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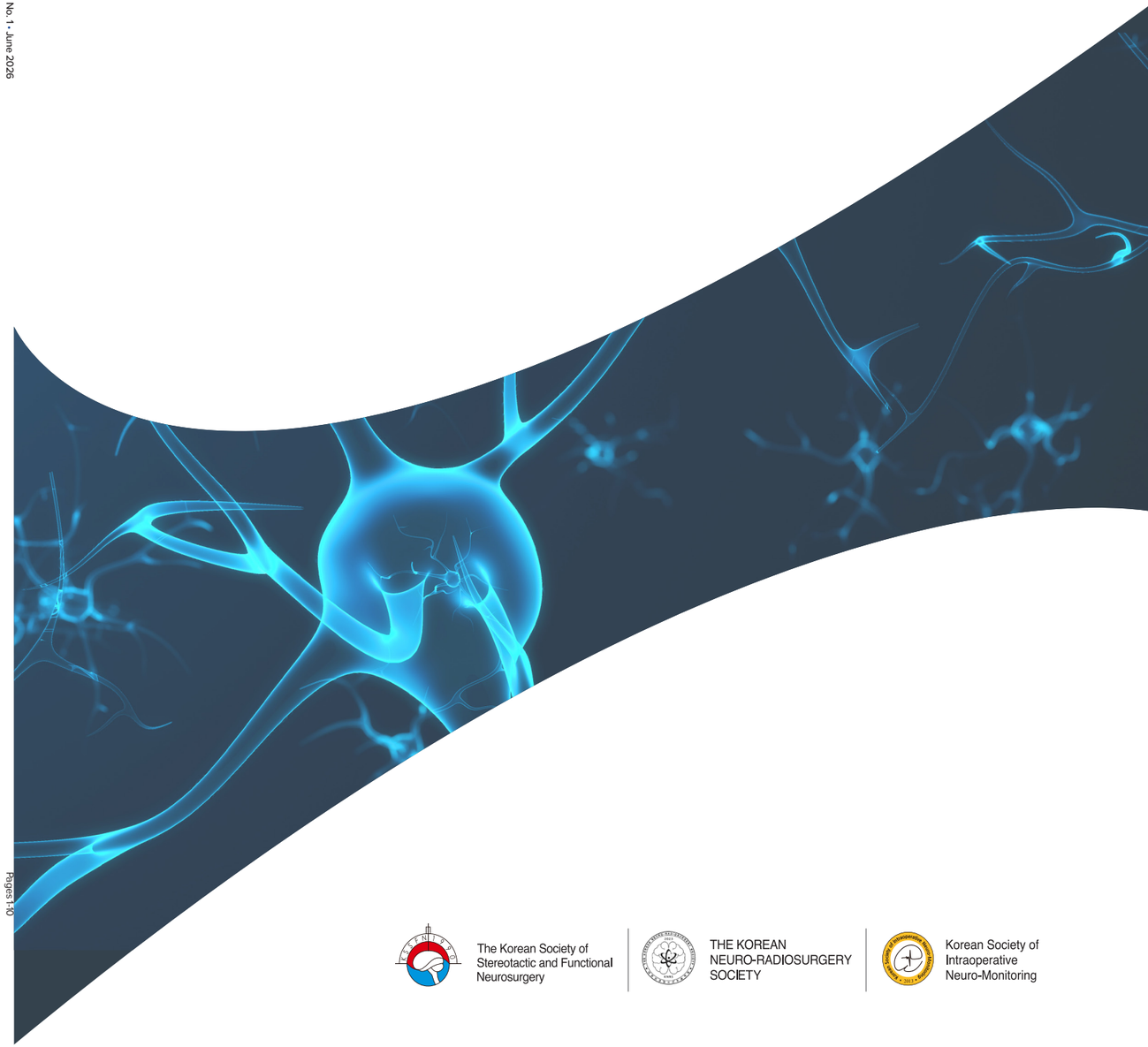

The Korean Society of Stereotactic and Functional Neurosurgery

THE KOREAN NEURO-RADIOSURGERY SOCIETY

Korean Society of Intraoperative Neuro-Monitoring

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Aims and Scope

Neurofunction (Neurofunction, NF) is a peer-reviewed journal and the official journal of the Korean Society of Stereotactic and Functional Neurosurgery, and published twice a year on the last day of June and September. This Journal publishes important papers covering the whole field of neurosurgery, including studies in neuroscience, neurology, and molecular biology. Studies on rare cases and technical notes of special instruments or equipment that might be useful to the field of neurosurgical science are also acceptable. Papers, to be accepted, will include clinical articles (clinical and laboratory research), case reports, brief reports, technical reports, review articles, letters to the editor, etc. Review articles can be published upon specific request by the journal. Authors can publish special drafts with the approval from the editorial board. Case reports should be brief, and avoid an extensive review of the literature.

