iMRI During Transsphenoidal Surgery

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KEYWORDS

• Interventional • Intraoperative • MRI • iMRI • Pituitary • Adenoma • Transsphenoidal

KEY POINTS

- Low- and high-field iMRI is used for resection control of pituitary macroadenomas.
- Expert interpretation of iMRI images is required to achieve best results.
- iMRI can improve outcomes of nonfunctioning and functioning pituitary macroadenomas.
- iMRI is not useful to detect functioning pituitary microadenomas.

INTRODUCTION

Transsphenoidal surgery (TSS) has an important role in the management of pituitary tumors. For many tumors, including nonfunctioning pituitary adenomas,[1] corticotrophin-secreting adenomas causing Cushing disease,[2] and growth hormone–secreting adenomas causing acromegaly,[3] TSS remains the treatment of first choice. Medical management has replaced TSS as the treatment of first choice for one type of pituitary tumor: prolactinoma. For the rest of the tumor types, patients are first advised to undergo TSS.

First described in 1907 by Schloffer, TSS was later refined and popularized by Harvey Cushing.[4] Despite rapid refinements in the technique that allowed for reduction of mortality rates to 5.3% by 1925,[5] the procedure was abandoned by Dr Cushing. With improved visualization through the operating microscope, Jules Hardy, reintroduced TSS in the modern era, setting the stage for a later development of techniques necessary for selective removal of microadenomas (tumors smaller than 1 cm) and macroadenomas.[4] Today, the procedure is widely used, and is the technique of choice for resection of pituitary tumors. For patients undergoing TSS for pituitary tumors, remission rates vary. In a recent meta-analysis, the mean remission rates (ranges) were 68.8% (27–100) for prolactinomas, 47.3% (3–92) for Non functioning adenoma (NFA), 61.2% (37–88) for growth hormone–secreting adenomas, and 71.3% (41–98) for corticotrophin-secreting adenoma tumors. Remission rates and incidence of recurrence have improved modestly over the past three decades.[6]

Currently, overcoming the following challenges could improve remission rates after pituitary surgery. (1) Visibility of small tumors: remission is dependent of the ability to detect the adenomas. (2) Visualization of true extent of large tumors: for larger tumors, cure rates are reduced by tumor remnants. (3) Visualization of tumor invasion: extension of tumor into the structures surrounding the sella. Technologies introduced to take on these challenges include endoscopy,[4] frameless stereotaxy,[7] color Doppler ultrasonography, and real-time intraoperative MRI (iMRI).[8–11]

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INTRAOPERATIVE MRI FOR TRANSSPHENOIDAL SURGERY

History of Intraoperative Imaging During Transsphenoidal Surgery

Surgeons routinely use adjunct imaging tools during TSS. Popularized by Jules Hardy,[12] intraoperative fluoroscopic imaging is widely used by surgeons to define the superior and inferior limits of the sella turcica.[13] Frameless stereotactic fluoroscopic guidance registers preoperative computed tomography or MRI images with intraoperative fluoroscopy.[14] This technique uses accurate stereotaxy to ensure that the surgical approach avoids injury to critical structures, such as the internal carotid arteries.[13] These stereotaxic techniques, however, are not useful for monitoring extent of resection (EOR; resection control) of pituitary macroadenomas. Intraoperative ultrasonography (iUSG), either by transcranial[15,16] or transsellar[17–19] routes, provides imaging of sellar/suprasellar contents in real time. Investigators have used iUSG to detect tumor residuals and critical structures, such as the carotid arteries.[17–19] In addition, iUSG has had some success in detecting microadenomas.[20,21] In patients with Cushing disease with negative preoperative imaging, iUSG detected up to 69% of microadenomas.[21] Despite significant advantages including ease of use, real-time imaging, low cost, and lack of radiation, iUSG remains infrequently used during TSS because of poor image quality.[13]

History of Intraoperative MRI for Transsphenoidal Surgery

Interventions in the head and neck region within the MRI suite were initially limited to needle biopsies and aspirations.[22] The limitations were the product of conventional horizontal bore design of the MRI machines. Long acquisition times compared with other guidance methods including computed tomography or fluoroscopy made interventions in the MRI suite complicated and difficult to perform.[23] Another MRI configuration was needed to ensure ease of manipulation and surgical access. A midfield MRI system (Signa SP, General Electric, Boston, MA) was conceptualized and installed at the Brigham and Women's Hospital in Boston in 1994 to address issues of surgical access.[24,25] Its "double doughnut" configuration allowed real-time monitoring and complete access to the surgical site and an iMRI tracking system for real-time stereotaxy and neuronavigation. The surgeon accessed the patient's head and neck region between two large doughnuts containing superconducting magnets. Although the surgical access was unparalleled among the iMRI system, the design was not widely replicated in other centers introducing iMRI systems. Another popular early design was the open MRI configuration that allowed improved lateral access, but with restricted vertical access. The examples include the Toshiba Access (Toshiba America Medical Systems, Tustin, CA) in a temple format, and the Magnetom Open (Siemens AG, Erlangen, Germany) in the C-arm format in Erlangen, Germany.[23] These and the subsequent iterations of iMRI invoked the single room, moveable table format that allowed surgery to be performed outside the 5-G line. Surgical procedures outside the 5-G line could be performed using the standard surgical instruments including the operating microscope, and patients could be moved quickly into the scanner for intraoperative imaging.[10] Initial reports of iMRI use for neurosurgical indications included TSS procedures.[10,26,27] Surgeons recognized the potential of iMRI for resection control of macroadenomas and for detection of intraoperative hematomas during TSS.[10,27] Other systems including the retractable ultra-low-field strength (PoleStar N-10 and N-20, Odin Medical Technologies, Newton, MA),[28–30] low-field-strength moveable magnet (Hitachi AIRIS II, Hitachi Medical, Twinsburg, OH),[31] high-field moveable magnet (IMRIS, Marconi Medical System, Winnipeg, Ontario, Canada), and the 3-T machines[32] have all been designed for optimal use of existing surgical tools and microscopes outside the 5-G line. The ability to use conventional tools likely reduces the barrier to introduction and adoption of iMRI procedures. Similarly, shared-resource strategies for using the iMRI machine for intraoperative imaging and routine diagnostic imaging are increasingly being adopted to offset initial investment costs.[31,33,34] Recently, most centers are reintroducing conventional horizontal bore machines with high (1.5 T) or ultra-high (3 T) field strength. Higher field strength improves image resolution and reduces image acquisition time, at the expense of surgical access during this period.

Types of Intraoperative MRI Systems

A variety of iMRI systems have been used during TSS (**Table 1**). The iMRI systems vary in field strengths (0.15–3 T), magnet configurations (eg, open, retractable, double doughnut), and room configurations. Most studies report that the primary benefit of iMRI during TSS lies in intraoperative detection of tumor residuals following maximal resection with conventional technique. Few studies compare the iMRI systems head-to-head to evaluate their comparative effectiveness in detecting tumor residuals.