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CASE REPORT

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Frontal damage and resolution of schizophrenia in a patient with self-inflicted gunshot wound: a case report

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Abstract

Background Craniocerebral self-inflicted gunshot wounds (SIGSW) are fatal in 90% of individuals, usually before reaching a hospital setting. We report a unique SIGSW survivor's residual neurologic deficits, imaging, neuropsychiatric findings, and improvement in psychosis.

Case presentation The patient is a 32-year-old right-handed Caucasian male with a medical history of paranoid schizophrenia who attempted suicide by SIGSW. After transport to the Emergency Department (ED), an emergent craniotomy was required for wound debridement, hematoma evacuation, and craniofacial reconstruction. He transitioned to rehabilitation and continued to improve. We evaluated him seven years later when he returned to the ED for breakthrough seizure activity. Detailed neurologic, neurobehavioral, and psychiatric evaluations were accomplished, including the Frontal Assessment Battery (FAB). His deficits included distractibility, impaired digit span, poor confrontation and generative naming, effortful spontaneous speech, and transcortical motor aphasia with frequent semantic paraphasic errors. Language comprehension was intact, and he answered simple questions with short responses. Psychiatric interviews of the patient and his mother revealed resolution of auditory hallucinations and paranoid delusions following recovery from the SIGSW.

Discussion Our testing revealed widespread deficits on the FAB. Neurobehavioral and language assessments suggested frontal lobe dysfunction, including transcortical motor aphasia. His psychiatric interview findings revealed similarity to findings report in the 1940s–50s after frontal leukotomy initially proposed by Egas Moniz.

Conclusion Frontal lobe damage produced cognitive and neurobehavioral impairments and improved neuropsychiatric symptoms such as hallucinations and psychosis in a SIGSW survivor.

Keywords Self-inflicted gunshot wound, Schizophrenia, Frontal battery assessment

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Background

Craniocerebral self-inflicted gunshot wounds (SIGSW) are fatal in approximately 90% of cases, usually before reaching a hospital. Only half of those individuals who survive long enough to reach the emergency department (ED) will survive [1]. These injuries have a far higher mortality rate than gunshot wounds to other portions of the body such as the heart and abdomen [1, 2]. Other factors related to poor patient outcome include high velocity bullets, dilated and unreactive pupils upon initial assessment, hypotension, hypoxia, coagulopathies, suicide attempt, advanced age, and the presence of perforating wounds [1].

Older men and individuals with psychiatric diagnoses are more likely than women to commit and complete suicide via lethal means such as SIGSW [3]. One study reported that nearly half of SIGSW survivors had a diagnosable psychiatric condition [3]. When using firearms in an attempted suicide, men are more likely than women to inflict injury to the craniocerebral and neck regions [3].

Craniocerebral SIGSW injuries are characterized based on the Matson classification criterion which ranges from grade I (mild) to grade IV (severe) [1]. In this case report, we present a gentleman with a Matson class IV craniocerebral SIGSW who survived with remarkable recovery of functional status 7 years post-injury. While it is not surprising that our patient was male, or that he carries a schizophrenia diagnosis, this case provides a rare opportunity to perform a physical, neurobehavioral exam, Frontal Assessment Battery (FAB), and psychiatric interview/assessment in a SIGSW survivor. Further, our report illustrates that both significant frontal lobe dysfunction and improvement of psychiatric symptoms may follow frontal lobe damage due to SIGSW. Since the 1930s when the Portuguese neurologist Egas Moniz demonstrated improvement in schizophrenia following destructive frontal lobe psychosurgery, there has been ongoing interest in the role of the frontal lobes in schizophrenia and other forms of treatment resistant mental disorder. Detailed consideration of such cases may enable us to better understand both the residual deficits and the potential areas of improvement in SIGSW survivors, many of whom suffer from psychiatric illness, and other individuals with acquired frontal lobe injury.

