

Technical Note

A modular concept to improve ergonomics, team visualization, and global accessibility - A technical note and proof of concept

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Objective

Modern neurosurgery increasingly relies on digital visualization tools, including operating microscopes, exoscopes, endoscopes, and intraoperative navigation. However, each modality has specific limitations regarding ergonomics, viewing axes, dependence on external monitors, and equal access to the operative image for all team members. This technical note presents a modular, translational proof-of-concept for XR-assisted visualization that may be developed for cranial, spinal, vascular, and functional neurosurgical procedures.

Methods

The concept provides for real-time transmission of images from different potential sources, including a smartphone camera, operating microscope, exoscope, or endoscope, to lightweight XR headsets worn by the surgeon and/or assisting team members. To date, only the technical connection between a smartphone camera and an XR headset has been implemented and tested. This enabled reliable live-video streaming to a head-mounted display with acceptable image quality and latency.

Integration of operating microscopes and exoscopes represents the next planned development stage and has not yet been implemented. A central component of this stage is a low-cost and portable integration pathway combining smartphone-based cameras with 3D-printed exoscope components. This is intended as an accessible visualization platform for training, smaller centers, and resource-limited or mobile settings.

Building on this initial proof-of-concept, a structured evaluation is planned with medical students and residents in skill-lab exercises, as well as with experienced neurosurgeons, to assess usability, ergonomics, perceived image quality, and educational value before considering live operative use.

Results

The smartphone-to-XR-headset connection proved technically feasible. It enabled a shared real-time image through a lightweight head-mounted display, independent of fixed monitor positions or microscope oculars. This confirms the fundamental technical premise of the modular XR concept and provides a functional basis for further development. Formal usability and performance testing with students, skill-lab participants, and clinicians is planned as the next step. Based on the current technical testing, no conclusions can yet be drawn regarding clinical benefit, intraoperative safety, or superiority over established visualization systems.

Conclusion

This work establishes an initial, technically validated proof-of-concept for smartphone-based XR visualization in neurosurgery. The planned skill-lab and user evaluation will help translate the technical demonstration into a practically tested tool. The results will provide the basis for subsequent integration of additional imaging sources, particularly microscopes and exoscopes, and for a carefully evaluated potential operative application across neurosurgical subspecialties.

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