

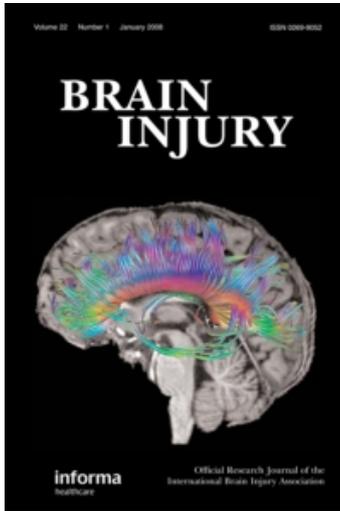
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## CASE STUDY

# Executive dysfunction in a case of transoral-frontal self-inflicted gunshot injury

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### Abstract

**Objective:** This study presents an in-depth neuropsychological study of the consequences of a survivable transoral penetrating gunshot injury resulting in lesions to frontal lobe structures.

**Design:** A case study of a woman who sustained a self-inflicted transoral gunshot injury that resulted in focal pathology to the frontal lobes.

**Methods:** Neuropsychological examination with a comprehensive battery of standard tests.

**Results:** Striking contrasts in performance were found on tests of executive function relating to planning and problem-solving ability, with marked impairment on a problem-solving task involving an action plan. Intact performance was seen on tests of memory.

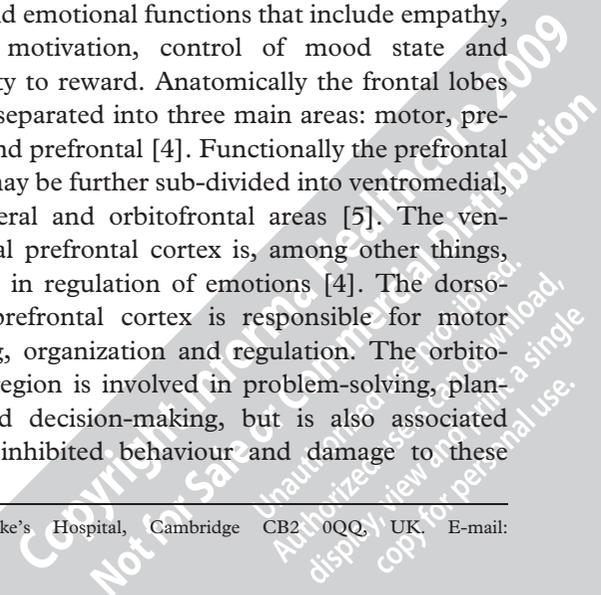
**Conclusions:** This case study demonstrates that transoral gunshot injury to the brain is survivable, though selective executive dysfunction may remain.

**Keywords:** Penetrating head injury, transoral, gunshot wound, executive dysfunction

### Introduction

While transoral penetrating head injuries have occasionally been reported, the literature lacks an in-depth neuropsychological study of the consequences of a survivable transoral penetrating injury resulting in lesions to frontal lobe structures. Notable single-case studies have documented neuropsychological sequelae in patients who have sustained a penetrating frontal lobe injury by other means, such as the famous patient Phineas Gage who incurred major behaviour changes [1] and the patient NA who suffered a paranasal penetrating head injury that damaged the mamillary bodies and the thalamus and left him with marked memory impairment [2]. One case report describes improvement in mood state following a transoral frontal lobe injury resulting from a suicide attempt with a gun [3], but no formal neuropsychological test findings were presented.

The frontal lobes have been associated with a wide range of functions, ranging from cognitive domains such as working memory, speech expression, planning, problem-solving and behavioural control to social and emotional functions that include empathy, insight, motivation, control of mood state and sensitivity to reward. Anatomically the frontal lobes may be separated into three main areas: motor, pre-motor and prefrontal [4]. Functionally the prefrontal cortex may be further sub-divided into ventromedial, dorsolateral and orbitofrontal areas [5]. The ventromedial prefrontal cortex is, among other things, involved in regulation of emotions [4]. The dorsolateral prefrontal cortex is responsible for motor planning, organization and regulation. The orbitofrontal region is involved in problem-solving, planning and decision-making, but is also associated with disinhibited behaviour and damage to these



structures often results in disinhibition, swearing, hypersexuality and poor social behaviour [4].