Case presentation

We report a 32-year-old, right-handed Caucasian male with paranoid schizophrenia at injury onset. Prior to developing schizophrenia, he was described as a hard-working, full-time employee and involved parent. At age 29, he was diagnosed with paranoid schizophrenia in accordance with DSM-5 criteria characterized primarily by auditory hallucinations, including five distinct, punishing voices [4]. This resulted in escalation of verbal aggression and two inpatient psychiatric hospital admissions. In the first admission, workup was notable for schizophrenia with the patient endorsing approximately two years of debilitating paranoid delusions and command auditory hallucinations. Family described a progressive marked decline in the patient's functioning due to worsening delusions that people, including law enforcement, were following, monitoring, and listening to his conversations. He became increasingly paranoid that strangers were "out to get him" and that a chip was implanted in his left ear to ensure others could "hear" his thoughts. The patient's presentation was further complicated by auditory command hallucinations with voices that frequently instructed him to harm or kill himself by either driving his car off the road, hanging himself or removing the chip that had been implanted in his ear.

During these admissions, the patient minimized his symptoms and falsified improvement to medical personnel. His family was not invited to participate in his care while hospitalized, resulting in the patient's medical noncompliance stemming from feelings of sedation making him unable to function at an acceptable level while under treatment. The distressing nature of the patient's psychotic processes ultimately led to his nearly fatal suicide attempt.

Immediately prior to the attempt, the patient was prescribed olanzapine but had not started taking the medication because it had not arrived from the mail order pharmacy. The patient informed his family of his planned suicide immediately prior to the SIGSW and was found in the woods by police after a 3-hour search. He had sustained a submental craniofacial SIGSW. On arrival to the Emergency Department (ED) the patient was intubated had a Glasgow Coma Scale (GCS) of 3 (E1, V1, M1) [5]. The initial non-contrasted computed tomography (CT) (not shown) revealed a large left frontal lobe intraparenchymal hemorrhage without evidence of a midline shift, metallic and bone fragments scattered in the frontal lobe, and multiple orbital and facial fractures.

Neurosurgery performed an emergent craniotomy for exploration and debridement of the gunshot wound area and evacuation of intracerebral hematoma with cranium closure requiring a graft secondary to the skull bone missing from the exit wound. Follow up imaging 7 years after injury reveals extensive frontal and moderate left temporal lobe encephalomalacia (Fig. 1).

Figure 2 depicts acute and chronic images of the skull surface. These images demonstrate the trajectory of the SIGSW, which entered under the chin near the midline, and exited anterior to the vertex, just to the right of midline.

After approximately a month of hospitalization, the patient was able to follow commands and was deemed stable for discharge to an inpatient rehabilitation facility,

