place and the attached wire is rolled into a 10 cm circle and taped to patient blanket. Safety checklist is then completed and patient transferred into iMRI [Figure 4]. Theater equipment remains sterile while the patient undergoes MRI to allow immediate continuation of surgery if required, thus improving efficiency and subsequently reducing operative time. The tracker is simply reconnected to the StealthStation™ and continuation of the operation occurs seamlessly. The intraoperative images are merged with the preoperative images allowing continuation of the operation without re-registration. Re-registration is not required as AxiEM tracker has remained in place during transfer to iMRI; however, the accuracy of the neuronavigation is always checked both on surface anatomy and during approach through to the sphenoid sinus. If accuracy was deemed not acceptable, then the patient can be re-registered prior to continuation of surgery as all intraoperative images are Stealth sequences. In our experience, there were no concerns with accuracy post-iMRI and none of the cases required repeat registration before further surgery.

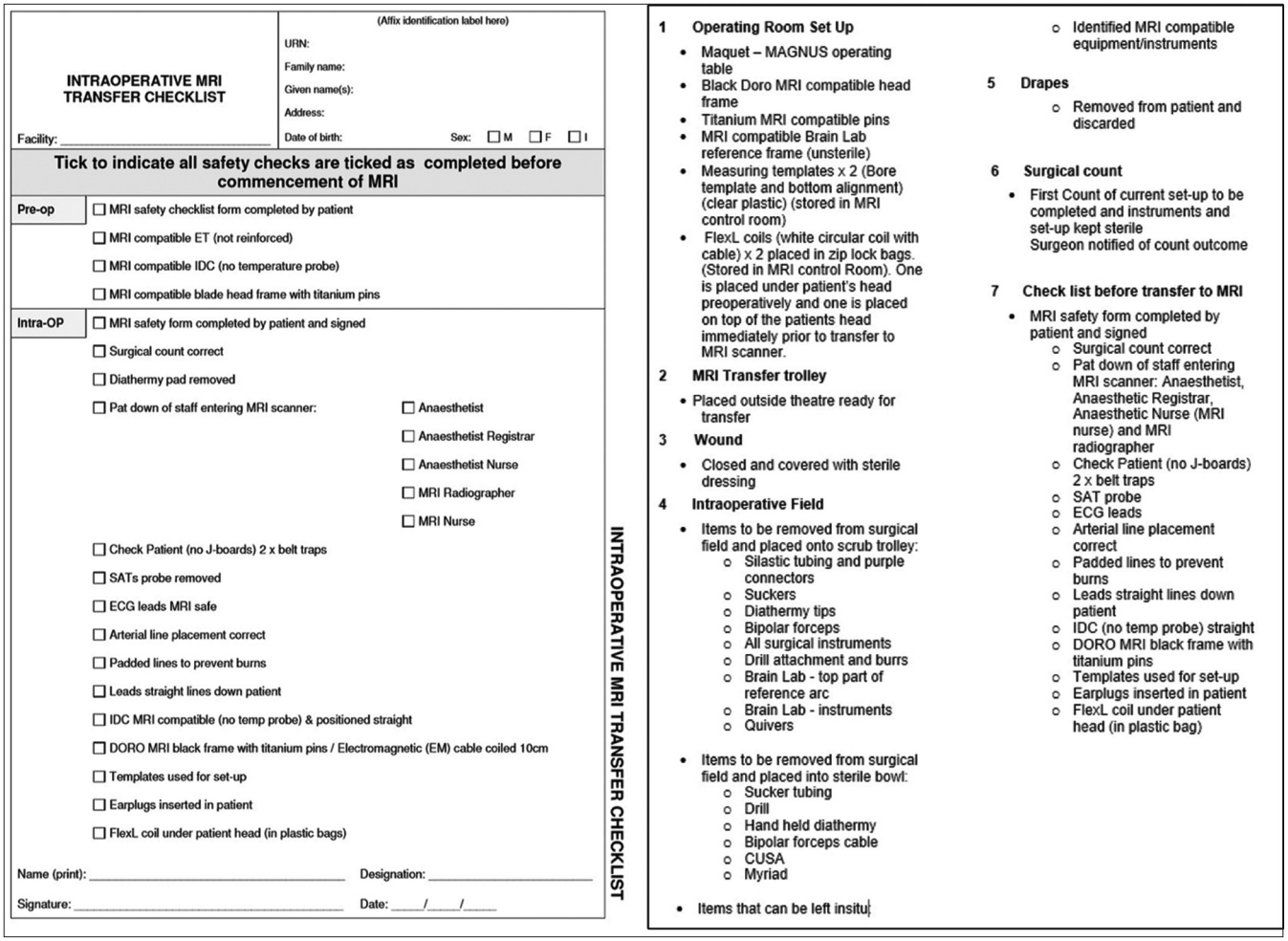
Postoperatively, patients are monitored closely in the neurosurgical intensive care or high dependency unit with daily input from the endocrinologist. Patients are subsequently stepped down to the neurosurgical ward after 24 h. Mechanical venous thromboembolism prophylaxis was started in theatre and chemical prophylaxis 72 h postsurgery. Patients are discharged when cleared by endocrinology and allied health in the absence of any neurosurgical complications not limited to hemorrhage or cerebrospinal fluid leak. They are instructed not to blow their nose and nasal saline flushes were commenced a week later. Patients were reviewed again by ophthalmology, endocrinology, and neurosurgery 3 months postsurgery with updated MRI and pituitary blood panel.

