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Micromirrors in Neurosurgery: Technical Overview and Benefits Assessment

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To watch the surgical videoclip, please visit http://turkishneurosurgery.org.tr/uploads/jtn-40601-video.mp4

ABSTRACT

AIM: To weight the benefits and limitations of intraoperative use of micromirrors in neurosurgery.

MATERIAL and METHODS: Surgical cases where micromirrors were employed were retrospectively selected from the surgical database of five different surgeons in different hospitals. Complications directly attributable to the micromirrors were assessed intraoperatively and confirmed with postoperative neuroimaging studies.

RESULTS: Fourteen patients were selected. The site of the lesion was as follows: posterior fossa (43%), frontal lobe (22%), temporal lobe (14%), parietal lobe (7%), insula (7%), and basal ganglia (7%). Five tumors (35%) were gliomas, 3 (21%) epidermoid, and 3 (21 %) supratentorial metastases. Two patients underwent microvascular decompression for neurovascular conflict, and 1 harbored a brain arteriovenous malformation. A gross total resection was achieved in all the tumors and the AVM, while an effective decompression was successfully performed in both patients with conflict. No complications directly attributable to the use of the micromirror occurred. A relatively easy learning curve was noted.

CONCLUSION: Micromirrors proved to be useful in enhancing the visualization of neurovascular structures and pathology residuals within deep-seated surgical fields without the need for fixed brain retraction. Their cost-effectiveness and easy learning curve constitute solid reasons for advocating a revitalization of this "old but gold" tool in neurosurgery.

KEYWORDS: Magnification, Micromirrors, Microsurgery, Neurosurgery, Surgical mirror

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INTRODUCTION

Micromirrors, also known as dental or mouth mirrors, were introduced in the 1800s (14), and later came into widespread use after the 1950s with the advent of front surface micromirrors for operative dentistry (12). Micromirrors have a small and dimmer viewing area that can provide a straight view of the back of a structure (5). Unlike the microscope or endoscope, they are not used to magnify the images, but to reflect light to a region or an area not directly accessible upon viewing (12). The micromirror can be utilized in addition to the use of the microscope or endoscope.

In the last decades, there has been a significant improvement in angled endoscopes. However, the angled endoscope does not allow a straight structural view (5); and depending on the narrow port of entry, it can also limit the use in tandem of the instruments (13).

The micromirror is one of the most important and widely used instruments of the dental armamentarium (12). Its use has been incorporated into neurosurgical practice with the advent of microneurosurgery. The most known micromirror in neurosurgery is the Yaşargil movable mirror (Braun, Melsungen, Germany) (18). However, studies reporting on its use inneurosurgical procedures are few, which may be due to the decline in its use, in part because of the development of other instruments and equipment, such as evolution of the last generations of high-definition microscopes and endoscopes in the previous two decades (5,13,17).

This study aims at highlighting the benefits and limitations of intraoperative use of micromirrors in neurosurgery.

MATERIAL and METHODS

The institutional ethic committees of the different hospitals where the surgical procedures were performed approved the present study.

We retrospectively reviewed the surgical database of five different surgeons to select those cases where micromirrors were used in combination with the surgical microscope. The utility and learning curve related to the use of micromirrors was assessed. Figure 1 reports the different mirrors that were used by the authors to reach blind spots or difficult angles during microsurgical procedures (Figure 1). Figure 2 illustrates the rationale for the intraoperative use of micromirrors consisting in “looking around the corner” (Figure 2). Database review was performed based on the operative charts and only those cases where the micromirror was used were included. Complications directly attributable to the use of micromirror were assessed intraoperatively and confirmed with postoperative neuroimaging studies during the follow-up.

RESULTS

Fourteen patients were selected. Patients’ age ranged between 17 and 78 years (average 51 years). The site of the lesion was as follows: posterior fossa (43%), frontal lobe (22%), temporal lobe (14%), parietal lobe (7%), insula (7%), basal ganglia (7%). Among tumors, 5 were gliomas (35%), 3 high-grade and 2 low-grade, 3 (21%) epidermoid, and 3 (21%) supratentorial metastases. Eleven patients underwent brain tumor resection, 2 microvascular de compressions for neurovascular conflict (NVC), and 1 brain arteriovenous malformation (AVM) resection. In all cases, the surgical microscope was used, and the size of micromirror was selected based on the overall surgical freedom of the surgical working corridor. A gross total resection was achieved in all the tumors and the AVM, while an effective decompression was successfully performed in both patients with NVC. No complications directly attributable to the use of the micromirror occurred, and a relatively easy learning curve was noted.