The topic of the functions of the frontal lobes is huge and the reader is referred to Miller and Cummings [4] and Stuss & Levine [5] for further reviews.

An earlier study of a similar type of injury [6] reported 11 cases of self-inflicted sub-mental and transoral gunshot wounds. One of the 11 cases died. Of the remaining 10 patients, three were reported as having made a full recovery, three had mild expressive dysphasia and the remaining four had anosmia as a residual deficit. One of the 10 cases was reported as being left with a 'moderate cognitive disorder', but no formal neuropsychological test data were reported.

This study reports a detailed neuropsychological investigations of a patient who survived a self-inflicted transoral gunshot wound that gave rise to focal pathology to frontal lobe structures. The goals were to document the presence or absence of any memory loss and to ascertain what, if any, executive dysfunction might be found. To the authors' knowledge, this is the first in-depth report of the neuropsychological profile associated with such an unusual form of penetrating brain injury.

### Case history

The patient, GS (who gave written permission for this report to be published), is a right-handed woman in her mid-40s who had a history of alcoholism, drug addiction, depression, previous suicide attempts and was positive for Hepatitis C. She was well-educated, having obtained an undergraduate degree in music in the early 1980s. On an adult reading test, her score was commensurate with a high average estimated pre-morbid intelligence quotient (an IQ of 117) [7].

GS presented to Addenbrooke's hospital in July 2007 with a Glasgow Coma Scale Score of 10, following a self-inflicted transoral gunshot injury where the entry wound involved the hard palate. CT demonstrated extensive, complex comminuted anterior skull base fractures, and haemorrhagic contusions of the anteromedial frontal lobes, with residual bony fragments and metallic shrapnel (Figure 1). There was also evidence of a bullet remnant high in the left parietal area (Figure 2).

Following a period in intensive care with ventilation and intracranial pressure monitoring, by November 2007 GS made a remarkable recovery from her physical injuries. Her only physical disability was a mild right-sided weakness with a foot drop. She was fully mobile, cooperative, eating well and self-caring on the ward. In the first few weeks of

her stay as an inpatient, there was evidence of disinhibition, in the form of swearing at staff and sexually inappropriate behaviour. This largely resolved and she retained relatively good insight into her situation. For example, she appeared to recognize that the suicide attempt was 'wrong' and she showed some degree of remorse over this. Psychiatric examination in October 2007 did not reveal any pervasive depression, psychotic symptoms or suicidal ideation. She was prescribed 2.5 mg of Olanzapine, which was administered daily. As GS was a foreign national, there were sparse details of her earlier life, although there were suggestions she had been abused as a child and may have been working as a prostitute just prior to her suicide attempt. Because of her status as a foreign national,



Figure 1. Axial CT image showing contusions and fragments of bone and bullet in anterior frontal region.

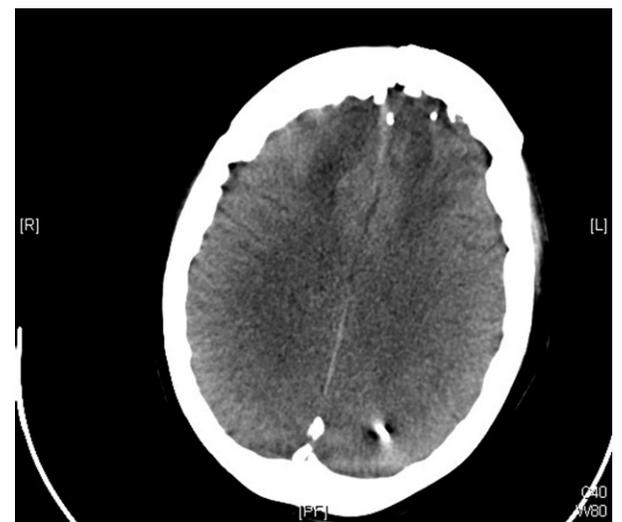


Figure 2. Axial CT image showing fragments of bullet in left high parietal region.

Table I. Summary of neuropsychological assessment.