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Review Article

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Endoscopic hippocampectomy via trans-orbital and middle temporal gyrus corridors: anatomy, techniques, outcomes, and surgical considerations: a systematic review and comparative analysis

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Mesial temporal lobe epilepsy is the most common focal epilepsy and is frequently drug-resistant. Although hippocampectomy provides favorable seizure control, conventional open approaches may cause visual, cognitive, or cortical morbidity. This review compares two minimally invasive endoscopic routes to the hippocampus: the transorbital and trans-middle temporal gyrus approaches. An AI-assisted systematic search of PubMed, Embase, and Scopus was performed through May 2025. Studies reporting purely endoscopic or endoscope-assisted hippocampectomy with extractable anatomical or clinical data were included. Seven studies met the criteria, including three cadaveric studies and four clinical reports involving 14 patients. Both approaches provided consistent access to the amygdala and hippocampus, and all reported patients achieved seizure freedom. No visual field defect or permanent morbidity was documented. Cadaveric data showed up to 97% hippocampal exposure through the transorbital route, whereas the trans-middle temporal gyrus approach offered shorter, more direct access but required cortical transgression. These findings suggest that both approaches are feasible minimally invasive alternatives to conventional hippocampectomy, with distinct anatomical advantages and risk profiles. Larger prospective studies are required to define indications, safety, and long-term outcomes.

KEY WORDS: Hippocampus, Epilepsy, Endoscope, Orbit, Temporal lobe

INTRODUCTION

Mesial temporal lobe epilepsy is the most common form of focal epilepsy in adults and is frequently refractory to medical treatment [1]. Hippocampectomy, either as part of an anterior temporal lobectomy or as a selective amygdalohippocampectomy, has been shown to provide excellent seizure control, with long-term seizure-freedom rates of 70–80% in appropriately selected patients [2-7]. Recent advances in endoscopic surgery have enabled less-invasive routes to the hippocampus. Two techniques are of particular interest: the endoscopic trans-orbital approach (TOA), which uses the lateral orbital wall to spare the neocortex, and the

endoscopic trans-middle temporal approach (TMTA), which accesses the temporal horn through a small corticectomy in the middle temporal gyrus. Both aim to minimize tissue disruption while maintaining seizure control, but differ in anatomical trajectory, technical demands, and complication profile.

This study reviews and compares the endoscopic TOA and TMTA for hippocampectomy, focusing on surgical feasibility, outcomes, and risks.

METHODS

Literature search strategy

An artificial intelligence (AI)-assisted literature search was performed to identify studies describing endoscopic approaches to hippocampectomy, with a specific focus on the endoscopic trans-orbital and endoscopic middle temporal gyrus corridors. The search combined conventional database queries with AI-based semantic search tools to maximize retrieval of relevant publications, including studies that may not be captured by keyword-only strategies.

Electronic databases (PubMed, Embase, and Scopus) were searched from inception to May 2025 using a combination of Medical Subject Headings (MeSH) and free-text terms: "*hippocampectomy*," "*amygdalohippocampectomy*," "*endoscopic*," "*transorbital*," "*trans-orbital*," "*middle temporal gyrus*," "*temporal approach*," "*temporal horn*," and "*mesial temporal lobe epilepsy*." Boolean operators ("AND," "OR") were applied to refine results. The AI-assisted component provided semantic expansion of search terms, identification of related anatomical synonyms, and cross-linking of relevant references cited in retrieved articles. Reference lists of included studies and relevant review articles were manually screened to identify further eligible publications.

Studies were included if they described a purely endoscopic or endoscope-assisted hippocampectomy or selective amygdalohippocampectomy; clearly specified the surgical corridor as trans-orbital or middle temporal gyrus (transcortical or transsulcal); reported either cadaveric feasibility data or clinical outcomes; and provided extractable data on patient number, seizure control, visual field outcomes, and other complications. Exclusion criteria included the use of microscopic approach without endoscopic assistance, procedures that did not include hippocampal resection, and an inability to separate data specific to the surgical approach.

Data extraction and synthesis

Two reviewers independently screened all identified titles, abstracts, and full texts. Disagreements were resolved by consensus. For each included study, the following variables were extracted: first author, year, study type, surgical approach, patient number, seizure control rate, incidence of visual field defects, other complications, and endoscope use.

Data were organized and synthesized descriptively. Due to heterogeneity in study design and outcome measures, a formal meta-analysis was not performed. Instead, a narrative comparative analysis was conducted to highlight key anatomical, technical, and clinical differences between the TOA and TMTA. The study selection process is summarized in a PRISMA (https://www.prisma-statement.org/) flow diagram (Fig. 1).