Tumor volume was measured on iMRI and the 3 months postsurgery MRI by three separate Neuroradiologists using InteleConnect EV 4.15.1 at three different time points at least 1 week apart with excellent inter- and intra-observer reliability. Tumor borders were segmented manually on coronal or sagittal T2 and T1 images postadministration of gadolinium. Statistical analysis was performed using R (R Core Team, 2017).

RESULTS

Between January 2016 and December 2017, 47 patients underwent elective trans-sphenoidal resection of sellar lesions at a single tertiary academic hospital. Commonly, two trans-sphenoidal operations were completed per theater list. The cohort had a mean age of 55 years, ranging from 26 years to 82 years. There was a slight female predilection with 21 male and 26 female patients. The average lesion measured 20 mm, ranging from as small as 3 mm to as large as 46 mm in the largest dimension. The most likely indication for surgical management was visual loss (25 patients) or impending visual loss (ten patients) with only 11 patients accounting for endocrinopathy as the primary indication of surgery. Ten patients had undergone prior trans-sphenoidal debulking. There were no operative deaths in this series. The results are available in [Table 1]. Furthermore, we experienced three (6.4%) cases of postoperative diabetes insipidus and two (4.3%) patients complicated by postoperative CSF rhinorrhea.

Through the use of iMRI, 44/47 (94%) patients were shown to have adequate resection of their sellar lesion following initial surgical intervention. More importantly, though the use of iMRI enabled immediate return to theater for three patients is demonstrated in [Figure 5]. Specifically, one case identified hematoma in the surgical cavity



INTRAOPERATIVE MRI TRANSFER CHECKLIST

(Affix identification label here)

URN:
Family name:
Given name(s):
Address:
Date of birth: Sex: ☐ M ☐ F ☐ I

Facility: _____

Tick to indicate all safety checks are ticked as completed before commencement of MRI

Pre-op
- ☐ MRI safety checklist form completed by patient
- ☐ MRI compatible ET (not reinforced)
- ☐ MRI compatible IDC (no temperature probe)
- ☐ MRI compatible blade head frame with titanium pins