Illustrative Cases

Case #1

A 53-years-old with a left cingulate glioblastoma underwent to contralateral interhemispheric transfalcine approach. The patient was placed supine with the head rotated right 45º head to exploit the gravity-assisted retraction of the right frontal lobe. The interhemispheric fissure was split, and the falx was then opened to reach the contralateral cingulate gyrus. Surgical resection of the tumor was carried out in between the supracallosal and cingulate sulcus. Intraoperatively, the superior inner aspect of the tumor was difficult to be visualized because out of the line of sight of the microscope. At this stage, the use of the micromirror, in combination with the 5-aminolevulinic acid and under a direct microscope view,

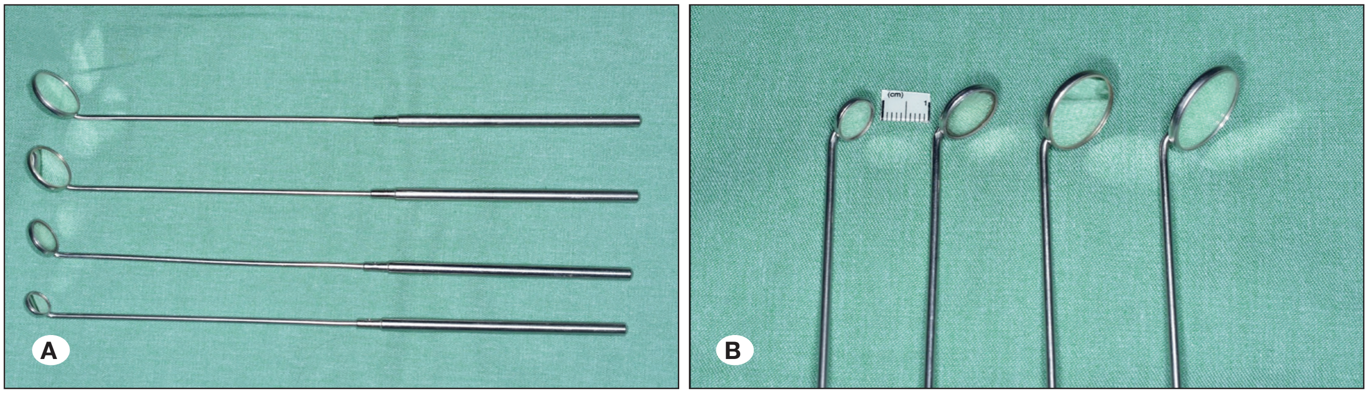

Figure 1: (A) Set of 45° angled micromirrors. **(B**) From left to right, 5 mm, 7 mm, 10 mm, and 12 mm micromirror.

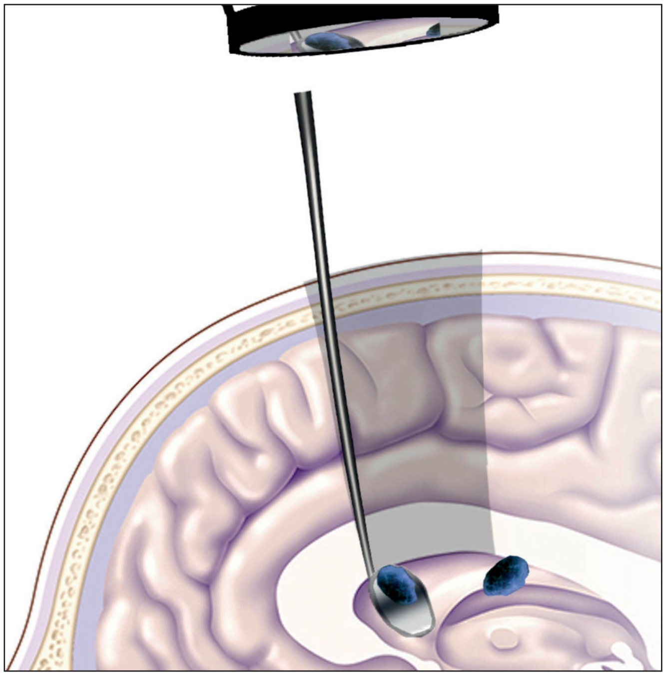

Figure 2: Digital illustration showing an example of the use of a micromirror to detect a remnant during the resection of a third ventricle tumor.

led to detect a small remnant that was successfully removed. The patient had an uneventful postoperative course and the postoperative MRI showed a gross total resection of the lesion (Figure 3).

Case #2

A 42-year-old man was diagnosed with an epidermoid tumor of the fourth ventricle. A telo-velar approach was executed with the patient in the semi-sitting position. Most of the tumor was easily reached. However, the superior aspect of the roof of the fourth ventricle was not visible. The insertion of an angled micromirror allowed for to identification of a wide residual part of the lesion that was resected. The patient was discharged neurologically intact on the 6th postoperative day, and the postoperative MRI showed a gross total resection of the tumor (Figure 4).