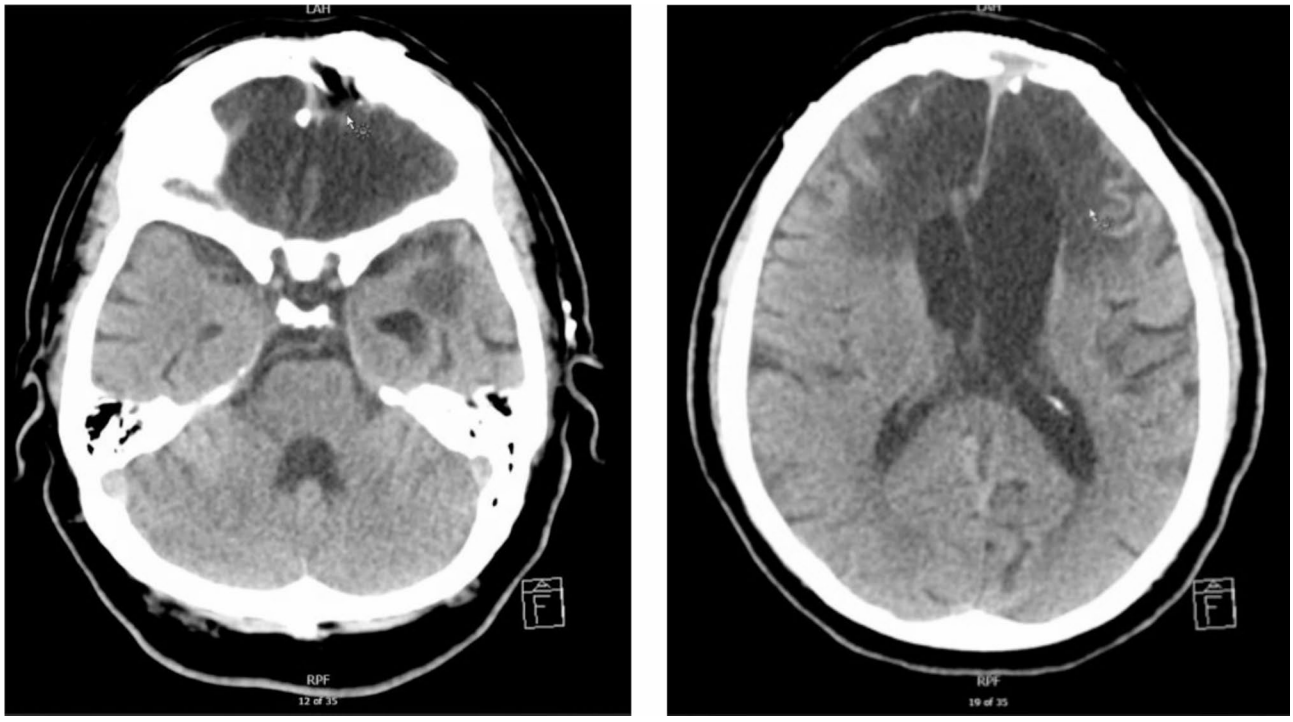

Fig. 1 Non-contrasted CT scan of the brain obtained 7 years after injury reveals encephalomalacia of the bilateral frontal and left temporal lobes

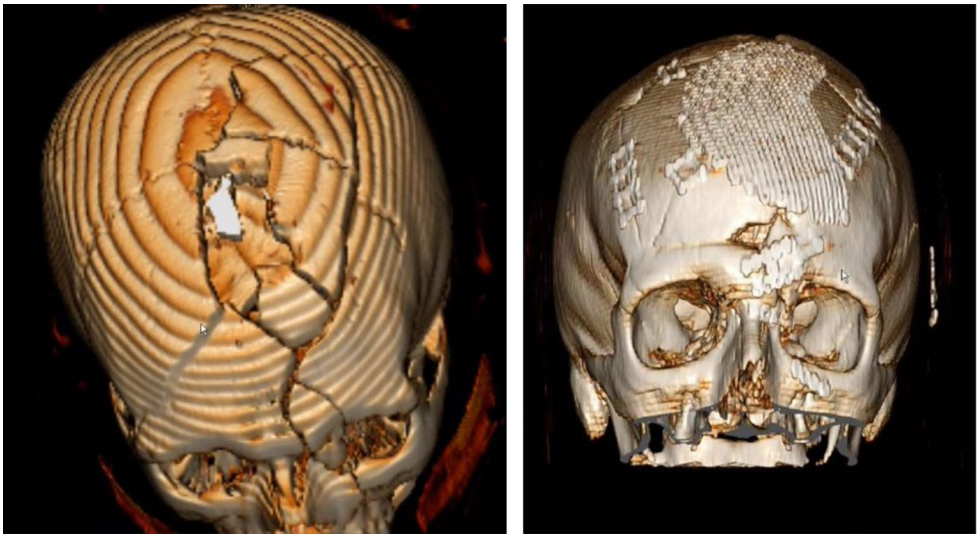

Fig. 2 Surface renderings of the skull are shown, based on bone window CT sequences performed acutely (left) and 7 years after the injury (right). The acute CT (left) reveals facial and skull fractures and a penetrating skull wound. These skull fractures and defect were repaired and a graft was placed on the skull in a series of operations (right), including open reduction and internal fixation of the facial fractures, cranialization of the frontal sinus, pericranial flap reconstruction of the skull defect, and titanium mesh cranioplasty

where poor insight, lack of safety awareness, and impulsivity requiring 24/7 supervision and redirection were noted. Several weeks later, the patient was discharged to home under the care of his mother with continued rehabilitation services. He remained under the care of his mother for the 7 years between discharge and the time of our initial encounter with him.

