Intraoperative magnetic resonance imaging

The use of intraoperative techniques to detect residual tumors has recently become increasingly important. Intraoperative MRI has long been considered the gold standard; however, it is not widely used because of high equipment costs and long acquisition times.

Consequently, real-time intraoperative ultrasound (ioUS), which is much less expensive than MRI, has gained popularity [1)]

Combined awake language and motor mapping and iMRI guidance is feasible for resection of brain lesions. A compact iMRI has unique advantages for this approach [2)].

see also Intraoperative MRI for resection of intracranial meningioma.

Implementation of intraoperative magnetic resonance imaging (iMRI) has been shown to optimize the extent of resection and safety of brain tumor surgery. In addition, iMRI can help account for the phenomenon of brain shift and can help to detect complications earlier than routine postoperative imaging, which can potentially improve patient outcome.

Intraoperative MRI is considered the gold standard among all intraoperative imaging technologies currently available. Its main indication is in the intraoperative detection of residual disease during tumour resections.

It allows real-time image-guided excision of brain tumors, especially gliomas and pituitary neuroendocrine tumors.

Intraoperative magnetic resonance imaging for pituitary neuroendocrine tumor surgery

Intraoperative magnetic resonance imaging for pituitary neuroendocrine tumor surgery

Noise of unknown origin

Low magnetic field iMRI devices may produce low-quality images due to nonideal imaging conditions in the operating room and additional noise of unknown origin.

Unbiased nonlocal means filter for iMRI de-noising proved very useful for image quality enhancement and assistance in the interpretation of iMR images [3)].

see 3 Tesla intraoperative magnetic resonance imaging.

Language

Intraoperative magnetic resonance imaging (iMRI) and functional neuronavigation may help maximize tumor resection, minimize language deficits in patients with gliomas involving language areas, and improve survival time for patients with glioblastomas [4].

Metaanalysis

The Medline, PubMed, Cochrane, Google Scholar databases were searched until September 26th, 2015 Randomized controlled trials (RCTs), two-arm prospective studies, retrospective studies in patients with glioblastoma/glioma who had received surgical treatment were included.

The primary outcome measures were the extent of tumor resection and tumor size reduction for using iMRI-guided or conventional neuronavigation-guided neurosurgery. Secondary outcomes included impact of surgery on the 6-month progression-free survival (PFS) and 12-month overall survival (OS) rates and surgical duration were also studied.

They found that iMRI was associated with greater rate of gross total resection (rGTR) compared with conventional neuronavigation procedures (3.16, 95% confidence interval [CI] 2.07-4.83, $P < 0.001$). We found no difference between the two neuronavigation approaches in extent of resection (EOR), tumor size reduction, or time required for surgery (P values ≥0.065). Intraoperative MRI was associated with a higher rate of progression-free survival (PFS) compared with conventional neuronavigation (odds ratio, 1.84; 95% CI of 1.15 to 2.95; $P = 0.012$), but the rate of overall survival (OS) between groups was similar ($P = 0.799$). Limitations of the study included the fact that data from non-RCTs were used, the small study population, and heterogeneity of outcomes across studies.

The findings indicate that iMRI more frequently resulted in more complete resections leading to improved PFS in patients with malignant gliomas [5].

Surveys

Coburger et al. performed a web-based survey among members of the European Association of Neurological Surgeons(EANS) from April to May 2017. The questionnaire included Intraoperative magnetic resonance imaging(iMRI), 5-aminolevulinic acid(5-ALA), intraoperative ultrasound(iUS),Na-Fluorescein and Intraoperative Computed Tomography(iCT). The value of each method in resection of glioblastoma(GB) and [Low-grade glioma]](LGG) and their role for intraoperative orientation and usability were rated based on Likert-scales from 1(not valuable/important) to 5(very valuable/important). A total score was calculated based on each sub-score. Mann-Whitney-U-test was used to compare ratings of imaging methods.

Among the 310 participants, iMRI and 5-ALA were regarded as the most valuable intraoperative imaging methods in GB-surgery (iMRIvs.5-ALA,p=0.573;mean 4.05(SE0.149)vs.4.22(SE0.216)). Both were considered significantly more valuable than iUS, Na-Fluorescein and iCT(p≤0.001).Compared to all other methods, iMRI received significantly higher ratings for the resection of LGGs (p<0.01,mean 4.21(SE 0.143)) as well as for intraoperative orientation (mean 4.00(SE0.166)).5-ALA was rated highest regarding intraoperative usability (mean 4.07(SE0.082)). iMRI showed the highest total score compared to all other imaging modalities(p<0.001,mean 15.95(SE 0.484)).

iMRI and 5-ALA were rated most valuable for GB-surgery, while only iMRI reached higher ratings in

LGG cases. iMRI was the best imaging method for intraoperative orientation as well as the most valuable method in overall rating. Considering the total score, 5-ALA and iUS received similar values and were rated second highest, followed by Na-Fluorescein and iCT [6].

