



Augmented Reality Navigation for Superficial Temporal Artery Mapping in Extracranial–Intracranial Bypass: Cadaver Validation and Clinical Translation

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Background

Accurate localization of the superficial temporal artery (STA) is critical for extracranial–intracranial (EC–IC) bypass, yet can be challenging in patients with variant anatomy or vascular disease. Conventional approaches rely on Doppler probes or duplex ultrasound, which may occlude small-caliber branches. Augmented reality (AR) navigation, leveraging preoperative imaging and real-time overlays, provides a direct visual map of vasculature on the surgical field. Our group previously developed an AR registration workflow using landmarking and surface-tracing.

Objective

To validate the registration accuracy of our AR navigation system in cadavers and assess its clinical utility for STA mapping in EC–IC bypass patients.

Methods

Five cadaver heads were procured. Neurosurgical residents and faculty (n=5) registered preoperative CT to cadavers using AR surface-tracing registration and drilled 12 preplanned burr holes per head (n=60) (Fig. 1a). Post-procedural CT was used to measure burr hole accuracy. Participants completed surveys comparing AR and conventional navigation (Table 1). Following validation, the AR system was applied in 4 consecutive patients undergoing EC–IC bypass. Average registration error, mapping times, and intraoperative applications (STA course visualization, graft length estimation, anastomosis planning, and cortical mapping post-dural opening) were documented (Figs. 1b–d).

Results

On cadavers, burr hole placement demonstrated a median error of 1.67 mm (IQR 0.99 mm). Likert-scale surveys favored AR for maintaining surgical focus (mean 4.57 vs 2.29, $p = 0.0004$), while also finding AR navigation to be intuitive to use and easily integrated into the surgical workflow (Table 1). In 4 clinical EC–IC bypass cases, average registration error was 1.75 mm, and STA mapping was completed in an average of 95 s. AR was used intraoperatively for graft length measurement, localization of anastomosis sites, and visualization of motor cortex after dural opening. All patients achieved robust revascularization on postoperative angiography.

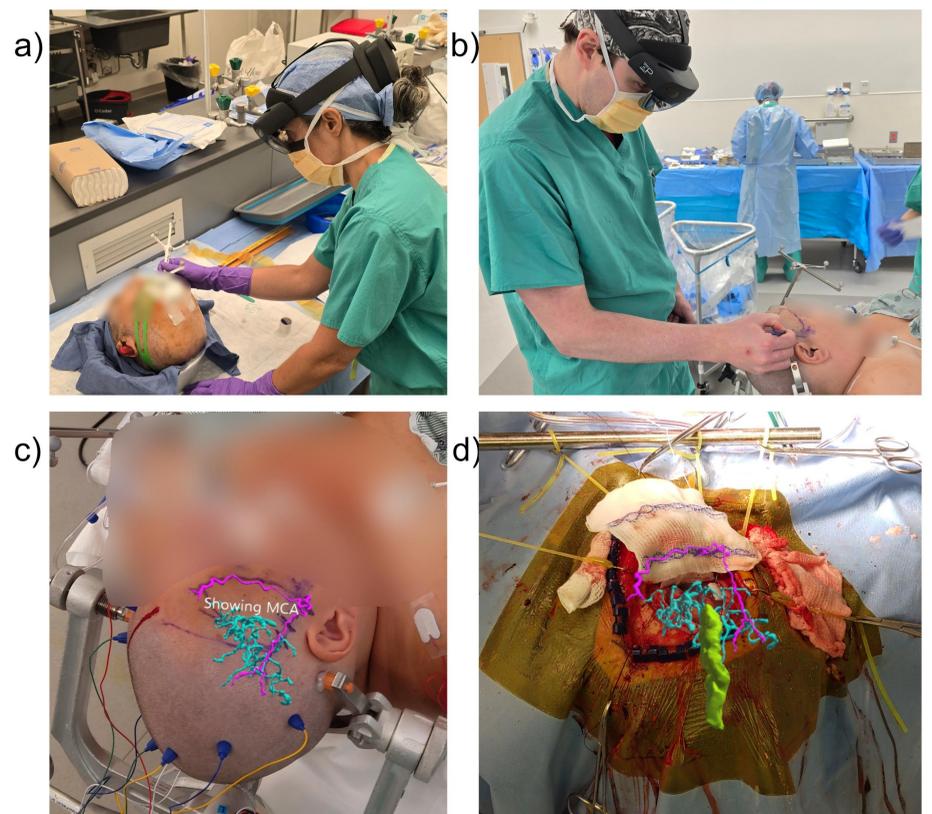


Figure 1. 1a) Cadaver accuracy study. 1b) Surgeon mapping STA with AR headset. 1c) AR overlay of STA and MCA on patient. 1d) AR overlay of recipient cortex and anastomosis sites.

Conclusion

This AR navigation system provided sub-2 mm registration accuracy comparable to conventional navigation, while enabling rapid (<2 min) STA localization and intraoperative planning. By projecting vascular anatomy and cortical landmarks directly into the surgeon's view, AR eliminated vascular occlusion by a handheld ultrasound probe, and improved workflow efficiency. In EC–IC bypass, AR offers a practical adjunct for STA mapping, graft planning, and intraoperative visualization.

	AR mean	Traditional navigation mean	Difference (p-value)
Intuitive to use	4.29	4.29	+0.00 (1.0000)
Easy to maintain focus on surgical field	4.57	2.29	+2.28 (0.0004)
Easily integrated into workflow	4.29	4.00	+0.29 (0.5939)
Provides accurate registration	4.57	4.29	+0.28 (0.4301)
Doesn't add significant time	3.86	3.14	+0.72 (0.0767)

Table 1. Surgeon feedback on AR vs traditional navigation (Likert 1–5).

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