Exoscopic and Augmented Reality Heads-Up Display Guided Neurological Surgery: A Descriptive Case Series

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Background

Conventional operative microscopes remain foundational in cranial and spinal surgery, but they impose ergonomic constraints related to posture, working distance, and viewing angles. Over time, sustained microscope use has been associated with fatigue and musculoskeletal strain, particularly during long or steep-angle cases.

Heads-up display (HUD) and augmented reality (AR) platforms aim to address these limitations by integrating neuronavigation, imaging, and fluorescence directly into the surgeon's visual field while preserving stereoscopic visualization. Despite growing adoption, real-world data on feasibility, safety, and workflow integration of HUD systems across diverse neurosurgical procedures remain limited.

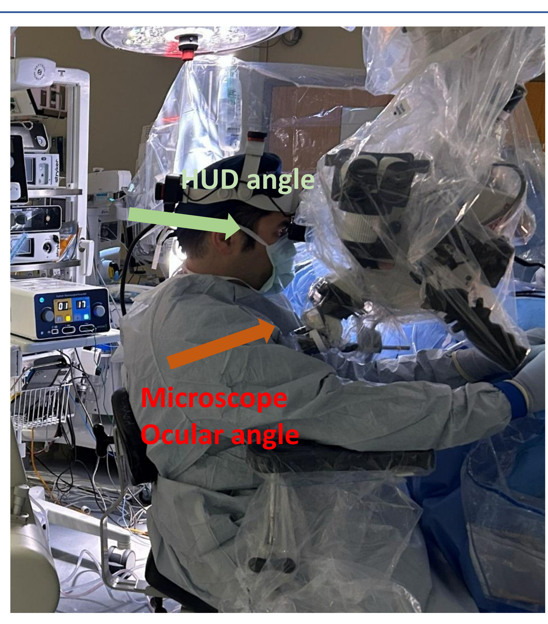

Figure 1. Retrosigmoid approach demonstrating improved ergonomic head positioning using a heads-up display compared with traditional microscope ocular alignment.

Figure 2. Head-mounted augmented reality visualization integrating multimodal intraoperative imaging.

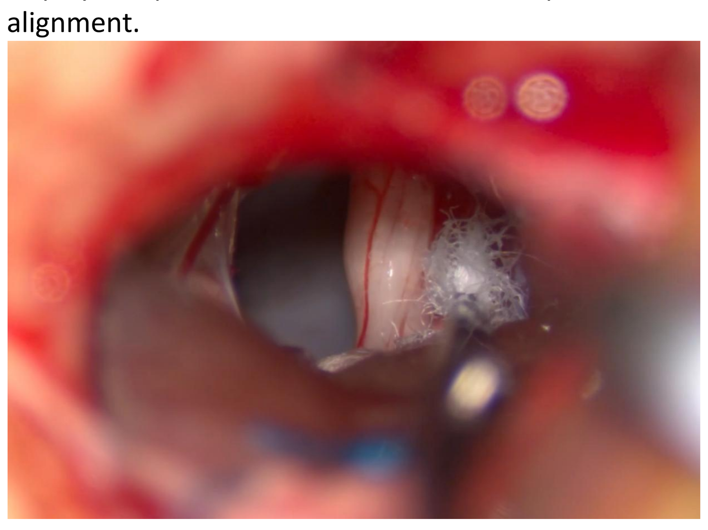

Figure 3. Intraoperative PTFE placement separating the superior cerebellar artery from the trigeminal nerve.

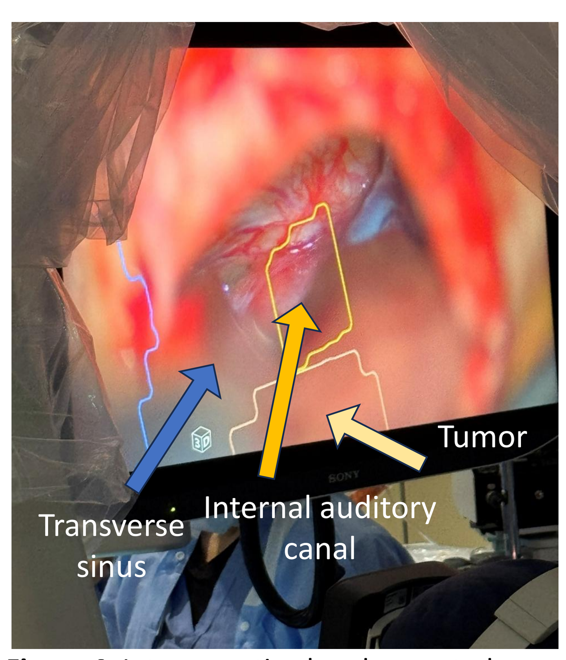

Figure 4. Intraoperative head-mounted augmented reality view demonstrating anatomic structure overlays during skull base surgery.

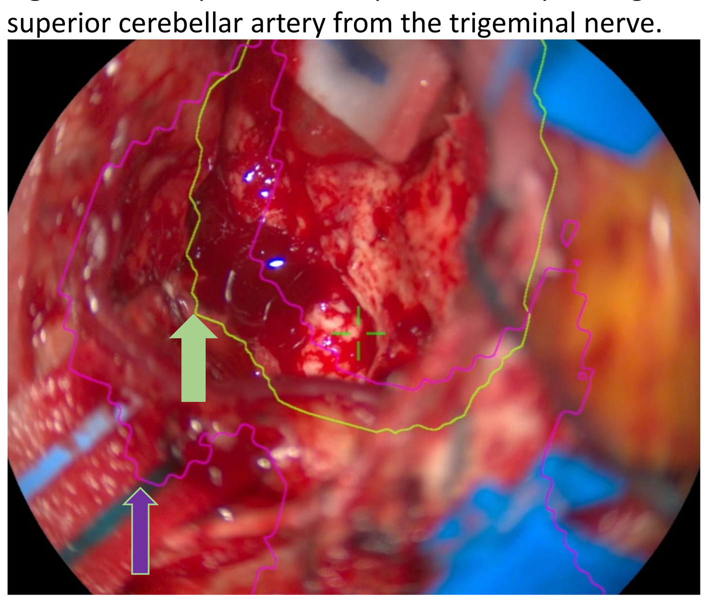

Figure 5. Microscopic resection was aided by augmented reality highlighting the tumor boarder (green, arrow) and peritumoral edema (purple, arrowhead).