Case series

2017

From February, 2009 to December, 2016, a study enrolled 156 patients, who underwent multimodal navigation and iMRI-guided brain biopsy in the Neurosurgery Department of PLA General Hospital. Metabolic information was used for biopsy target selection. Intraoperative guidance helped biopsy trajectory avoid the eloquent structures. iMRI was performed to prove the biopsy accuracy and to revise the incorrect biopsy. Diagnostic rate, perioperative neurological status, surgical parameter, and surgical outcome were recorded. Results: The first iMRI helped to revise 7 (4.5%) incorrect biopsy sites, and final iMRI confirmed biopsy accuracy in all cases. Postoperative diagnostic rate was 96.8% (151/156). No statistical difference was found between postoperative and preoperative neurological statuses, despite 86 (55.1%) lesions were adjacent to eloquent areas. Additionally, iMRI detected 6 (3.8%) intraoperative hematomas that were treated immediately. Conclusions: Brian biopsy with iMRI and multimodal navigation is a safe, accurate and efficient biopsy modality. This technique may help increase the biopsy accuracy with low morbidity and mortality [7].

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68 patients with a primary or a Glioblastoma recurrence scheduled for surgery including fluorescence guidance and neuronavigation were included (mean age: 59 years, 26 female, 42 male patients). The ioMRI after the first resection included transverse FLAIR, DWI, T2-FFE and T1-3d FFE +/- GD-DPTA. The second resection was performed whenever residual contrast-enhancing tissue was detected on ioMRI. Resected tissue samples were histopathologically evaluated (gold standard). Additionally, they evaluated the early postoperative MRI scan acquired within 48h post-OP for remaining enhancing tissue and compared them with the ioMRI scan. Results In 43 patients ioMRI indicated residual tumorous tissue, which could be confirmed in the histological specimens of the second resection. In 16 (4 with recurrent, 12 with primary glioblastoma) cases, ioMRI revealed truly negative results without residual tumor and follow-up MRI confirmed complete resection. In 7 cases (3 with recurrent, 4 with primary glioblastoma) ioMRI revealed a suspicious result without tumorous tissue in the histopathological workup.In 2 (1 for each group) patients, residual tumorous tissue was detected in spite of negative ioMRI. IoMRI had a sensitivity of 95% (94% recurrent and 96% for primary glioblastoma) and a specificity of 69.5% (57% and 75%, respectively). The positive predictive value was 86% (84% for recurrent and 87% for primary glioblastoma), and the negative predictive value was 88% (80% and 92%, respectively). Conclusion ioMRI is effective for detecting remaining tumorous tissue after glioma resection. However, scars and leakage of contrast agent can be misleading and limit specificity. Key points · Intraoperative MRI (ioMRI) presents with a high sensitivity for residual contrast-enhancing tumorous tissue during glioma resection.. · Contrast leakage due to bleeding and scars with reactive contrast enhancement can cause possible misleading artifacts in ioMRI, leading to a limited specificity of ioMRI.. · Bleeding control in glioma resection is crucial for successful usage of ioMRO for glioma resection [8].

2015

In 300 consecutive patients, three sequential groups (groups A, B, C; n=100 each) were compared with respect to time management, complications and technical difficulties to assess improvement in these parameters with experience.

Raheja et al observed a reduction in the number of technical difficulties (p<0.001), time to induction (p<0.001) and total anesthesia time (p=0.007) in sequential groups. IOMRI was performed for neuronavigation guidance (n=252) and intraoperative validation of extent of resection (EOR; n=67). Performing IOMRI increased the EOR over and beyond the primary surgical attempt in 20.5% (29/141) and 18% (11/61) of patients undergoing glioma and pituitary surgery, respectively. Overall, EOR improved in 59.7% of patients undergoing IOMRI (40/67). Intraoperative tractography and real-time navigation using re-uploaded IOMRI images (accounting for brain shift) helps in intraoperative planning to reduce complications. IOMRI is an asset to neurosurgeons, helping to augment the EOR, especially in glioma and pituitary surgery, with no significant increase in morbidity to the patient [9).

2013

Brell et al. retrospectively reviewed the first 21 patients operated on the aid of this technology. Maximal safe resection was the surgical goal in all cases. Surgeries were performed using conventional instrumentation and the required assistance in each case.

The mean number of intraoperative studies was 2.3 per procedure (range: 2 to 4). Intraoperative studies proved that the surgical goal had been achieved in 15 patients (71.4%), and detected residual tumour in 6 cases (28.5%). After comparing the last intraoperative image and the postoperative study, 2 cases (9.5%) were considered as “false negatives”.

Intraoperative MRI is a safe, reliable and useful tool for guided resection of brain tumours. Low-field devices provide images of sufficient quality at a lower cost; therefore their universalisation seems feasible [10)].

Case reports

Giordano et al. describe two explicative cases including the setup, positioning, and the complete workflow of the surgical approach with intraoperative imaging. Even if the configuration of iopMRI equipment was originally designed for cranial surgery, they have demonstrated the feasibility of cervical intramedullary glioma resection with the aid of high-field iopMRI. This tool was extremely useful to evaluate the extent of tumor removal and to obtain a higher resection rate, but still need some enhancement in the configuration of the headrest coil and surgical table to allow better patient positioning [11)].

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