Intra-OP
- ☐ MRI safety form completed by patient and signed
- ☐ Surgical count correct
- ☐ Diathermy pad removed
- ☐ Pat down of staff entering MRI scanner:
  - ☐ Anaesthetist
  - ☐ Anaesthetist Registrar
  - ☐ Anaesthetist Nurse
  - ☐ MRI Radiographer
  - ☐ MRI Nurse
- ☐ Check Patient (no J-boards) 2 x belt traps
- ☐ SATs probe removed
- ☐ ECG leads MRI safe
- ☐ Arterial line placement correct
- ☐ Padded lines to prevent burns
- ☐ Leads straight lines down patient
- ☐ IDC MRI compatible (no temp probe) & positioned straight
- ☐ DORO MRI black frame with titanium pins / Electromagnetic (EM) cable coiled 10cm
- ☐ Templates used for set-up
- ☐ Earplugs inserted in patient
- ☐ FlexL coil under patient head (in plastic bags)

Name (print): _____ Designation: _____

Signature: _____ Date: ____/____/____

INTRAOPERATIVE MRI TRANSFER CHECKLIST

1 Operating Room Set Up
- Maquet – MAGNUS operating table
- Black Doro MRI compatible head frame
- Titanium MRI compatible pins
- MRI compatible Brain Lab reference frame (unsterile)
- Measuring templates x 2 (Bore template and bottom alignment) (clear plastic) (stored in MRI control room)
- FlexL coils (white circular coil with cable) x 2 placed in zip lock bags. (Stored in MRI control Room). One is placed under patient's head preoperatively and one is placed on top of the patients head immediately prior to transfer to MRI scanner.

2 MRI Transfer trolley
- Placed outside theatre ready for transfer

3 Wound
- Closed and covered with sterile dressing

4 Intraoperative Field
- Items to be removed from surgical field and placed onto scrub trolley:
  - Silastic tubing and purple connectors
  - Suckers
  - Diathermy tips
  - Bipolar forceps
  - All surgical instruments
  - Drill attachment and burrs
  - Brain Lab - top part of reference arc
  - Brain Lab - instruments
  - Quivers
- Items to be removed from surgical field and placed into sterile bowl:
  - Sucker tubing
  - Drill
  - Hand held diathermy
  - Bipolar forceps cable
  - CUSA
  - Myriad
- Items that can be left insitu
  - Identified MRI compatible equipment/instruments

5 Drapes
- Removed from patient and discarded

6 Surgical count
- First Count of current set-up to be completed and instruments and set-up kept sterile
  Surgeon notified of count outcome

7 Check list before transfer to MRI
- MRI safety form completed by patient and signed
  - Surgical count correct
  - Pat down of staff entering MRI scanner: Anaesthetist, Anaesthetic Registrar, Anaesthetic Nurse (MRI nurse) and MRI radiographer
  - Check Patient (no J-boards) 2 x belt traps
  - SAT probe
  - ECG leads
  - Arterial line placement correct
  - Padded lines to prevent burns
  - Leads straight lines down patient
  - IDC (no temp probe) straight
  - DORO MRI black frame with titanium pins
  - Templates used for set-up
  - Earplugs inserted in patient
  - FlexL coil under patient head (in plastic bag)

Figure 4: Intraoperative magnetic resonance imaging (MRI) checklist: An added safety check to ensure that only MRI-compatible equipment accompany the patient into the scanner.

requiring immediate re-exploration and evacuation. Early identification of this hemorrhage enabled early return to theater, mitigating risk to the patient's vision. Two patients were identified to have suboptimal decompression, allowing further resection within the same anesthetic. This subsequently avoided a return to theatre at a later stage. This is not only cost efficient but also minimizes morbidity for the patients.

In these cases that required a return to theater post-iMRI, the intraoperative images were merged with the pre-operative images and the accuracy of the neuronavigation was maintained in all three cases, with none requiring re-registration. This streamlines a return to theater, which is important especially in the setting of the patient with intra-operative hematoma, as further delays to the re-exploration and evacuation may have led to permanent visual loss. All three cases returned to the iMRI once evacuation or further debulking performed, ensuring that adequate decompression had been achieved.