Case #3

A 35-year-old male affected by a large epidermoid tumor of the right cerebellopontine angle underwent a retrosigmoid approach with the patient in the semi-sitting position. The tumor caused a severe displacement of the brainstem and involved upward the right posterior incisural space. The resection was carried out piece-by-piece achieving a progressive decompression of the brainstem. The infratentorial

Table I: Demographic and Clinical Data of the Patients Cohort

Case	Sex	Age (years)	Presentation	Diagnosis	Location
1	Male	53	Personality disturbances.	GBM	Left anterior cingulate gyrus
2	Female	37	Asymptomatic	Breast carcinoma metastases	Right posterior insular lobe
3	Male	45	Trigeminal neuralgia	Vascular compression	Right trigeminal nerve
4	Male	42	Headache, gait disturbances	Epidermoid tumor	Fourth ventricle
5	Female	58	Left side hemiparesis	Astrocytoma grade II	Right central cingulate gyrus
6	Female	73	Gait disturbances	GBM	Left cingulate isthmus
7	Female	56	Trigeminal neuralgia	Vascular compression	Left trigeminal nerve
8	Male	48	Ataxia, diplopia	Epidermoid tumor	Perimesencephalic cisterns; tentorial incisura
9	Female	17	Hearing loss	Epidermoid tumor	Left CPA
10	Male	69	Memory disturbances, epilepsy	Anaplastic astrocytoma Grade III	Left parahippocampal gyrus
11	Male	74	Asymptomatic	Lung carcinoma metastases	Right fusiform gyrus
12	Female	34	Headaches	Central Neurocytoma	Left lateral ventricle
13	Female	29	Epilepsy	AVM	Interhemispheric
14	Female	78	Seizures, headaches, acute consciousness impairment	Colon adenocarcinoma metastasis	Right hemispheric cerebellum

***GTR:** Gross-total resection, **NTR:** Near-total resection, **GBM:** Glioblastoma.*

portion of the mass was reached through a supracerebellar corridor. The final inspection of the surgical field was completed with the aid of the micromirror. It was turned 360° within the cerebellopontine angle, this maneuver allowing the detection of a small infratentorial remnant. The remnant was then removed using an extreme upward and median line of sight of the microscope, and the patient was discharged without deficits on the 3rd postoperative day. MRI at 3 months confirmed the gross total resection of the mass (Video 1).

Case #4

A 34-year-old female underwent a left anterior interhemispheric transcallosal approach in the supine position because of a left lateral ventricle central neurocytoma that involved the frontal horn and body of the ventricle. The lateral margins of the upper surface of the lesion adhered to the ventricular surface of the corpus callosum, this part of the tumor falling into a blind spot for the visualization with the microscope. The use of an angled

