Surgical Resection for Epilepsy Following Cerebral Gunshot Wounds

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■ OBJECTIVE: **The surgical management of epilepsy after penetrating gunshot wounds (GSWs) to the head has not been described in the modern era. Given the extensive damage to the cranium and cortex from such injuries, the safety and efficacy of surgical intervention are unclear. We report surgical strategy and outcomes after resection for medically refractory epilepsy following GSWs in 4 patients.**

■ METHODS: **A prospectively compiled database of 325 patients with epilepsy was used to identify patients undergoing surgery for medically refractory epilepsy after a GSW to the brain. Seizure frequency, scalp and intracranial electroencephalography evaluation, type of resection, and seizure outcomes were compiled.**

■ RESULTS: **All 4 patients underwent direct electrocorticography recordings either with implanted electrodes or intraoperatively that were used to drive surgical decision making. All patients had intracranial shrapnel fragments and large areas of encephalomalacia on imaging. Intracranial electrodes were placed in 2 patients to localize seizure onsets. Two patients underwent frontal lobe resections, and the other 2 patients underwent multilobar resections. Latency between injury and epilepsy surgery was 12 years, and mean age at surgery was 28 years. In all cases, epilepsy surgery led to a significant improvement in seizure control (Engel class I, 2 patients; II, 1 patient; and III, 1 patient).**

■ CONCLUSIONS: **Epilepsy is common after penetrating head injury, and the incidence is likely to increase given the growing numbers of armed conflicts in urban centers worldwide. In selected cases, intracranial monitoring and surgical resections may be safely performed and can lead to favorable seizure outcomes.**

INTRODUCTION

Gunshot wounds (GSWs) to the brain were first described in military personnel following wars in the past 150 years.[1] In recent decades, civilian gun violence has escalated in the United States[2] as well as globally. The number of resulting brain injuries has reached epidemic proportions, especially affecting young individuals.[3] Many patients die as a result of GSWs to the brain; however, an increasing number survive. Although estimates vary, a significant percentage of the survivors (11.4%–53%) develop posttraumatic epilepsy, which in many instances is refractory to antiepileptic drug therapy.[4-6] GSWs account for approximately 4% of cases of focal epilepsy in the general population and represent the leading cause of new-onset epilepsy in the second and third decades of life.[7-10]

The surgical treatment of traumatic epilepsy that developed after shrapnel or bullet wounds to the head was first described by Foerster and Penfield[11] in the years following World War I. These cases were used to pioneer surgical approaches for focal epilepsy in the preanticonvulsant era. Using local anesthesia and cortical stimulation, a resection of the scar was used to achieve seizure control. Although surgical resections in the management of posttraumatic epilepsy after blunt head trauma are well described,[8,12] to the best of our knowledge, surgical approaches

Key words
- Encephalomalacia
- Frontal lobectomy
- Intractable epilepsy
- Posttraumatic epilepsy
- Resective surgery for epilepsy

Abbreviations and Acronyms
ECoG: Electrocorticography
EEG: Electroencephalography
GSW: Gunshot wound
MRI: Magnetic resonance imaging
SDE: Subdural electrode
SEEG: Stereotactic electroencephalography

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to treat epilepsy after penetrating craniocerebral GSWs have not been described since Foerster and Penfield's original reports. One reason may be the increasingly lethal or disabling nature of such injuries, as larger caliber and higher velocity missiles have become more widely available. Another possible reason is the extensive and sometimes diffuse nature of these injuries and the presence of intracranial adhesions that are thought to preclude surgical options.[13] In this study, we report the demographic characteristics, presurgical evaluation, surgical strategies, and outcomes in patients undergoing resections for medically refractory epilepsy after penetrating GSWs to the brain. We seek to determine if surgical approaches are a safe and therapeutically meaningful option in these patients.

MATERIALS AND METHODS

This study was approved by the local institutional review board for the protection of human subjects. A prospectively compiled database of epilepsy patients at our institution (2005—2013) was used to identify all patients who underwent surgery for medically refractory epilepsy resulting from a prior craniocerebral GSW. All patients underwent a comprehensive presurgical evaluation at our epilepsy monitoring unit, including scalp video electroencephalography (EEG), brain imaging, and neuropsychological testing. Two patients additionally underwent invasive EEG monitoring with subdural electrodes (SDEs). Data regarding demographics, seizure frequency and semiology, scalp EEG findings, imaging abnormalities, intracranial EEG evaluation, type of surgical resection, and seizure outcomes were compiled (Table 1). All cases were reviewed at a multidisciplinary epilepsy patient management conference where a surgical strategy was agreed on.

RESULTS

From the epilepsy surgery database of 325 adult patients, 4 patients with a prior history of posttraumatic epilepsy after craniocerebral GSWs were identified. In 3 of 4 patients, the first seizure occurred within 1 year of sustaining a GSW. Two patients had prior surgical interventions at the time of the GSW. Patient 3 had undergone a craniectomy soon after the injury and a cranioplasty 2

Table 1. Demographics, Seizure Frequency, Semiology, and Clinical Presentation of Patients Undergoing Surgical Resections for Epilepsy After Cerebral Gunshot Wounds

Case	Sex/ Handedness	Hemisphere	Age GSW/ Seizure onset (years)	Age at Surgery (years)	Time from GSW to Epilepsy Surgery (years)	Seizure Semiology*	Seizure Frequency	Physical Examination	Prior Surgeries	Preoperative Neuropsychological Profile
1	M/L	L	13/19	28	15	Complex motor (vocalization) → right face/arm clonic → ± generalized tonic-clonic	1/week	Nonfocal	None	VIQ, 116; PIQ, 93
2	F/L	L	5/5	26	21	Right body tonic → complex motor (vocalization) → ± right body clonic	1/week	Nonfocal	Vagal nerve stimulator	VIQ, 70; PIQ, 71
3	M/L	R	18/18	21	3	Left versive → left arm tonic-clonic	2/month	Prosthetic R eye	Hemicraniectomy, cranioplasty, VP shunt	NA
4	M/R	R	30/30	38	8	Automotor → L arm sensory → ± L body tonic	4/day	Mild L hemiparesis (arm > leg)	Right frontotemporal-parietal craniotomy and débridement	VIQ, 85; PIQ, 79
						Automotor → L arm sensory → ± L body tonic → ± generalized tonic-clonic	4/week			

GSW, gunshot wound; M, male; L, left; VIQ, verbal IQ; PIQ, performance IQ; F, female; R, right; VP, ventriculoperitoneal; NA, not available.
*Seizure semiologies follow the classification outlined in Luders et al.[14]: The breakdown of individual seizures to ≥1 phases indexed by a single defining quality, with the arrow indicating continuity. The ± symbol indicates phases seen in only a proportion of seizures. Seizure types: automotor, fumbling movements of distal upper extremity and/or oroalimentary movements; complex motor, aimless or confused movements of proximal and distal musculature and/or moderate vocalizations; versive, extreme sustained deviation of the head and eyes to one side.