DISCUSSION

The use of iMRI helps identify residual tumor as well as complications such as hemorrhage. This reduces morbidity for the patient and negates the need for a second procedure, which subsequently reduces patient risk and is cost saving. However, navigation during iMRI guided trans-sphenoidal debulking has traditionally required cranial fixation. Frameless stereotaxis using endoscopy is an accepted alternative improving accuracy and allowing flexibility of the approach. All stereotaxis is limited by its reliance on preoperative data sets. To the best of our knowledge, this is the first study, in English language literature, describing, and investigating the combined use of frameless stereotaxis with endoscopy and iMRI for trans-sphenoidal debulking of sellar lesions.

Utilizing iMRI helps to increase the extent of resection. Fomekong *et al.* (2014) reported 65% gross total resection, 8% near total resection, 19% subtotal resection, and 8% partial resection at 3 months postsurgery when using their

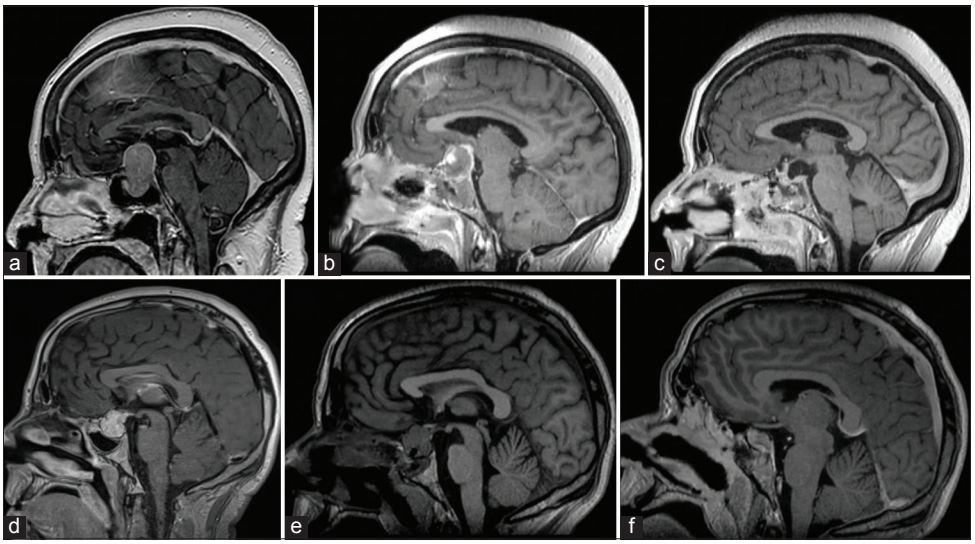


Figure 5: Influence of intraoperative magnetic resonance imaging (iMRI) on surgical management. (a) sagittal T1 gadolinium enhanced preoperative MRI demonstrating a pituitary macroadenoma. (b) iMRI demonstrating active contrast extravasation requiring immediate return to theater. (c) hemostasis was achieved and postoperative MRI demonstrated a gross total resection. (d) Sagittal T1 gadolinium enhanced preoperative MRI of another patient demonstrating compression of the optic apparatus. (e) iMRI demonstrating inadequate decompression of the optic apparatus warranting a return to theatre for further debulking. (f) Three months postoperative MRI demonstrating near total resection with adequate decompression of the optic apparatus thereby reducing morbidity.

Table 1: Patient demographics and outcomes.

	All patients	Non-functioning adenomas	Functioning adenomas
Mean age at surgery (years)	55 (26–82)	58 (29–82)	39 (26–71)
Male/Female	21/26	17/21	4/5
Visual field deficits	25/47 (53%)	25/38 (66%)	0/9 (0%)
Postsurgical remnant	14/43 (33%)	12/34 (35%)	2/9 (22%)
Mean tumor volume (mm^3)	15.4 (3–33)	18.2 (10–37)	5.7 (3–12)
Cavernous Sinus Invasion (Knosp Grade)	0: 12/47 (26%) 1: 12/47 (26%) 2: 5/47 (11%) 3: 8/47 (17%) 4: 6/47 (13%)	0: 5/38 (13%) 1: 11/38 (11%) 2: 4/38 (11%) 3: 8/38 (21%) 4: 6/38 (16%)	0: 7/9 (78%) 1: 1/9 (11%) 2: 1/9 (11%) 3: 0/9 (0%) 4: 0/9 (0%)
Pituitary dysfunction			
Preoperative	14/47 (30%)	5/38 (13%)	9/9 (100%)
Postoperative	7/47 (15%)	4/38 (11%)	3/9 (33%)