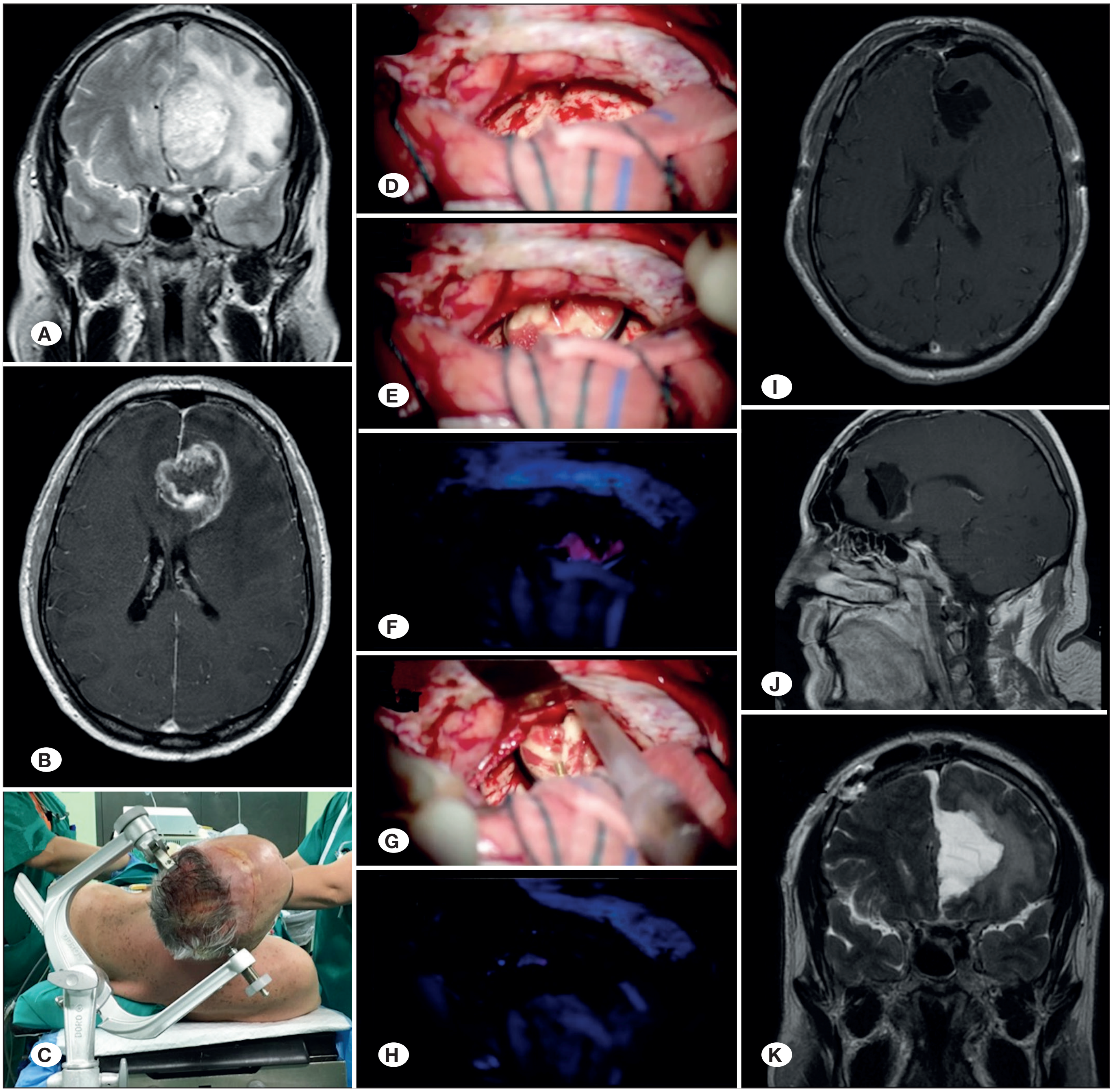

Figure 3: Preoperative **A)** coronal T2-weighted and **B)** axial T1-weighted gadolinium contrast-enhanced MRI. **C)** Surgical positioning. **D-H)** Sequential intraoperative pictures during 5-ALA-assisted tumor resection. Postoperative **I)** axial and **J)** T1-weighted contrast-enhanced MRI. **K)** Postoperative T2-weighted coronal MRI.

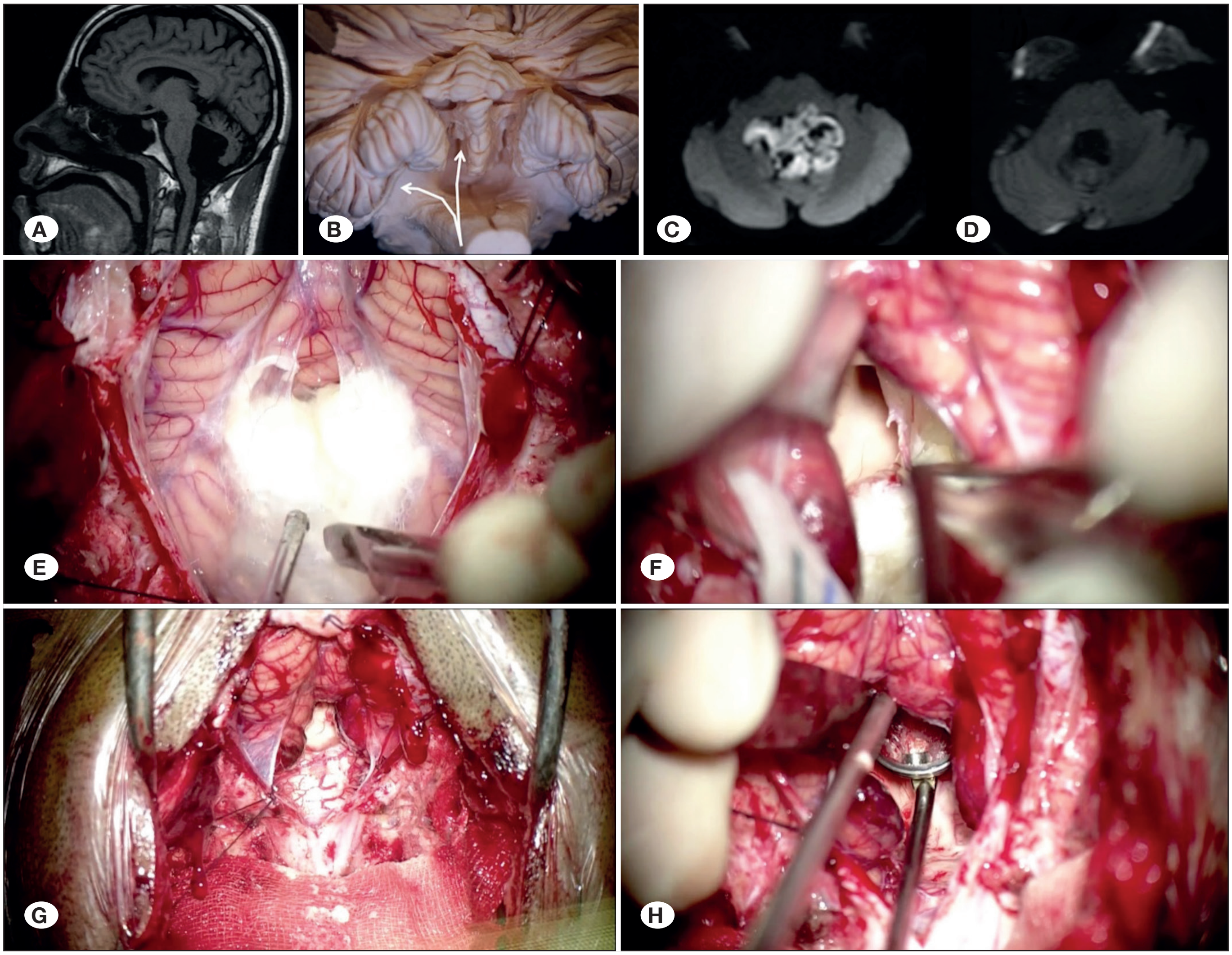

Figure 4: A) Preoperative sagittal T1-weighted MRI. **B)** Anatomical specimen showing the uvulotonsilar and cerebellotonsilar fissures (white arrows). **C)** Preoperative and **D)** postoperative axial diffusion-weighted MRI. **E-H)** Sequential intraoperative pictures during tumor resection.