Neuropsychological test	Raw score	Level of functioning
<b>Memory</b>		
AMIPB prose recall immediate [21]	45/56	75th–90th percentile
AMIPB prose recall delayed	42/56	75th–90th percentile
Rey Complex Figure Copy (3 min delay)	26/36	82nd percentile
Rey Complex Figure Copy (30 min delay)	26/36	82nd percentile
WAIS-III Digit Span	20/30	Average
Recognition Memory Test Faces [22]	42/50	Low average
Recognition Memory Test Words [22]	48/50	Above average
<b>Verbal skills</b>		
NART estimated pre-morbid IQ [7]	117	High average
Graded Naming Test [23]	26/30	95th percentile
WAIS-III Comprehension	30/33	Above average
WAIS-III Similarities	29/33	Above average
WAIS-III Arithmetic	18/22	Above average
Phonemic verbal fluency (FAS)	20	Moderate impairment
Categorical verbal fluency (animal naming)	15	Mild impairment
<b>Non-verbal skills</b>		
WAIS-III Block design	28/68	Low average
Rey Complex Figure Copy	36/36	Normal
VOSP Object Decision [24]	18/20	Normal
VOSP Silhouettes	20/30	Normal
WAIS-III Digit Symbol Coding	43/133	Moderate impairment
<b>Executive function</b>		
Brixton Spatial Anticipation [22]	7 errors	High average
Hayling Inhibition Test [22]	5	Average
Modified Card Sorting Test	5 categories	Mild impairment
BADS Rule Shift	4	Normal
BADS Action Program	0	Marked impairment
BADS Key Search	1	Moderate impairment
BADS Temporal Judgement	1	Moderate impairment
BADS Zoo Map	4	Normal
BADS Modified Six Elements	3	Normal
BADS Overall Score (age corrected)	73	Low average

AMIPB = Adult Memory and Information Processing Battery; WAIS = Wechsler Adult Intelligence Scale; NART = National Adult Reading Test; VOSP = Visual Object and Space Perception; BADS = Behavioural Assessment of the Dysexecutive Syndrome.

and in view of the fact that she had smuggled a gun into the country, she was deported from the UK following discharge from hospital, thus excluding the possibility of detailed follow-up.

Detailed neuropsychological testing was carried out in October 2007, ~10 weeks after the injury, at which time GS complained of few cognitive symptoms. A summary of her neuropsychological test scores is given in Table I.

On memory testing, GS performed very well on immediate and delayed recall of a short story, short-term and delayed recall of a complex figure. Her scores were well above average. On recognition memory for faces and words, she scored in the low-average range and her forward and backward digit span scores were within normal limits. Verbal skills were generally intact, in the form of good scores on tests of picture naming, verbal reasoning and oral arithmetic, although both phonemic and categorical verbal fluency was impaired. Non-verbal skills, in terms of performance on perceptual-motor tasks and visuospatial reasoning tests, were also preserved,

although GS did show moderate impairment on a timed digit-symbol coding task [8].

On some tests of executive function GS performed well. On the Brixton test (a test of spatial anticipation), she scored in the high-average range. On a test of verbal inhibition (the Hayling test) her score was average. She was well able to follow a rule and switch the rule when required (Rule Shift cards from the Behavioural assessment of Dysexecutive Syndrome (BADS) [9]. She was only mildly impaired on the Modified Card Sorting test (MCST) [10]. On a demanding test of planning (Zoo Map from the BADS) she achieved the maximum score. Her score was in the normal range on the modified six elements task, also from the BADS, where she was required to complete six tasks in 10 minutes following certain rules. These various executive function test scores were in marked contrast to her performance on the Action programme test from the BADS. In this problem-solving task, she was required to follow certain rules and to work out how to extract a cork from a tube using some pieces of equipment.

She looked at the materials and seemed to have no idea at all how to proceed. She picked up the metal hook, looked at it and put it down. She seemed unable to decide what to do next. She could not attempt any of the steps. She was then given the first prompt. This did not help. She was then given another prompt, but this did not help either. She failed to respond to any of the prompts and scored zero. This was in striking contrast to the Zoo Map, an apparently more demanding planning task, where she scored the maximum number of points.

GS also had difficulty in Temporal Judgement (estimating how long it would take to complete certain routine tasks) and how to plan a search of a field in which she was asked to imagine she had lost her keys.

## Discussion

This study has reported an unusual case of self-inflicted transoral gunshot injury that led to focal pathology to the orbitofrontal cortex. On neuropsychological testing, striking contrasts were found on tests of executive functioning. Memory, language and visuoperceptual functions were largely preserved, but selective deficits were found on some tests of executive function.