3T iMRI.[4] Similarly, Li *et al.* (2015) increased complete tumor resection rate from 60% to 80% in their cohort of 30 patients using a 1.5T iMRI.[6] However, Pal'a *et al.* (2017) demonstrated smaller intraoperative residual tumor volumes in the endoscopic group compared to the microsurgical group that translated to significantly fewer additional resections (28.6% compared to 52.9%, respectively).[8] Similarly, Zaidi *et al.* (2016) utilized high resolution iMRI in endoscopic trans-sphenoidal surgery to convert one subtotal resection and four near total resections to gross total resections in their cohort of 27 patients.[14]

The routine use of endoscopy might explain the relatively low rate of return to theatre for suboptimal decompression identified using iMRI in our patient cohort. Also using the 30° endoscope to check recesses allows better visualization maximizing safe resection. While gross total resection is the goal, postoperative tumor remnant is not an independent risk factor for tumor recurrence/regrowth, which is more likely to be attributed to immunopathological status, invasion of the cavernous sinus and absence of postoperative radiotherapy.[2] The objective of surgical management is maximal safe resection ensuring the safety of the patient. Also decreasing mass effect to save vision and/or minimizing the hypersecretory state whilst avoiding neurovascular structures will minimize morbidity and mortality.

The use of iMRI provides real-time information on the extent of resection to ensure the mass effect on the optic apparatus has been relieved and to ensure no complications such as secondary hemorrhage, pneumocephaly or acute hydrocephalus. In our patient cohort, we identified a case of active venous hemorrhage on the iMRI that warranted a return to theater to facilitate urgent hemostasis. The rate of hemorrhagic complication in our cohort appears to be lower than available literature and this could be secondary to the Pittsburgh model where two heads and four hands are better than one head and two hands.[7] Moreover, Razak *et al.* (2012) found decreased hemorrhagic complications in the endoscopic

group compared to the microsurgical group likely secondary to the superior visualization.[9] Our complication rates are slightly lower than available literature on iMRI in trans-sphenoidal surgery but this was not statistically significant given the small cohort of patients. We experienced three (6.4%) cases of postoperative diabetes insipidus and two (4.3%) patients complicated by postoperative CSF rhinorrhea, while Li *et al*. (2015) reported three (10%) patients with diabetes insipidus and four (13.3%) cases of postoperative CSF rhinorrhea.[6]

The use of the endoscope improves visualization intraoperatively. Fortunately, the use of the endoscope does not generate any interference with the AxiEM system. Meticulous care is made in the positioning of the AxiEM Field Emitter and ensuring no metallic equipment being used in the surgical field, including using a gelatinous head rest. Using this technique, there was no cases where interference was noted from use of the endoscope.

Use of frameless stereotaxis is safe and as accurate as cranial fixation. Frameless stereotaxis allows flexibility for the ENT surgeon to tilt the head without losing the registration and allows the neurosurgeon to operate with both hands allowing safe maximal resection. Combining these techniques with iMRI allows navigation in real time as post resection MRI can be merged without requiring re-registration. Seeing the intraoperative images in real time allows more confident removal of residual tumor as the operators receive accurate information on location of sensitive structures that need to be avoided, such as optic chiasm, allowing focus on intraoperative maneuvers. This increases safety to the patient, decreases the need for a second surgery and is cost effective for the hospital.

CONCLUSION

This is the first study in English language literature to describe and investigate the combined use of frameless stereotaxis for endoscopy and iMRI to guide trans-sphenoidal debulking of sellar lesions. The use of frameless stereotaxis facilitates the use of endoscopy and iMRI without cranial fixation to assist in safe maximal resection of sellar lesions while minimizing morbidity.

Declaration of patient consent

Patient's consent not required as patients identity is not disclosed or compromised.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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