micromirror allowed reaching the hidden portion of the lesion, achieving a total resection. No complications occurred and the patient was discharged three days later. MRI confirmed the complete resection of the (Figure 5).

Case #5

A 52-year-old female underwent a right interhemispheric contralateral transfalcine approach for an interhemispheric AVM with an arterial feeder from the right distal anterior cerebral artery and a single draining vein in the superior sagittal sinus. Intraoperatively, micromirror allowed for easily detecting of the superior pole of the AVM hidden above the paracentral lobule. The AVM was completely resected as confirmed by the postoperative digital subtraction angiography and the patient was discharged 3 days later without deficits (Figure 6).

DISCUSSION

Technical Overview

Mirrors may be the oldest optical element that can harness the power of light (16), and has been developed based on the reflections of a water pond while retaining its ability to interact light and reflection. The images formed by a mirror are either real or virtual, depending on the proximity of the object. The virtual image can be calculated in respect of its size and geometry, and it is produced by extensions from all incidental light rays that intersect behind the reflective surface. In contrast,the real image is produced from the extensions from the incident and reflected rays that converge in front of the mirror.

In neurosurgery, movable or fixed mirrors can be used to see objects that are out of the field of view, such as around a corner,or the superior aspect of the superior medullary velum or the roof of the lateral ventricle. Unlike the microscope or the