After his initial recovery, the patient developed a complex partial seizure disorder, for which we first examined the patient 7 years after the SIGSW. He was hospitalized for breakthrough seizures despite compliance with Levetiracetam 1500 mg twice daily, and examined in the acute, postictal period, several times during his hospitalization, and following his recovery to baseline mental status. Detailed history, examination, neurobehavioral

Fig. 3 On the Multiple Loops test (left), the patient was instructed to copy the image on the top left of the paper exactly as it was written and to repeatedly draw this image across the page. The patient drew one image with the correct number of loops in a horizontal orientation. On the sharp wave, square wave test (right), the patient was asked to continue the pattern of alternating square and sharp waves across the page in one continuous line drawing. The patient was able to copy the sequence with one error but was unable to continue the sequence across the page

examination, and frontal lobe evaluation were accomplished. Following his discharge, additional psychiatric phone interviews of the patient and his mother were conducted. In the acute post-ictal period, he was able to answer yes/no questions but unable to provide any relevant history. Therefore, this report details the findings obtained after his return to his baseline cognitive status, as affirmed by his mother, 7 years after the injury.

Deficits were noted on routine neurologic examination, including dysarthria, blindness in the left eye, and a left visual field deficit in his intact right eye. There was no significant motor weakness, but diffuse hyperreflexia, right Babinski, and bilateral lower extremity clonus were noted. Coordination was impaired in the right arm. Sensory function was preserved, and he could ambulate independently.

Neurobehavioral examination revealed normal arousal/alertness, but he was easily distracted during testing. His responses were at times delayed, and at other times impulsive. Language testing revealed impaired object naming, including body parts, and poor generative naming. Fluency was impaired but there was no apraxia of speech. Repetition was preserved. Thus, he was best classified as having residual transcortical motor aphasia without apraxia. Executive function assessment revealed perseveration on verbal tasks.

To further examine frontal lobe functions, the Frontal Assessment Battery (FAB) was administered [6]. He earned a score of four points out of a total of 18 possible points (severely impaired) on the FAB, earning points on question four (one point) which tests sensitivity to interference, and question six (three points) which tests for environmental autonomy. His aphasia significantly impacted his ability to perform question two. He displayed difficulties completing the Luria serial hand sequences task. On the multiple loops test, he produced a single copy of the prompt in the incorrect orientation, suggesting stimulus boundedness. When asked to draw an alternating sequence of sharp waves followed by square waves (alternating motor programs), he again copied the image. On both tasks, he copied the prompt without extending the pattern as instructed (Fig. 3). Other deficits were noted in planning and judgement.

Despite these substantial neurologic, neurobehavioral and FAB deficits, his mother provided a detailed account of neuropsychiatric recovery; she noted that he is doing remarkably well with complete resolution of his prominent schizophrenia symptoms. She confirmed that the patient no longer has auditory hallucinations, a consistent part of his schizophrenia for years prior to the SIGSW. In addition, he lacks symptoms suggestive of paranoia, depression, and lacks any suicidal ideation. His mood was reported and observed to be good natured, without evidence of pathological anger, agitation, or anxiety. In fact, he has no recollection of the SIGSW. When asked directly if he recalls completing a submental SIGSW, he responded that he never has, nor would he ever complete such an action. Despite improvement of his mental disorder, the patient suffers significant impaired in activities of daily living. He cannot handle his own finances because he compulsively spends money. He cannot cook or prepare his own meals because of short term memory impairment. He cannot organize his medications or drive to his own medical appointments. He can however still perform self-maintenance tasks such as brushing his own teeth or bathing himself. His mobility was persevered and his ability to interact with people whom he knows is improved since the SIGSW; however, he will never be able to live without a fulltime caregiver moving forward.

Discussion

The SIGSW damaged the bifrontal and left temporal lobes. It is likely there is damage to other structures that cannot be readily identified on the CT scan. The damage from his SIGSW caused significant disability for our patient who became unable to work or live unsupervised due to a large array of basic neurologic and cognitive deficits. Many neurological, behavioral, and neuropsychiatric functions were affected, as commonly encountered with frontal lobe and temporal damage [6, 7].