Diffusion–tensor imaging–magnetic resonance imaging data acquisition and optic radiation fiber tracking

For illustrative purposes, diffusion-tensor imaging data from a neurologically normal individual were used to evaluate the anatomical relationships among the hippocampus, amygdala, and Meyer's loop. The images were processed and reconstructed using commercially available software (Elements; Brainlab) following

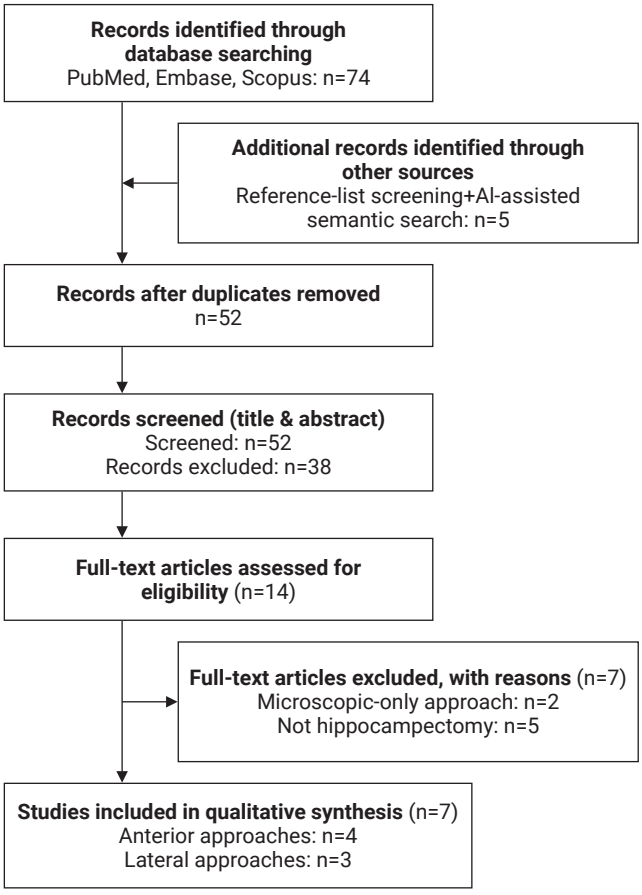

Fig. 1. PRISMA flow diagram summarizing the study selection process for inclusion in this review. AI: artificial intelligence.

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previously published protocols [8]. After correction for cranial distortion and co-registration with T1-weighted anatomical images, regions of interest were placed over the lateral geniculate body and the optic tract ipsilateral to the side of approach. Optic radiation tractography was then performed using a minimum fiber-length threshold of 35 mm and a fractional anisotropy cutoff of 0.15. Three-dimensional reconstructions were generated to demonstrate the expected surgical trajectories for the TOAs and TMTAs (Fig. 2).

Ethics statement

This study is based on a review of previously published literature and does not involve human participants or identifiable personal data. The need for institutional review board approval was therefore waived.

RESULTS

Seven studies met the inclusion criteria following the literature search (Table 1) [9-15]. Of these, four studies used an anterior approach (three trans-orbital and one anterior transmaxillary) and three employed a lateral approach through the middle temporal gyrus. Three were cadaveric feasibility studies, and four were clinical series or case reports.

Among the clinical studies, the total number of patients was 14 (13 trans-orbital/anterior group; 1 middle temporal gyrus group). Although the sample sizes were small, all patients remained seizure-free during the reported follow-up periods. No cases of visual field defects were documented in the included clinical series. Reported complications were minimal, with no permanent morbidity described.

Cadaveric studies consistently demonstrated adequate exposure of the hippocampus and amygdala through both approaches, with anatomic preservation of critical structures when performed according to described techniques.