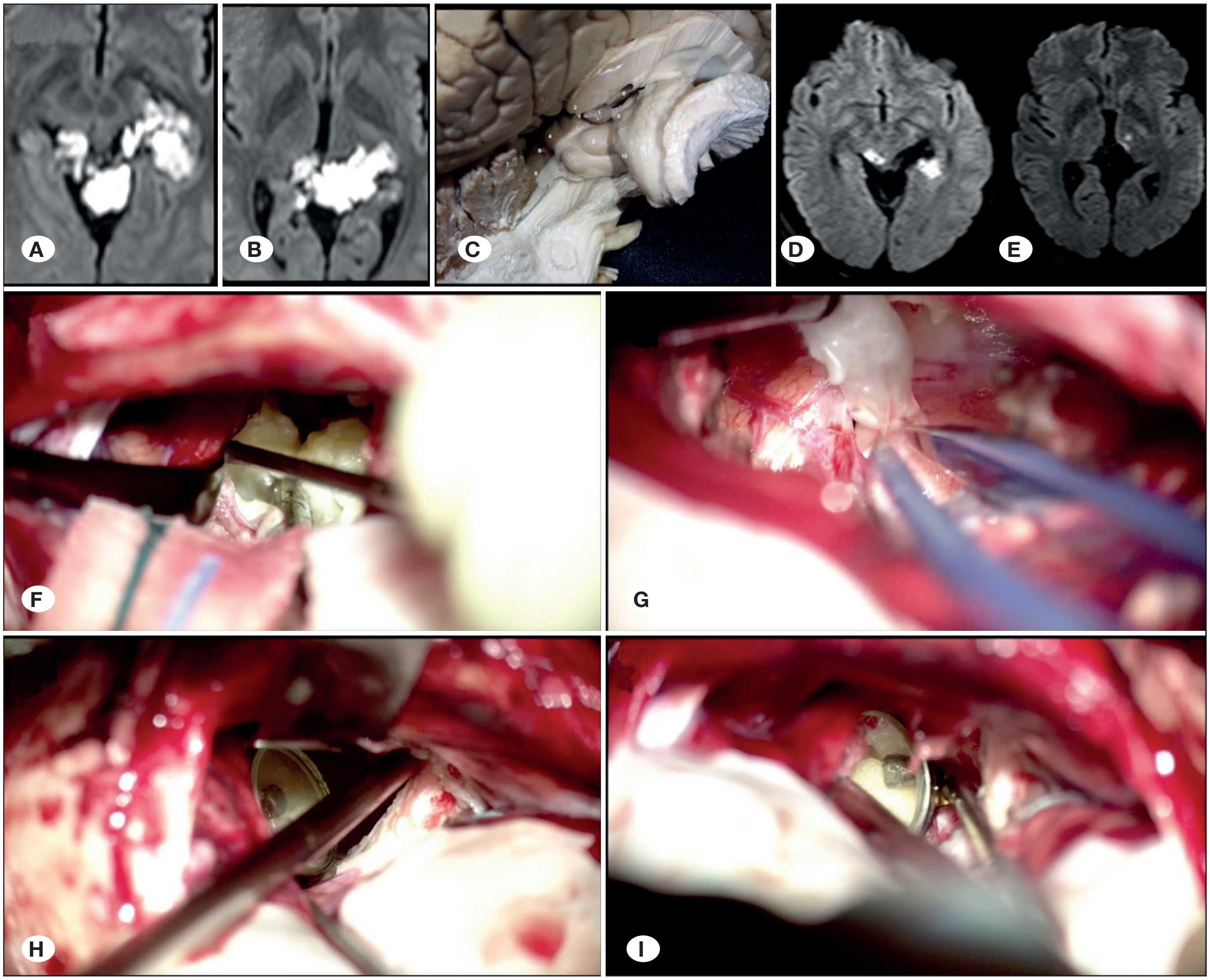

Figure 5: A) Sagittal, and **B)** axial T1-weighted contrast-enhanced MRI. **C)** Brain hemisphere specimen showing the lateral ventricle for anatomical orientation. **D)** Patient position in the operative room for anterior interhemispheric transcallosal approach. **E-F)** Intraoperative pictures during micromirrors-assisted resection of the tumor. Postoperative **G)** sagittal and **H)** coronal T1-weighted contrast-enhanced MRI.

endoscope, the micromirror does not allow direct visualization but reflection of structures without brain retraction (16).

Use in Tandem with Microscope

The use of micromirrors can be adjunctive to that of the surgical microscope. The 45°-angled view of the micromirror brings the incident light beam coming from the microscope in a wide range of directions thanks to the 360° rotation of the instrument. As a consequence, the illumination power of the surgical microscope is significantly enhanced.

Benefits in Tumor Resection

The application of micromirrors in tumoral resection has been initially recommended in the management of tumors of the sellar, suprasellar, and parasellar regions. Abe et al. were among the first to report the benefits of the use of micromirrors in the management of a pediatric craniopharyngioma operated on via a transsphenoidal approach (1). They highlighted the importance of the illumination and visual guidance accomplished with the tool.

Naik and colleagues reported the key steps of the management of a complex mucocele through an anterior orbitotomy via eyelid crease approach where the use of the micromirror enhanced the indirect illumination of the narrow and limited surgical field (11). Paranthala and Surash summarized the applications of mirrors in complex cranial neurosurgery, emphasizing the increased visualization and illumination through narrow access corridors (13). They recommended using mirrors around the tumor capsule, posterior fossa, and deep and narrow corridors in general, especially stressing the reliability of the instrument in detecting small tumor remnants hidden within blind spots.