To characterize frontal lobe dysfunction, we relied on neurobehavioral examination as well as the FAB, a short, comprehensive assessment of frontal lobe function that has been externally validated as a bedside tool utilized in a hospital setting [6]. This assessment revealed the patient was unable to conceptualize abstract reasoning behind the relationship of two objects (e.g., the relationship between a bicycle and a train, or between a watch and a ruler). Some patients with frontal lobe dysfunction can draw concrete similarities; our patient's inability to draw even concrete conclusions may be partly related to his language processing deficiency [7]. He also has limited mental flexibility and verbal fluency with transcortical motor aphasia. Left frontal lobe injuries are particularly known to result in word production impairments [6, 7]. Interestingly, he was able to demonstrate some understanding of conflicting instructions when testing for sensitivity to interference, suggesting compensation for some aspects of frontal lobe dysfunction. It is also important to consider that patients with frontal lobe dysfunction lose their ability to focus attention and are often distractable, further impairing their ability to comprehend testing instructions [6].

Taking neurobehavioral and FAB findings into account, all three classical patterns of frontal lobe dysfunction were evident: medial frontal (e.g., apathy), lateral frontal (dysexecutive), and ventral/orbital frontal lobe symptoms (obsessively repeating the same word) [8]. Damage to the medial frontal lobe gaze centers likely impaired his eye movements and oculomotor control. Patients with coronal bullet trajectories often exhibit severe ocular injuries such as catastrophic orbital trauma, as in this case, which resulted in blindness in the left and impaired vision in the right eye [9]. Damage to the left optic nerve, chiasm, and tracts is likely, given preservation of the globe on CT. None of the above deficits are particularly surprising, given the severity of the trauma produced by the SIGSW. Emotional and personality changes secondary to SIGSW have been documented in the literature dating back to 1923 [10]. What is most surprising is the eradication of psychosis and hallucinosis, and the improvement in his longstanding psychiatric disorders, as reported by his mother and supported by repeated psychiatric interviews.

The history of frontal leukotomy is relevant to our discussion of this case. Dr. Egas Moniz was a neurologist who won the Nobel Peace Prize in 1949 for his reports that prefrontal leukotomies provided therapeutic benefit for patients experiencing symptoms of schizophrenia [11]. Prior to his work, popular schizophrenia treatments were of limited usefulness: hypoglycemic coma, malariotherapy, and electric convulsive therapy (ECT). The frontal lobes, left temporal lobe, and basal ganglia were, and still today are believed to be primary sites of neurologic derangement in schizophrenia; positive symptoms, such as prominent hallucinations and delusions, are strongly associated with abnormal dopaminergic signaling [12]. At the time, Moniz's approach to schizophrenia treatment was practiced by neurosurgeons across the world based on the evidence pointing to frontal lobe dysfunction as the primary etiology of disease [11]. We suspect that the damage seen in our patient produced therapeutic benefits similar to those encountered by Egas Moniz.

Surgeons and family members alike reported that schizophrenic patients who underwent prefrontal leukotomy no longer appeared distressed and had positive emotional experiences [13]. They believed strongly that the emotional and symptomatic benefits favored psychosurgery compared to the risks of morbidity and mortality from such operation [13]. Literature from the 1930s to 1950s illustrates that frontal leukotomy revolutionized treatment and was unanimously supported by hospital personnel in the mid-1900s for patients with chronic, untreatable psychotic disorders who lacked other effective treatment options [14]. Many of the studies regarding these procedures were primarily focused on recovery of premorbid psychiatric symptomatology, which contained documented findings similar to those observed in our patient [10]. However, the studies evaluating the utility of psychosurgery lacked control patients, objective outcome measures, and clear descriptions of patient characteristics, among other limitations [12]. Frontal leukotomy procedures are no longer performed for schizophrenia, and a review of current psychosurgical techniques is beyond the scope of this report.

Our patient underwent a self-induced frontal lobectomy secondary to SIGSW and experienced improvements in some aspects of personality, mood, and psychosis/hallucinosis. These changes and symptomatic resolution of hallucinations are almost certainly the result of his SIGSW, though surgical debridement may have contributed to this effect. The results largely resemble those noted by Moniz and his colleagues back in the 1930s, including complete or near-complete resolution of psychiatric symptoms, short term memory loss, impaired learning, inability to hold a job, impaired social cognition, and the need for constant supervision [13].