The clinical outcome for the patient was relatively good, given the severity and potentially lethal nature of the injury that she sustained. This case supports the observations made by Kriet et al. [6], who reported a surprisingly good outcome in their series of 11 patients with sub-mental and transoral penetrating brain injuries. The fact that the bullets fragmented and missed critical structures such as major blood vessels and optic nerves may have contributed to the good clinical recovery shown by GS. The absence of significant memory impairment may reflect the sparing of basal forebrain structures, involvement of which has been shown to compromise memory functioning in earlier penetrating missile injury studies [11]. The impairment seen on tests of digit-symbol coding and verbal fluency may reflect the executive component of these tasks (particularly mental flexibility and strategy formation).

The selective deficits shown by GS on specific executive function tests of planning and problem-solving are consistent with observations in cognitive neuroscience that link the primate orbitofrontal cortex with representations of outcomes of actions and their subsequent impact on behavioural control [12, 13]. As expected, given the nature of her injury, she showed impaired performance on some executive tests; her fluency scores were down and her performance on the MCST was mildly impaired, yet

she was able to complete other executive tests without error. Her worst performance was on the Action Plan task. Why was she so poor at this? It is possible that there was faulty processing of feedback information during this task related to a possible specific role of the orbitofrontal cortex for this type of cognitive activity [14]. Although formal feedback was not provided, implicit feedback in the form of prompts were provided at each step. GS did not benefit from any of the cues. Another alternative explanation for her poor performance is that GS was unable to plan and initiate the steps involved in the task despite good planning on the Zoo Map and Modified Six Elements sub-tests. The reason for this could have been due to the presence or absence of written instructions. All the tests she did well on included written instructions regarding the rule(s) she was supposed to be following, whereas the tests she did badly on (although the verbal instructions were clear) did not include a written record of the rules that could be checked during the test. As such, the failed tests were ones where the participant was given a scenario in which s/he had to self-generate a response, keeping a set of constraints in mind. Maybe GS's planning problems only became apparent when she could not keep track of and importantly could not check the rules of a specific test? This is also consistent with her relatively poor Verbal Fluency performance. A third alternative is that the problem to be solved in the Action Plan was of a different nature than the problem to be solved in the Zoo Map task. In 1997, Zelazo et al. [15] proposed a problem-solving framework describing distinct phases of executive functioning that are temporally and functionally distinct. These are (i) problem representation, (ii) planning, (iii) execution and (iv) evaluation. In the Zoo Map and Modified Six Elements sub-tests all the components of the problem are present but need to be organized in a particular way and GS was able to complete all four stages of the framework. In the action plan sub-test, the person needs to work out that water is required to make the cork float to the top of the tube and then decide how to achieve this. An internal schema or representation is required. In the Action Plan task, GS either failed to recognize this as a problem (failure at stage i) or failed to identify the steps required to solve the problem (failure at stage ii). The Action Plan is a different kind of problem-solving task altogether from the Zoo Map and double dissociations can be found in clinical practice [16]. The various explanations are not mutually exclusive and GS's failure on specific sub-tests could be due, in part, to all three reasons.

People with orbitofrontal damage are also likely to show poor social behaviour, but GS was, after the first few weeks, behaving in a reasonably

appropriate manner. The lack of behavioural problems could have been due, in part, to the fact that she was in a constrained, structured ward environment and had no access to alcohol during her stay in hospital. It is not known, of course, what her behaviour was like once she was discharged from hospital and deported from the UK.

The selectivity of the patient's executive function deficit is unlike that seen in association with alcohol or drug abuse [17–20]. For example, people who have abused alcohol may have memory and visuo-spatial difficulties, whereas GS performed within the normal range on these tests.

Although GS did not report any evidence of depression at the time of examination, ~3 months after the injury, it is too early to say whether her case represents a further example of self-inflicted leucotomy. The only one similar case previously reported [3] might suggest that this patient's depression and suicide risk would improve, but it is difficult to make a precise prediction in this respect. GS's long-term prognosis is unclear as follow-up was not possible due to her unavailability. However, it is worth noting that during this 3 month period the patient herself was aware of a significant improvement in her mood state compared to her pre-injury psychological functioning.

In conclusion, the 'clinical pearls' that emanate from this case study are that transoral gunshot injury is survivable, that executive dysfunction may remain, but that it can be highly selective.

**Declaration of interest:** The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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