Surgical techniques

A review of the surgical techniques described in the included

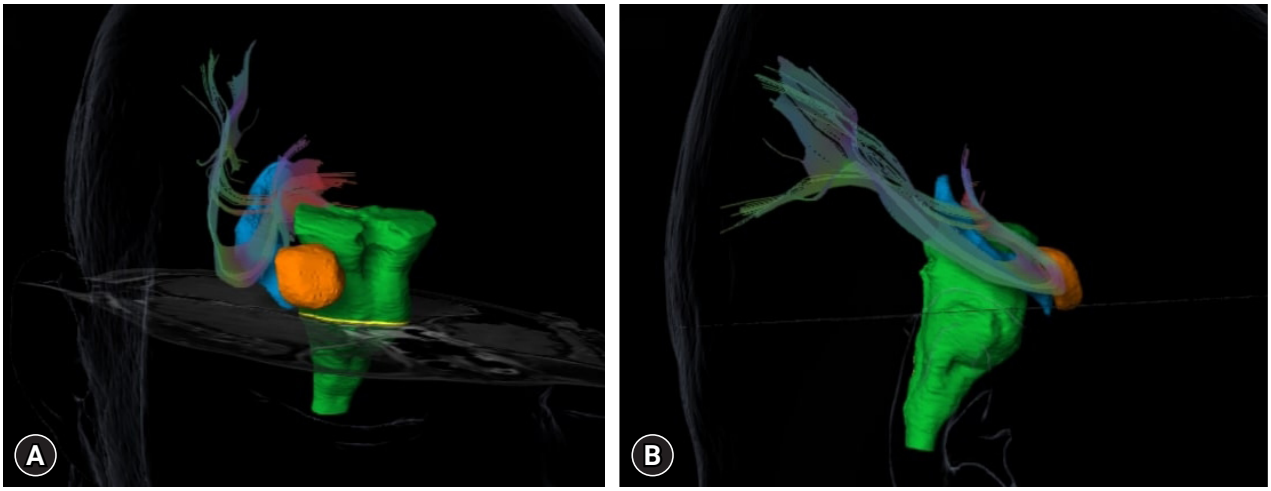

Fig. 2. (A) Anatomical relationships of the hippocampus, amygdala, and Meyer's loop in the trans-orbital approach. The surgical trajectory can avoid Meyer's loop. (B) Anatomical relationships of the hippocampus, amygdala, and Meyer's loop in the trans-middle temporal approach. The surgical trajectory is obscured by Meyer's loop, increasing the risk of injury.

Table 1. Summary of analyzed cadaveric and clinical studies on endoscopic hippocampectomy

First author (year)	Approach	Subject	Patients (n)	Seizure control rate	Visual field defect rate
Chen (2014) [9]	Anterior (TOA)	Cadaveric	NA	NA	NA
Chen (2015) [10]	Anterior (TOA)	Clinical	2	Seizure-free	Not reported
Mandel (2017) [11]	Anterior (TOA)	Clinical	8	Seizure-free	Not reported
Gonzalez-Martinez (2023) [12]	Anterior (TMA)	Clinical	3	Seizure-free	Not reported
Lau (2022) [13]	Lateral (TMTA)	Cadaveric	NA	NA	NA
Silbergeld (1995) [14]	Lateral (TMTA)	Cadaveric	NA	NA	NA
Uda (2021) [15]	Lateral (TMTA)	Clinical	1	Seizure-free	Not reported

TOA: trans-orbital approach, TMA: transmaxillary approach, TMTA: trans-middle temporal approach, NA: not available.

studies revealed consistent procedural patterns within each approach category.

For the TOA, most authors employed either an upper eyelid (transpalpebral) incision or an eyebrow/lateral canthal skin incision to minimize visible scarring. The lateral orbital rim and wall were partially drilled or removed to create a bony window toward the anterior temporal fossa. Dissection proceeded along the inferior orbital fissure toward the temporal pole, avoiding injury to orbital contents and anterior cranial nerves. The temporal horn was then opened, and the amygdala and hippocampus were exposed and resected using 0° and 30° endoscopes. Reconstruction of the orbital wall was performed in some cases with titanium mesh or plates to restore anatomical contour.

For the TMTA, a small keyhole craniotomy was created over the middle temporal gyrus, typically anterior to the vein of Labbé and above the zygomatic arch. A minimal corticectomy, which was placed in the inferior portion of the gyrus to reduce the risk to Meyer's loop, was made to enter the subcortical white matter and reach the temporal horn. The hippocampus and amygdala were then identified and resected under pure endoscopic or endoscope-assisted visualization. The cortical entry was kept as small as possible to minimize disruption of eloquent white-matter tracts and reduce the risk of postoperative visual or language deficits.

DISCUSSION

Hippocampectomy remains a cornerstone of surgical management of mesial temporal lobe epilepsy, offering high rates of long-term seizure control in appropriately selected patients [16,17]. Traditionally performed through open approaches such as anterior temporal lobectomy with amygdalohippocampectomy, the procedure has well-established efficacy but carries risks of visual field deficits, cognitive decline, and other complications related to cortical and white-matter disruption [5,18,19].

The advent of high-definition endoscopy and refined skull base techniques has enabled the development of minimally invasive routes to the hippocampus. These approaches aim to preserve brain structures, minimize cosmetic impact, and potentially reduce morbidity while maintaining seizure control efficacy. In this review, a total of seven studies (three cadaveric and four clinical) were identified, encompassing 14 patients (13 trans-orbital/anterior and 1 middle temporal gyrus). All reported seizure freedom during follow-up, with no visual field deficits or permanent morbidity documented. Cadaveric studies confirmed that both approaches allow for reliable exposure of the hippocampus and amygdala when anatomical landmarks are respected.