Although it is possible improvement of the patient's psychosis could in part be attributed to the neuromodulator changes that occur within the brain during seizure activity similar to ECT, this has not been studied in the literature. There is an established connection between patients with seizure disorders as well as schizophrenia. Some literature states that this associate is due to similar connectivity changes between neurons in the brain. However, the etiology of the seizure activity in this patient is secondary to structural brain damage. In addition, ECT impacts the neuronal synapses antagonistically in the

schizophrenic patient population [15]. It is not likely that the seizure activity in this patient would result in resolution of psychosis.

A recent review article noted neuromodulation and neurosurgical intervention remain desirable treatment options for treatment-resistant schizophrenia because they may (a) avoid adverse effects of antipsychotic medication, (b) eliminate concerns of noncompliance, and (c) offer treatment options beyond clozapine, the current option for treatment-resistant schizophrenia [16]. Current understanding suggests that prefrontal cortex dysfunction is involved in manifesting schizophrenic symptomatology, including hallucinations and delusions; however, the mechanisms are not well understood. This lack of understanding confounds ethical advances beyond Moniz's previous neurosurgical discoveries, since destructive psychosurgical interventions often produce deficits along with observed therapeutic benefits [16, 17]. Further research on neuromodulatory interventions has the potential to expand safety margins by targeting specific brain structures, while allowing the intervention to be discontinued if adverse effects are shown to outweigh therapeutic benefits.

After a detailed search through the literature, we believe this is the first report of SIGSW followed by improvement of hallucinations and delusions, possibly due to the ~95% mortality of such cases. A main limitation of this report is the absence of workup including lumbar puncture, urine drug analyses, vitamin deficiencies in addition to intelligence and personality assessments pre- and post-injury. A second limitation is that the patient previously falsified symptomatic improvement, and his own testimony is also hampered by substantial cognitive and language deficits. Also, support for symptomatic improvement largely derives from the account given by his mother, his primary caretaker. Given her 7-year period of close observation, however, we considered her account likely to be valid.

The symptomatic improvement seen in this case report contributes to a growing paradigm emerging in the literature of neurologic injury. Although the number of devastating neurologic injuries are largely the majority, there are cases like this one in which the neurologic outcome for the patient can be positive [18]. A recent study revealed that there can be improvements to personality and behavior following brain injury, when mapping brain lesions, these positive impacts primarily occur when impacting the bilateral frontal polar regions as seen in our case [18].

Conclusion

In conclusion, extensive neurobehavioral testing was performed in a patient with a significant craniofacial SIGSW who is doing remarkably well 7 years later. This rare opportunity allowed for observation of deficits experienced by a survivor of SIGSW, and to collect reliable reports of his behavior. Detailed clinical assessment revealed deficits in attention, impulse control, memory, speech and language, planning, judgement, motor programming, and reflexes. In addition to these many neurobehavioral deficits, however, our patient saw complete resolution of all prominent schizophrenia symptoms, an outcome resembling the controversial work and observations of Dr. Moniz many years ago. Drastic and widespread brain damage, as observed in this case, may not be necessary to achieve therapeutic benefits, and we certainly do not endorse or condone SIGSW as a form of schizophrenia treatment. However, this case supports the possibility that nondestructive frontal lobe interventions such as neuromodulation may reveal new therapeutic options for individuals with severe or treatment-resistant schizophrenia.

Abbreviations

SIGSW	self-inflicted gunshot wounds
ED	Emergency Department
FAB	Frontal Assessment Battery
GCS	Glasgow Coma Scale
CT	computed tomography
ECT	electric convulsive therapy

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Author contributions

SS conducted neurologic testing and psychiatric examination. MK analyzed patient psychiatric data and history. JA analyzed and interpreted patient data regarding the neurologic disease. All authors read and approved the final manuscript.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

Approval for participation in this manuscript was provided by the patient and his primary caregiver. Informed consent was obtained from the patient and his legal guardian.

Consent for publication

Informed consent for publication was obtained prior to the creation of this manuscript. Informed consent was obtained from the patient and his legal guardian.

Competing interests

The authors declare no competing interests.

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