Fairway to fractures: Income inequality and violent crime as the driving factors for golf club-related assaults – a case series of 21 compound skull fractures

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Background. Golf club-related traumatic brain injuries are an uncommon occurrence in adults, and the use of golf clubs as a weapon of interpersonal assault resulting in compound skull fractures is rare.
Objective. To present a case series of golf club-related compound skull fractures in adults secondary to assault, representing the largest study of this entity to date.
Methods. A retrospective analysis was performed of a prospectively maintained database for patients admitted to Tygerberg Academic Hospital in Cape Town, South Africa, with golf club-related compound skull fractures between 1 January 2018 and 31 December 2021. Data on demographic details, computed tomography brain image findings, presenting Glasgow Coma Scale, surgical operative notes, septic complications and outcomes at discharge were collected.
Results. A total of 21 patients were included. The majority were male (95.2%) and the mean age was 32.6 years. Fractures were most commonly seen in the frontal bone (*n*=9), followed by parietal (*n*=8), temporal (*n*=3) and occipital (*n*=1) bones. Depressed skull fractures were the most common type of injury, and local pneumocephalus was present in the majority of patients. The mean presenting Glasgow Coma Scale was 14, and most patients had no focal neurological deficits. Surgical debridement was required in the majority of patients, with a high rate of septic complications (33.3%). However, most patients had good neurological outcomes at discharge, and the mean length of stay was 11.9 days.
Conclusion. This study highlights the potential dangers of golf clubs as a weapon of interpersonal assault, and the need for prompt and appropriate management of compound skull fractures to reduce the risk of complications.

Keywords: golf club, assault, head trauma, skull fracture

S Afr Med J 2024;114(11):2268. https://doi.org/10.7196/SAMJ.2024.v114i11.2268

Golf-related traumatic brain injuries are mostly encountered in children when they unintentionally enter the swing zone of a golf club, with reported case fatalities.[1-5] Adult golf-related head injuries secondary to club or ball strikes are uncommon, and the use of golf clubs as a weapon of interpersonal assault resulting in compound skull fractures is rare.[6] The golf club has several factors that make it a particularly dangerous weapon. These include properties inherent in its design, as this maximises the velocity of a weighted club head. The club head has a leading edge that imparts force to a small surface area, resulting in more severe damage to the skull.[7] The injury pattern caused by a golf club produces the conditions known to be risk factors for septic complications, such as dural injury and free bone fragments.[8,9] Additionally, the surface of the club head is soil-contaminated, increasing the risk of septic complications.[10] We report a case series of golf club-related compound skull fractures in adults secondary to assault, which represents the largest study of this entity to date.

Methods

A retrospective analysis was performed of a prospectively maintained database for patients admitted to Tygerberg Academic Hospital in Cape Town, South Africa (SA), with golf club-related compound skull fractures between 1 January 2018 and 31 December 2021. Admission criteria were: presence of intracranial haemorrhage or contusions that required neurological observations; repeat imaging or surgical evacuation; significant fracture fragment depression; dural violation or contaminated wounds that required surgical debridement; and fracture elevation. Data were captured on a custom designed database (Research Electronic Data Capture (REDCap)) after approval from the institutional and Stellenbosch University Health Research Ethics (HREC) board, who granted a waiver of consent (ref. no. S20/04/088). The trial was registered with the National Health Research Database (ref. no. WC_202006_044). This case series has been reported in line with the PROCESS Guideline.[11] Statistical analysis was performed with the aid of SPPS version 27 (IBM Corp., USA), and descriptive statistics were calculated.

Patients were included in the study if they were adults (>18 years) and identified with the diagnosis of compound skull fracture due to assault with a golf club. This was determined by reviewing admission data on mechanism of injury and computed tomography brain (CTB) images. The parameters evaluated and recorded were data on demographic details, CTB findings, specifically the location of the fracture, degree of depression or elevation of fracture fragments, presence of pneumocephalus, either local in the immediate fracture area or distant to the site of fracture, injury to the air sinuses and dural venous sinuses and underlying intracranial pathology, presenting Glasgow Coma Scale (GCS) and presence of focal neurological deficit, surgical operative notes, specifically presence of dural injury and operative time, septic complications as well as length of stay (LoS) and outcomes classified according to Extended Glasgow Outcome Scale (GOSE) at discharge.

The standard practice for management of compound skull fractures in our unit is prompt primary wound care, specifically cleaning and suturing under local anaesthesia, prophylactic administration of a broad-spectrum antimicrobial, anti-tetanus toxoid, prophylactic anti-epileptic drugs and early definitive surgical debridement and dural repair, if needed. The standard antibiotic regimen employed is a single dose of 2 g cefazolin via intravenous infusion. A standard daily review during admission, and documentation of neurological outcome at discharge and at outpatient review at 6 weeks, were performed.

Results

A total of 21 patients were included with golf club-related compound skull fractures secondary to assault. The details of the patients are summarised in Table 1, and Figs 1 - 3.

The mean age of the patients was 32.6 years (range 20 - 60 years, standard deviation (SD) 9.96). The majority (95.2%) presented with depressed skull fractures (*n*=20). The mean (SD) depth of bony depression was 13.05 (4.37) mm. Elevated fracture fragments were seen in 4 patients, and the mean (SD) distance of elevation above the outer table of the skull was 13.4 (4.56) mm, as demonstrated in Figs 4 - 6. Local pneumocephalus was present in 16, while distant pneumocephalus was present in 8, with 1 having tension pneumocephalus (Fig. 2). Five had superior sagittal sinus injury, 2 involving the anterior third, 2 involving the middle third and 1 involving the posterior third of the sinus.