COMPARATIVE ANALYSIS AND ANATOMICAL CONSIDERATIONS

TOA provides access through the lateral orbital wall, sparing the temporal neocortex and white matter. Cadaveric data indicate that up to 97% of hippocampal length can be exposed, while clinical reports show excellent cosmetic outcomes through transpalpebral or eyelid-crease incisions [9]. However, risks include injury to orbital contents, extraocular muscles, and cranial nerves traversing the cavernous sinus [20]. TMTA uses a small corticectomy through the middle temporal gyrus to reach the temporal horn. This provides a

Table 2. Surgical considerations for the trans-orbital and trans-middle temporal gyrus approaches for endoscopic hippocampectomy

Category	Trans-orbital approach	Trans-middle temporal approach
Surgical route	Access via orbital rim through the lateral orbital wall	Direct access through the middle temporal gyrus cortex
Cortical/white-matter involvement	Minimal disruption; preservation of temporal neocortex and white matter	Cortical entry via middle temporal gyrus; partial resection of temporal cortex and white matter
Temporal cortex disruption	Minimal (no neocortical entry)	Moderate (cortical entry required)
Meyer's loop risk	Relatively low (trajectory avoids optic radiation)	Higher risk due to proximity of entry point
Vascular structures at risk	Zygomatic vessels; risk to orbital vasculature	Vein of Labbé; temporal lobe vasculature
Cranial nerve (CN)/skull base risk	Higher (risk to CN III/IV/VI, orbital structures, cavernous sinus)	Lower
Distance/trajectory	Longer, angled route through orbit	Shorter, more direct route
Surgical accessibility and extent of resection	Up to 97% hippocampal exposure possible (cadaveric studies)	Selective hippocampus and amygdala resection feasible
Cosmesis/invasiveness	Minimally invasive; eyelid crease incision with excellent cosmetic outcome	Requires scalp incision and craniotomy; more invasive
Postoperative complications	Potential orbital injury, globe displacement	Risk of visual field loss (Meyer's loop), cognitive or language deficits
Clinical indications	Medial temporal pathologies (hippocampus, amygdala); when cosmesis and neocortical preservation are priorities	Broader range including lateral temporal lesions; when wider exposure is needed

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shorter, more direct route and wider exposure, but involves cortical and subcortical transgression, increasing the risk to Meyer's loop, temporal vasculature, and language pathways (Fig. 2) [13,14].

Table 2 summarizes these differences. In brief, TOA minimizes cortical disruption and favors cosmesis but entails orbital risks, whereas TMTA offers broader access at the expense of potential neocortical and visual pathway injury. The choice of approach should be guided by lesion location, surgical goals, and patient-specific anatomical constraints.

FUTURE DIRECTIONS

Both approaches remain in early stages of clinical application. Larger, prospective, multicenter studies are required to establish their comparative efficacy, neurocognitive outcomes, and long-term complication profiles. Integration of advanced tools such as image-guided navigation, tractography-based planning, and augmented reality overlays may further improve safety, particularly in preserving Meyer's loop and other eloquent structures. From a clinical standpoint, the TOA may be preferable in anterior mesial temporal pathologies prioritizing cosmesis and neocortical preservation, whereas the middle temporal approach may be appropriate for cases requiring broader access or when orbital expertise is limited. Ultimately, these minimally invasive techniques should be regarded as complementary surgical strategies for mesial temporal lobe epilepsy.

LIMITATIONS

The present review is limited by the small number of published studies, heterogeneous designs, and small patient volume, which precludes a meaningful statistical comparison of the approaches. Follow-up durations were short, and detailed neurocognitive and visual assessments were largely absent. In addition, most data were derived from cadaveric feasibility studies or isolated case reports, restricting generalizability to broader clinical practice.

CONCLUSION

Both the endoscopic TOA and TMTA appear to be safe, effective, and minimally invasive routes for hippocampectomy, but the current evidence is limited. Larger prospective studies are required to better define their comparative advantages, patient selection criteria, and long-term outcomes.

CONFLICTS OF INTEREST

Min Ho Lee is an Editor of this journal and was not involved in the review process or editorial decision-making for this manuscript. No other potential conflict of interest relevant to this article was reported.

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Gamma Knife radiosurgery with magnetic resonance/computed tomography fusion imaging for a patient unable to extend the neck

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Gamma Knife radiosurgery (GKRS) is a widely accepted and precise treatment modality for brain neoplasms, and it primarily relies on accurate magnetic resonance imaging (MRI) for lesion localization. However, standard MRI techniques pose significant challenges in patients with severe cervical spine immobility. Here, we describe a case involving a 79-year-old patient with newly diagnosed lung cancer who presented with three metastatic brain lesions requiring GKRS. Because of severe neck stiffness caused by ankylosing spondylitis, the patient's head could not be adequately positioned within the MRI head coil, compromising image quality and localization precision. To address this limitation, computed tomography (CT) imaging was performed after MRI, and the magnetic resonance (MR)/CT datasets were fused using GammaPlan software. Comparative analysis between MR-only imaging and MR/CT fusion imaging demonstrated notable improvements in lesion delineation accuracy based on the fused dataset, allowing more precise radiosurgical targeting. This case highlights the clinical utility and necessity of MR/CT fusion imaging to achieve accurate lesion targeting and treatment efficacy in patients with substantial cervical spine mobility restrictions.