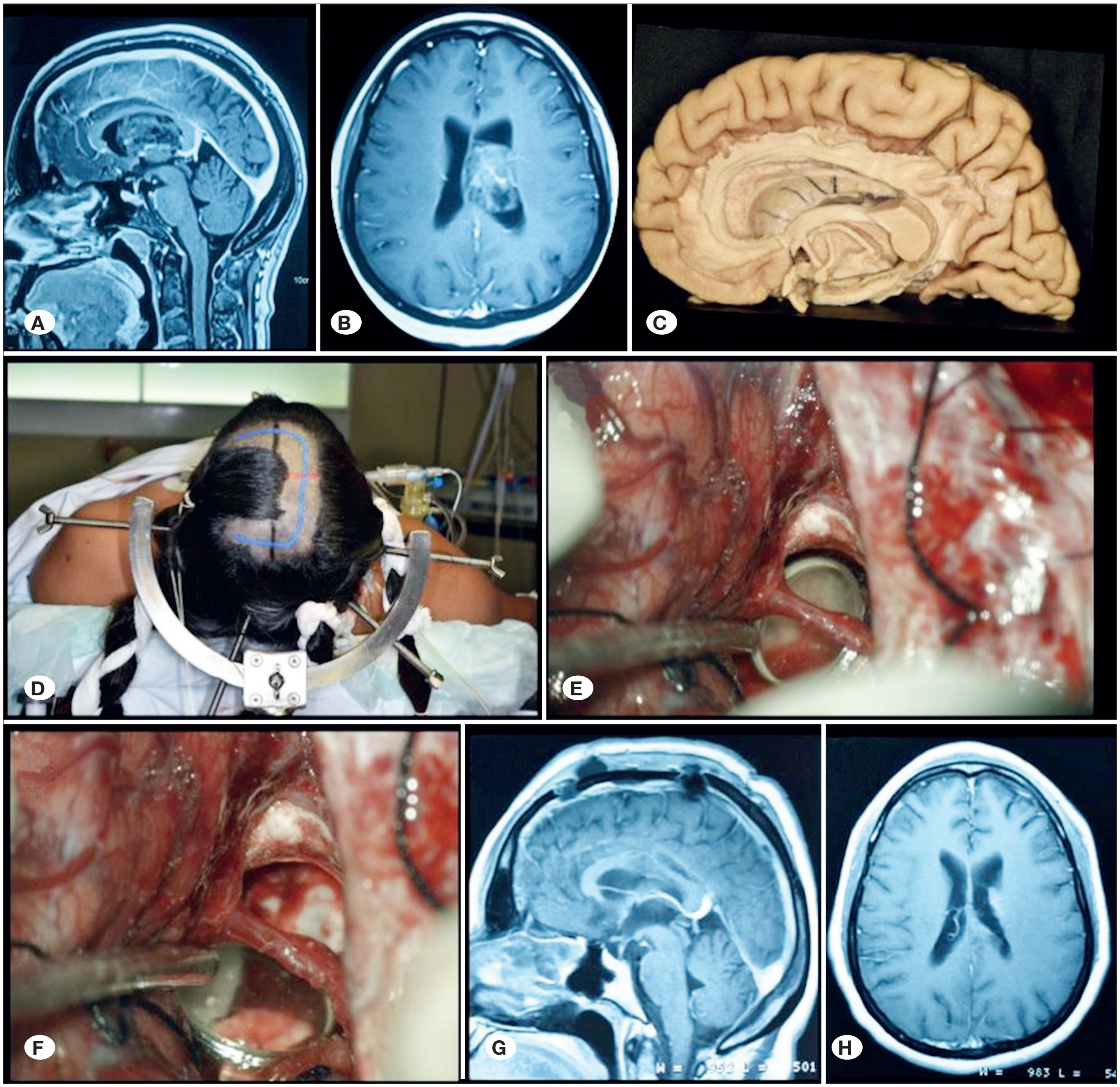

Figure 6: A) Lateral, and **B)** anterior-posterior 3D angiography. **C)** Preoperative sagittal T1-weighted MRI. **D-E)** Intraoperative pictures obtained during a right interhemispheric contralateral transfalcine approach revealing the helpfulness of the micromirrors in detecting the superior pole of the AVM. Postoperative **F)** lateral and **G)** anterior-posterior digital subtraction angiography. **H)** Postoperative sagittal T1-weighted MRI.

Our overall experience allowed us to confirm the same indications, to which to add also selected cases of tumors affecting the spinal canal, like in a pediatric case treated by the authors (2). Worthy of note is the utility of mirrors during the fourth ventricle surgery, as shown by the herein reported illustrative case #2 where the introduction of the angled micromirror allowed to identify of a wide tumor residual adherent to the inner layer of the superior medullary velum. It also allowed for avoiding rigid cerebellar retraction.

Benefits in Neurovascular Surgery

Micromirror applications in neurovascular surgery include laboratory practice for anastomosis (3,19), brain aneurysm clipping (5), vascular decompression for MVCs, and AVM resection. For vascular visualization, the “black-wall first” or “one-way up” technique for micro anastomosis presents difficulties in the visualization of the back wall of the vessel given the limited space. Harris et al. have found useful the micromirror in passing the suture inversely from the anterior view (4). Similarly, offending arteries involved in NVCs can be easily visualized from a posterior, superior, and inferior perspective using angled micromirrors. The use of micromirrors during aneurysm surgery can be critical to visualize the posterior wall of the vessel and the presence of small perforators around the neck of the aneurysm. The sparing of the perforating arteries and the avoidance of stenosis are critical in giant