Figure 6. 5-ALA fluorescence overlaid with augmented reality tumor mapping.

Objective

To describe early clinical implementation of the Leica ARveo 8 with the MyVeo HUD across consecutive cranial and spinal procedures, focusing on feasibility, safety, ergonomic impact, and workflow integration (including AR neuronavigation and fluorescence).

Key Conclusions

In this early consecutive series, HUD-guided neurosurgery was feasible across a broad range of spinal and cranial procedures, with a very low conversion rate and **no HUD-attributable intraoperative complications**. Integrating AR neuronavigation and fluorescence directly into the visual field supported intraoperative orientation and maintained workflow continuity while enabling a more ergonomic "heads-up" posture.

- **Feasibility & safety:** reliable completion across routine and complex cases
- **Ergonomics:** improved surgeon posture and reduced perceived fatigue
- **Workflow:** navigation/fluorescence overlays reduced attention-shifting and improved intraoperative orientation

Surgical approaches		Pathologies treated	
Cranial	n = 25	Craniotomy	1
Frontal craniotomy	3	Ependymoma	1
Frontal, endoscopic then transcortical	1	Glioblastoma	1
Frontotemporal craniotomy	7	ICH evacuation	1
Interhemispheric, transcallosal	1	Intracranial hemorrhage evacuation	1
Occipital craniotomy	1	Metastatic breast	1
Parietal craniotomy	2	Oligodendroglioma	1
Retrosigmoid	4	Petroclival meningioma	1
Retrosigmoid, extended middle cranial fossa	1	Recurrent medulloblastoma	1
Suboccipital craniotomy	3	Trigeminal neuralgia	1
Temporal craniotomy	2	Vestibular schwannoma	1
		Brainstem solitary fibrous tumor	1
Glioblastoma	6	Cavernous sinus abscess	1
Meningioma	2	Colloid cyst	1
Sphenoid wing meningioma	2	Craniopharyngioma	1

Table 1. Case distribution by surgical approach and treated pathology.

Study Design and Key Findings

We conducted a multi-surgeon, single-institution retrospective consecutive case series (January–September 2025). Ninety cranial and spinal procedures were performed using stereoscopic 4K HUD visualization with real-time integration of AR neuronavigation and, when indicated, fluorescence guidance (5-ALA and/or ICG).

HUD-guided visualization was successfully used to complete **89 of 90** procedures. **One case required conversion** to conventional microscopy due to insufficient visualization at high magnification early in the learning curve. **No intraoperative complications were attributable to HUD use.** Across cases, surgeons reported improved posture, reduced fatigue, and improved workflow continuity, with overlays (navigation/fluorescence) supporting intraoperative orientation and decision-making.

Cohort snapshot:

- Total procedures: **90** (Spine **65**; Cranial **25**)
- Completion with HUD: **89/90 (99%)**; conversion: **1/90 (1%)**
- HUD features used: **AR neuronavigation**, **5-ALA**, **ICG** (case-dependent)
- HUD-attributable intraoperative complications: **0**

Limitations

This study is limited by its retrospective, single-center design and the absence of a comparator group, which precludes direct comparison to conventional microscopy or exoscopic platforms. Ergonomic impact was assessed subjectively without validated measurement tools, and outcomes such as operative time, cognitive load, and extent of resection were not formally quantified. A learning curve was observed, with the single conversion occurring during high-magnification visualization demands early in the series.

Future Directions

Future work should move beyond feasibility by directly comparing HUD systems with operative microscopes and exoscopes using objective endpoints. Priorities include standardized ergonomic metrics, workflow efficiency measures, and cost-effectiveness analyses, ideally supported by multicenter registries that harmonize reporting and accelerate generalizable conclusions.

- Prospective comparative studies (HUD vs microscope vs exoscope)
- Objective ergonomics/workflow/cost analyses and standardized outcome reporting
- Multicenter registries to improve generalizability and benchmarking

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References

1. Nounaka Y, Matano F, Umeoka K, et al. Head mounted three-dimensional high-definition display system for microscopic surgical field observation: An observational study. *World Neurosurg*. 2025;201124256. doi: 10.1016/j.wneu.2025.124256
2. Rahman R, Wood ME, Qian L, Price CL, Johnson AA, Osgood GM. Head-mounted display use in surgery: A systematic review. *Surg Innov*. 2020;27(1):88-100. doi: 10.1177/1553350619871787
3. Montemurro N, Scerrati A, Ricciardi L, Trevisi G. The exoscope in neurosurgery: An overview of the current literature of intraoperative use in brain and spine surgery. *J Clin Med*. 2021;11(1):doi: 10.3390/jcm11010223
4. Yoon JW, Chen RE, Han PK, Si P, Freeman WD, Pirris SM. Technical feasibility and safety of an intraoperative head-up display device during spine instrumentation. *Int J Med Robot*. 2017;13(3):doi: 10.1002/rcs.1770