KEY WORDS: Ankylosing spondylitis, Brain metastases, Magnetic resonance imaging, Radiosurgery

INTRODUCTION

Stereotactic radiosurgery (SRS) using the Gamma Knife system is an effective modality for the treatment of brain tumors. The precision of SRS is heavily dependent on accurate imaging, particularly high-resolution magnetic resonance imaging (MRI), for lesion localization and treatment planning. However, MRI can be limited by patient-related factors such as anatomical deformities or mobility restrictions that hinder optimal positioning during scanning. In such cases, inaccurate head placement may lead to distortion or misregistration of anatomical landmarks, thereby compromising the effectiveness and safety of the radiosurgical procedure. Unlike MRI, computed tomography (CT) imaging does not require placement within a rigid head coil, making it feasible even in patients with severe neck motion limitations. This allows acquisition of high-quality stereotactic reference images despite physical constraints that compromise magnetic resonance (MR) positioning.

MR/CT image fusion techniques have been developed to overcome these lim-

itations, combining the superior soft tissue contrast of MRI with the geometric stability of CT. This fusion approach is especially valuable in patients with spinal conditions such as ankylosing spondylitis, which may severely limit cervical motion and interfere with traditional frame-based MRI acquisition. Several studies have demonstrated the improved accuracy of lesion targeting when MR/CT co-registration is applied during Gamma Knife radiosurgery (GKRS) [1-6]. Here, we present a rare case in which MR/CT fusion imaging was essential to overcome positioning limitations and achieve accurate radiosurgical planning.

CASE REPORT

A 79-year-old male with newly diagnosed lung cancer presented with three metastatic brain lesions requiring GKRS. A stereotactic frame (Leksell G-frame, Elekta) was applied prior to imaging; however, the patient had a history of ankylosing spondylitis, evident as bamboo spine on previous spinal CT, which severely limited cervical motion and prevented adequate head extension during MRI acquisition (Fig. 1).

Due to the restricted neck extension, the patient's head could not be properly positioned within the MRI head coil. During the initial MR-only planning, we noticed fiducial misalignment suggestive of stereotactic geometric inaccuracy (Fig. 2A). Because the rigid MRI head coil constrains head insertion angle and head extension, adequate positioning could not be achieved in this patient with ankylosing spondylitis. In contrast, the open CT gantry allowed neutral positioning with external support, providing a geo-

Fig. 1. Sagittal spinal computed tomography (CT) image showing classic bamboo spine consistent with advanced ankylosing spondylitis, explaining the patient's severely limited cervical mobility. This figure illustrates why the rigid magnetic resonance imaging head coil restricts sufficient head extension compared with the more open CT gantry, which permits neutral positioning with external support and provides a more stable stereotactic reference.

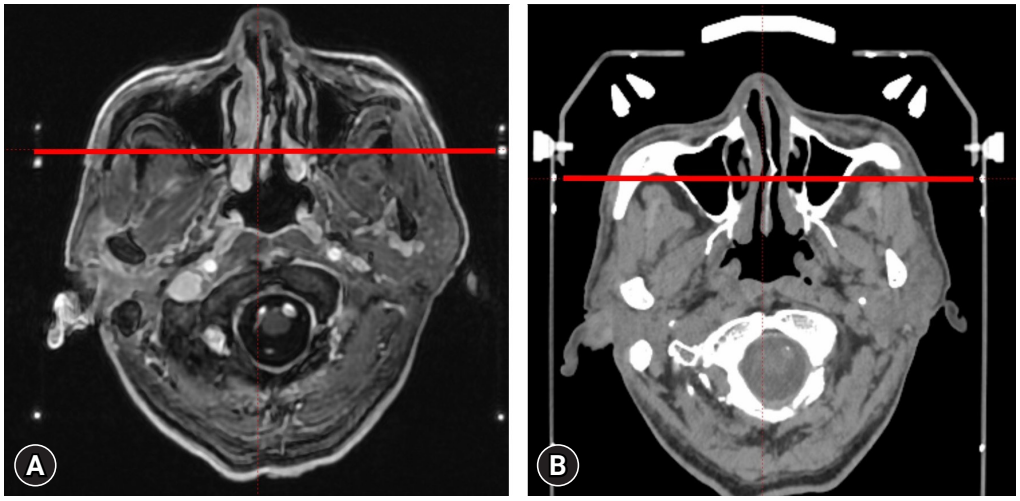

Fig. 2. Comparison of fiducial marker alignment. (A) Magnetic resonance imaging obtained with compromised head positioning shows visible distortion and misalignment of fiducial markers. (B) Computed tomography (CT) acquired in the same stereotactic frame demonstrates proper alignment, allowing accurate co-registration. Red lines indicate loci of misregistration on the magnetic resonance-only dataset compared with correct alignment on CT.

