Awake High-Flow Extracranial to Intracranial Bypass for Complex Cerebral Aneurysms: Institutional Clinical Trial Results

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OBJECTIVE: **Assess the potential added benefit to patient outcomes of "awake" neurological testing when compared with standard neurophysiologic testing performed under general endotracheal anesthesia.**

METHODS: **Prospective study of 30 consecutive adult patients who underwent awake high flow extracranial to intracranial (HFEC-IC) bypass. Clinical neurological and neurophysiologic findings were recorded. Primary outcome measures were the incidence of stroke/cerebrovascular accident (CVA), length of stay, discharge to rehabilitation, 30-day modified Rankin scale score, and death. An analysis was also performed of a retrospective control cohort (n = 110 patients who underwent HFEC-IC for internal carotid artery (ICA) aneurysms under standard general endotracheal anesthesia).**

RESULTS: **Five patients (16.6%) developed clinical awake neurological changes (4, contralateral hemiparesis; 1, ipsilateral visual changes) during the 10-minute ICA occlusion test. These patients had 2 kinks in the graft, 1 vasospasm, 1 requiring reconstruction of the distal anastomosis, and 1 developed blurring of vision that reversed after the removal of the distal permanent clip on the ICA. Three of these 5 patients had asynchronous clinical "awake" neurological and neurophysiologic changes. Two patients (7%) developed CVA. Median length of stay was 4 days. Twenty-eight of 30 patients were discharged to home. Median modified Rankin scale score was 1. There were no deaths in this series. Absolute risk reduction in the awake craniotomy group (n = 30) relative to control retrospective group (n = 110) was 7% for CVA, 9% for discharge to rehabilitation, and 10% for graft patency.**

CONCLUSIONS: **Temporary ICA occlusion during HFEC-IC bypass for ICA aneurysms in conjunction with awake intraoperative clinical testing was effective in detecting a subset of patients (n = 3, 10%) in whom neurological deficit was not detected by neurophysiologic monitoring alone.**

INTRODUCTION

Awake craniotomy is a well-established procedure that has been used widely for glioma resection and functional procedures that require neurological monitoring of eloquent cortical and subcortical areas.[1-19] Awake procedures have also been used for similar purposes in cerebrovascular surgery, specifically for carotid endarterectomy.[20-22] Multiple case reports describing the use of awake craniotomy for aneurysms have also been presented in the literature, including 3 cases of distal vessel occlusion for mycotic aneurysm,[23] clipping an ophthalmic artery

Key words
- Aneurysm
- Awake craniotomy
- EC-IC bypass
- Outcome

Abbreviations and Acronyms
ARR: Absolute risk reduction
CI: Confidence interval
CVA: Cerebrovascular accident
FDA: Food and Drug Administration
GEA: General endotracheal anesthesia
HFEC-IC: High flow extracranial to intracranial
ICA: Internal carotid artery
LOS: Length of stay
mRS: modified Rankin scale
PED: Pipeline embolization device
RRR: Relative risk reduction
SD: Standard deviation

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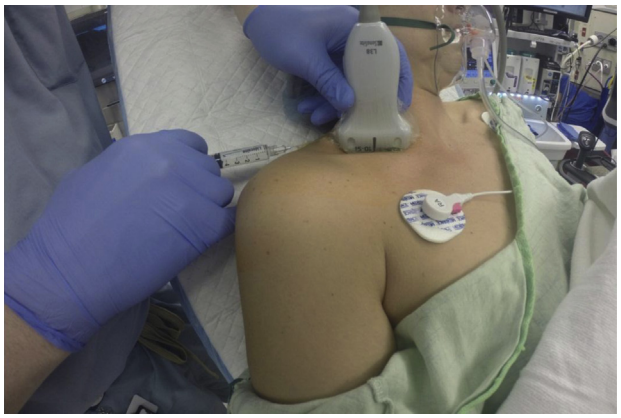

Figure 1. Ultrasound-guided supraclavicular nerve block. Operating room photograph demonstrating the positioning of the patient (semisitting) with the head turned away to the contralateral side. The lateral insertion point of the sternocleidomastoid muscle on the clavicle identifying the block site (as demonstrated in this photograph). Subsequent to this step, the supraclavicular area is prepped sterilely and a sterile glove is placed on the ultrasound probe to continue with the block.

aneurysm with intraoperative visual testing,[24] trapping a giant fusiform middle cerebral artery aneurysm,[25] and anterior choroidal artery aneurysm clipping.[26] We recently published the first prospective series ($n = 30$) of awake clipping of unruptured intracranial aneurysms and compared our results to our own control patients (retrospective series, $n = 30$) who underwent standard unruptured intracranial aneurysm clipping under general endotracheal anesthesia (GEA).[27] Median length of stay (LOS) was reduced from 5 days in our GEA control to 3 days in our prospective awake craniotomy series. In addition, the procedure-related stroke rate was reduced from 10% in the GEA control to 3% in the prospective awake craniotomy series.[27]

The 5-year cumulative risk of rupture of large and giant internal carotid artery (ICA) aneurysms is 40%.[28,29] High flow extracranial to intracranial (HFEC-IC) bypass for complex aneurysms of the ICA is considered one of the standard treatments. The 2 critical steps during HFEC-IC bypass that are paramount in the outcome of the patient are: 1) temporary occlusion of the recipient vessel for the distal anastomosis and 2) permanent occlusion of the parent vessel after the bypass. In standard (GEA) procedures, electrophysiologic monitoring is the basis for monitoring neurological function. Despite detailed neurophysiologic monitoring,

Table 1. Participant Characteristics and Outcomes Stratified by Study Group ($n = 140$)

	Total n (%)	Awake Prospective (n = 30) n (%)	GEA Retrospective (n = 110) n (%)	*P Value
Age, mean ± SD, years	48.4 ± 7.2	50.1 ± 6.5	48.0 ± 7.3	0.1632
Gender				0.6372
Female	74 (52.9)	17 (56.7)	57 (51.8)	
Male	66 (47.1)	13 (43.3)	53 (48.2)	
Side				0.7014
Left	75 (53.6)	17 (56.7)	58 (51.7)	
Right	65 (46.4)	13 (43.3)	52 (48.3)	
Length of stay, mean ± SD, days	6.4 ± 1.9	4.0 ± 1.2	7.0 ± 1.6	<0.0001
Mortality				0.3409
Dead	6 (4.3)	0 (0.0)	6 (5.5)	
Alive	134 (95.7)	30 (100.0)	104 (94.5)	
CVA status				0.5274
Yes CVA	17 (12.1)	2 (6.7)	15 (13.6)	
No CVA	123 (87.9)	28 (93.3)	95 (86.4)	
Discharge location				0.3655
Rehab	16 (13.6)	2 (6.7)	17 (15.5)	
No rehab	121 (86.4)	28 (93.3)	93 (84.5)	
Graft patency				0.1206
Patent	129 (92.1)	30 (100.0)	99 (90.0)	
Nonpatent	11 (7.9)	0 (0.0)	11 (10.0)	

GEA, general endotracheal anesthesia; SD, standard deviation; CVA, cerebrovascular accident.
*Based on χ^2 or Fisher's exact test where appropriate.