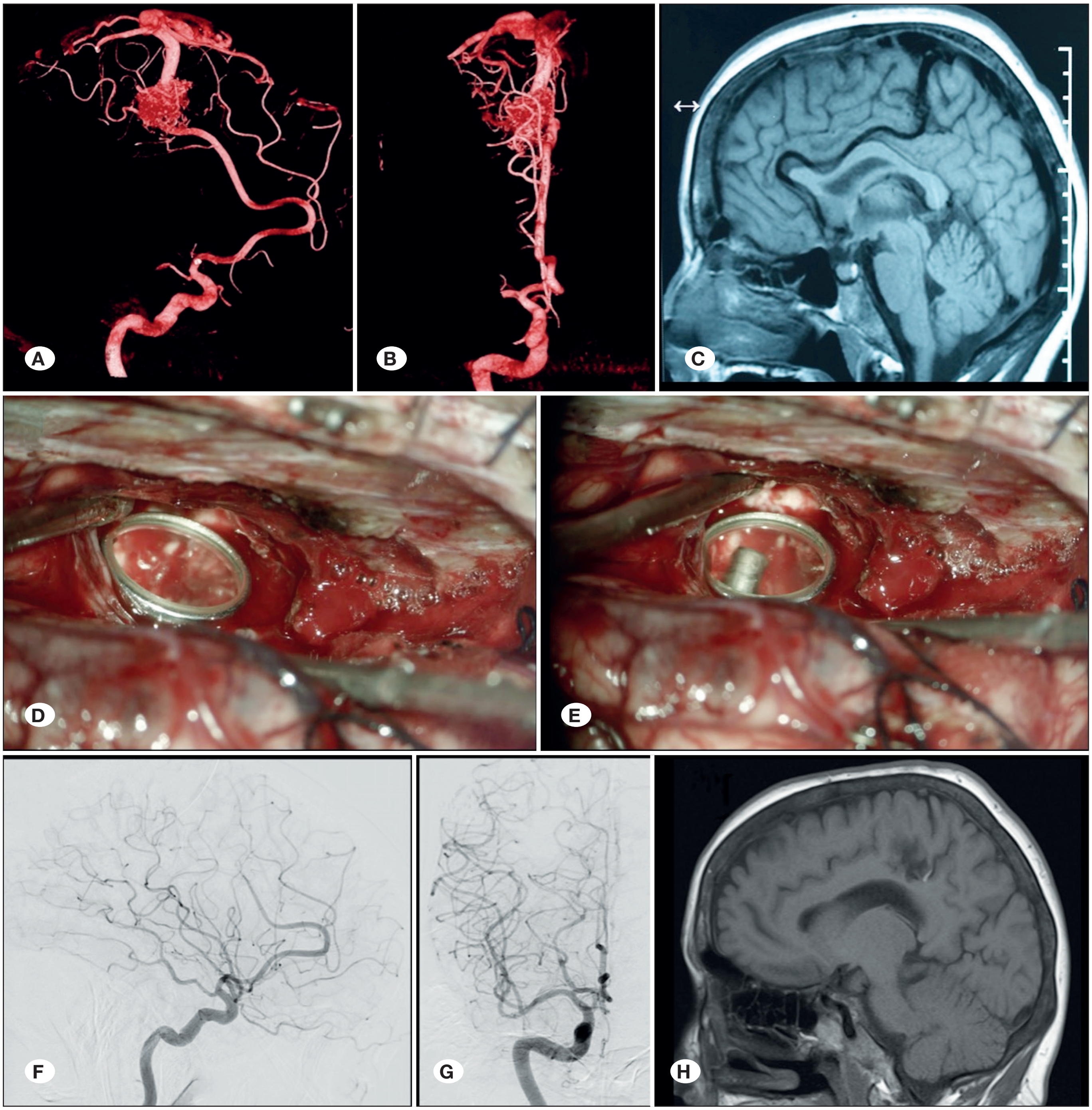

Figure 7: Lateral **(A)** and anteroposterior **(B)** 3D angiography showing an interhemispheric AVM with an arterial feeder from the right anterior cerebral artery and a single draining vein in the superior sagittal sinus. **C)** Preoperative sagittal T1-weighted MRI showing the AVM in the paracentral sulcus and the related flow void. **D, E)** Intraoperative pictures obtained during a right interhemispheric contralateral transfalcine approach revealing the helpfulness of the micromirrors in detect the superior pole of the AVM hidden above the paracentral lobe. Postoperative digital subtraction angiography in lateral **(F)** and anteroposterior projection **(G)** documenting the complete resection of the AVM. (H) Sagittal T1-weighted postoperative MRI.

aneurysms and no less in other neurovascular procedures, as already stressed by our group elsewhere (7-10). Moreover, the combination of the micromirror and indocyanine green videoangiography has been recognized as useful for the clipping of posterior communicating artery aneurysms (6,17).

Technical Evolution of the Micromirrors

New smart dental mirrors also integrate micro-cameras and tiny light-emitting-diodes (LEDs) (15). However, the handle for these tools remains little ergonomic for neurosurgical use. This technical evolution can theoretically improve the illumination and visualization of deep-seated lesions although pieces of evidence about this high technology have not been reported yet for neurosurgery.

Technical Limitations

The need for a precise spatial mastering of the instrument in deep-seated surgical fields, the relatively limited freedom for mirror rotation, the not infrequent fogging, and the need for a visuospatial interpretation of the reflected images are the main limitations of the use of micromirrors. A slower introduction within the surgical field and slight heating of the mirror with warm saline are practical tricks for avoiding fogging.

In the authors' experience, the use of micromirrors proved to be useful in the detection of small tumor remnants in deep-seated surgical fields. Different neurovascular structures can be visualized without the need for rigid brain retraction.

The cost-effectiveness and the easy learning curve related to their use are the main strengths of the micromirrors.

The present study is limited in terms of the number of treated patients and homogeneity. Accordingly, further investigations are necessary to draw definitive conclusions about the real utility in neurosurgery of this "old but gold" tool.

CONCLUSION

Further studies are needed to compare angles of view of angled endoscopes versus angled micromirrors, as well as the freedom for the mirror's rotation in deep areas. Finally, to evaluate the impact on the brain retraction related to the use of micromirrors, postoperative Fluid Attenuated Inversion Recovery (FLAIR) MRI imaging of patients operated on with and without the adjunct of the micromirrors ought to be compared.

AUTHORSHIP CONTRIBUTION

Study conception and design: EGOR, MB, SL
Data collection: AGL, PGL, JFV
Analysis and interpretation of results: IJB, WSR
Draft manuscript preparation: EGOR, AGL
Critical revision of the article: MB, AC, WSR, SL
All authors (EGOR, MB, PGL, AC, JFV, AGL, IJB, WSR, SL) reviewed the results and approved the final version of the manuscript.

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