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metrically stable reference for stereotactic registration. A CT scan was subsequently acquired with the stereotactic frame in place, and MR/CT fusion in GammaPlan (Elekta) corrected the spatial discrepancy, thereby enabling accurate target delineation (Fig. 2B).

The MR and CT images were fused using GammaPlan software, enabling high-accuracy co-registration despite the limitations of the initial MRI (Fig. 3). This fusion enabled accurate lesion targeting and facilitated precise treatment planning.

Comparative review of the radiosurgical plans revealed a noticeable discrepancy. To visualize stereotactic registration error, the 50% isodose line prescribed on the MR/CT fusion-based plan was overlaid onto the MR-only dataset: the MR-only–based plan showed inaccurate tumor contouring, while the MR/CT fusion-based plan demonstrated precise tumor targeting and appropriate dose coverage (Fig. 4).

This study was approved by the Institutional Review Board of Kyungpook National University Hospital (2025-05-009) with a waiver of informed consent for anonymized single-patient case reporting.

DISCUSSION

This case highlights several important considerations regarding imaging strategy in SRS for patients with limited cervical mobility. MR/CT fusion imaging effectively mitigates geometric uncertainty that arises from suboptimal MRI positioning. When fiducial misalignment or field-of-view limitations compromise MRI accuracy, rigid or deformable co-registration with CT can restore spatial fidelity. Pappas et al. [1] demonstrated that MR/CT fusion reduced centroid error from over 1.5 mm to less than 0.5 mm in phantom studies. Nakazawa et al. [2] corroborated these findings in a clinical setting, with mean targeting error across 40 targets measured at just 0.3 mm.

Furthermore, prior studies emphasize the need to assess and address image distortion, particularly in 3T MRI systems. Peripheral distortions greater than 1 mm, as reported by Theocharis et al. [3], can significantly impact targeting accuracy if not corrected. Tools such as distortion phantoms and standardized registration protocols, as explored by Damyanovich et al. [4] and Ulin et al. [5], ensure co-registration consistency across institutions and clinical platforms. These methods are essential to maintain the high precision required for SRS.

In addition, the clinical value of MR/CT fusion becomes especially evident in patients with musculoskeletal deformities, such as those with ankylosing spondylitis. These patients, often elderly and frail, may not tolerate the strict positioning needed for standard frame-based MRI protocols. Yu et al. [6] demonstrated that image fusion effectively compensated for such limitations, supporting accurate targeting despite mechanical limitations. Consistent use of fusion techniques or distortion correction improves tumor control rates without increasing toxicity, even in anatomically complex cases.

Taken together, these findings strongly support the integration of MR/CT fusion as a routine option within radiosurgical plan-

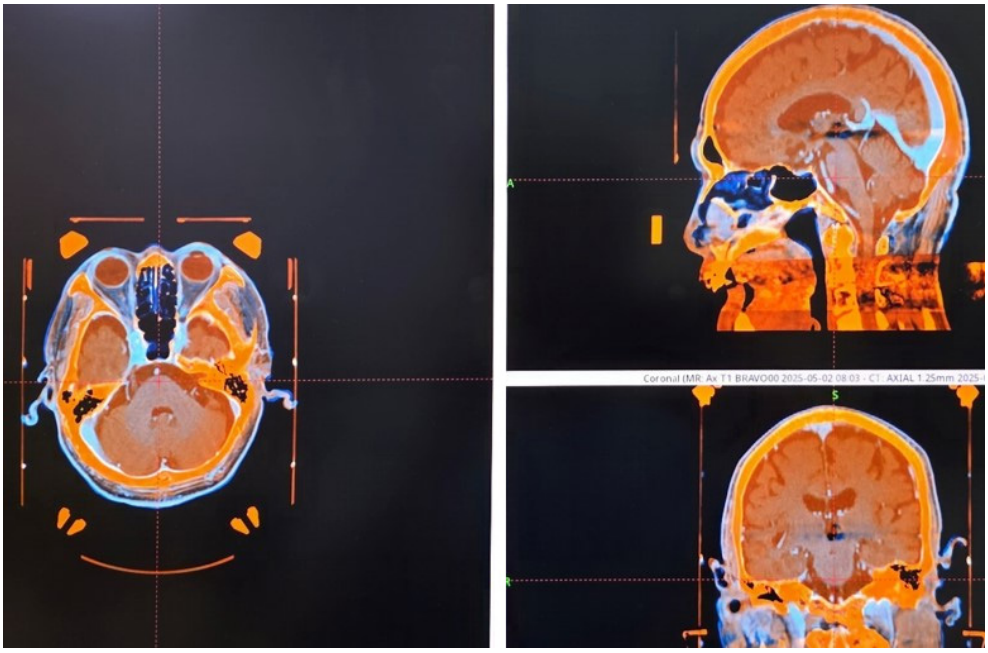

Fig. 3. Magnetic resonance imaging/computed tomography fusion process using GammaPlan software. The images show anatomical correspondence across modalities, resulting in improved spatial fidelity for radiosurgical planning.

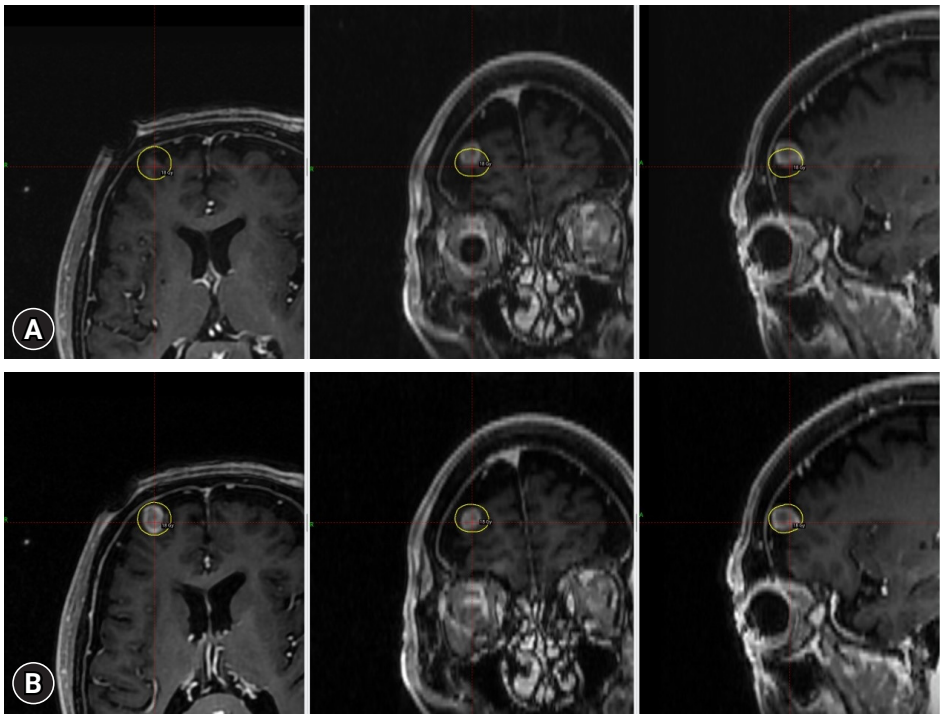

Fig. 4. Dose-planning comparison. The radiosurgical plan based on the magnetic resonance (MR) imaging-only dataset (A) demonstrates suboptimal tumor targeting. The MR/computed tomography (CT) fusion-based plan (B) shows improved conformity of dose distribution to tumor boundaries. To visualize stereotactic registration error, the 50% isodose line prescribed on the MR/CT fusion-based plan was overlaid onto the MR-only dataset.

ning workflows. This approach enhances spatial accuracy, accommodates challenging patient anatomies, and upholds the high precision standards required in GKRS. Future directions may include real-time fusion algorithms and adaptive planning systems to further streamline the treatment process.

CONCLUSION

MR/CT fusion imaging represents a valuable adjunct in GKRS for patients with substantial cervical spine mobility limitations, ensuring accurate targeting and effective treatment outcomes.

CONFLICTS OF INTEREST

Seong-Hyun Park is an Editor of this journal and was not involved in the review process or editorial decision-making for this manuscript. No other potential conflict of interest relevant to this article was reported.

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Instructions for authors

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Lettieri C, Rinalodo S, Devigili G, Pauletto G, Verriello L, Budai R, et al. Deep brain stimulation: subthalamic electrophysiological activity in awake and anesthetized patients. Clin Neurophysiol 2012;123:2406-13

► **Book**

Conover WJ. Practical Nonparametric Statistics, 2nd ed. Jon Wiley & Sons, 1971, pp216-8

► **Chapter in a book**

Ojemann RG. Surgical management of bacterial intracranial aneurysms. In: Schmideck HH, Sweet HH (eds). Operative Neurosurgical Techniques: Indications, Methods and Results, 2nd ed. Grune & Stratton, 1988, Vol 2, pp997-1001

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