The mean (SD) presenting GCS was 14 (2.23), and the majority had no focal deficit (*n*=16). Two patients presented with a left-sided hemiplegia, 1 had a right-sided hemiplegia and aphasia, 1 had a right-sided hemiplegia only and 1 patient had only aphasia, all with intracerebral haematomas in locations congruent with their neurological deficit. Surgical intervention was indicated and performed in 19 patients (90.4%), with 57.1% (*n*=12) having a dural breach. The mean (SD) time to surgery was 108.2 (SD 81.16) hours.

All patients had complete follow-up data. The sepsis rate was 33.3% (*n*=7). Fig. 7 depicts the type of septic complications, all of which required surgical intervention and intravenous antimicrobial treatment. Fig. 5 depicts an example of a brain abscess. The majority of patients had good neurological outcomes at discharge, with GOSE of 7 and 8 (*n*=16), and the mean (SD) LoS was 11.9 (10.21) days, of which 21.3 days were in those with septic complications (SD 12.26) (Fig. 8) and 7.2 days (SD 7.13) in those with no septic complications.

Discussion

Golf club-related head injury in South Africa

In SA, assault is a common mechanism of injury. SA is one of the most violent countries in the world, as evidenced by high homicide and serious assault rates, especially among young adult males residing in Cape Town's townships.[12-14] Blunt head trauma makes up 70% of blunt force trauma homicides in the Cape Town Metropole.[13,15] This is amplified by prevalent poverty, substance abuse and gang-related violence, which are known risk factors for serious assault.[12,13,16,17] Although still uncommon, golf clubs are emerging as a contemporary cause of head injury,[18] but are mainly accidental, and in a predominantly paediatric population residing in well-developed countries,[1,3,4,6] with no previous reports on assault-related golf club head injuries in adults.

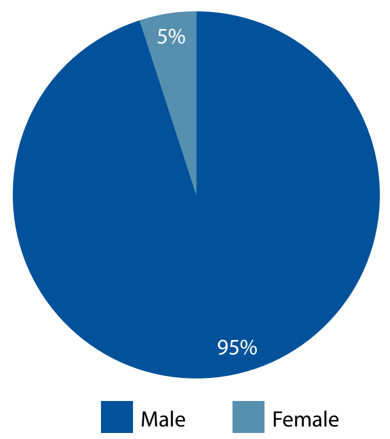

Fig. 1. Gender distribution.

Table 1. Demographics, clinical details and outcomes of 21 patients with compound skull fractures due to assault with a golf club

Age (years)	Sex	Admit GCS	Location, laterality	Dural injury	Sinuses involved: Dural	Sinuses involved: Air	Pneumocephalus: Local	Pneumocephalus: Distant	Sepsis	Surgery	LoS (days)	GOSE
25	M	15	L parietal	No	Sagittal	No	No	No	Yes	Yes	35	4
28	M	14	L parietal	Yes	No	No	Yes	Yes	No	Yes	7	8
27	M	11T	L temporal	Yes	No	No	Yes	No	No	Yes	8	6
43	M	15	R frontal	Yes	No	Frontal	Yes	No	No	Yes	4	8
39	F	15	R frontal	Yes	No	No	Yes	No	Yes	Yes	12	8
26	M	15	L parietal	Yes	Sagittal	No	Yes	No	No	Yes	1	8
42	M	15	R frontal	Yes	No	No	Yes	Yes	Yes	Yes	26	8
24	M	11	L temporal	No	No	No	No	No	No	Yes	7	6
23	M	15	R frontal	Yes	No	Frontal	Yes	Yes	Yes	Yes	8	8
29	M	15	R parietal	Yes	No	No	Yes	No	No	Yes	3	8
26	M	12	L parietal	No	No	No	Yes	Yes	Yes	Yes	12	6
32	M	6T	R frontal	Yes	Sagittal	Frontal	Yes	Yes	Yes	Yes	36	7
29	M	15	L temporal	Yes	No	No	Yes	No	No	Yes	20	8
30	M	15	L parietal	No	No	No	No	No	No	Yes	1	8
33	M	15	L frontal	Yes	No	No	Yes	Yes	No	Yes	5	8
33	M	14	R parietal	No	No	No	No	No	Yes	Yes	20	8
34	M	15	R parietal	Yes	No	No	Yes	Yes	No	Yes	13	5
28	M	15	R frontal	No	No	No	Yes	No	No	No	14	8
53	M	15	L frontal	No	No	No	No	No	No	Yes	4	8
20	M	15	R occipital	No	Sagittal	No	Yes	No	No	Yes	4	8
60	M	14	R frontal	No	Sagittal	No	Yes	No	No	No	10	8

GCS = Glasgow Coma Scale; LoS = length of stay; GOSE = Extended Glasgow Outcome Scale; M = male; L = left; T = intubated; R = right; F = female.

This may be because worldwide accessibility to the sport and its equipment is limited owing to exclusivity[19-21] and cost.[22] SA has >300 000 registered local golfers,[23] and it also attracts a growing number of golfing tourists.[24] This setting of well-developed golf infrastructure coupled with a high background prevalence of serious assault is a unique set of circumstances, likely related to SA having the highest income inequality in the world, as measured by the Gini coefficient.[25] In SA, 55.5% of the population (30.3 million people) lives at the poverty line,[26] yet countrywide there are >400 golf courses and 70 golf estates.[21,23,27]

According to data published by the World Bank, the United Nations Office on Drugs and Crime and the Royal and Ancient Golf Club (R&A), SA ranks among the top 10 countries in the world in terms of the highest number of golf courses,[28] but has the second-highest serious assault rate,[29] and a significant discrepancy in income inequality compared with other nations where golf is popular (Table 2).[30] The reasons for income inequality are complex and multifactorial. The economic legacy of the Apartheid system of government remains; however, youth unemployment and labour market instability have been shown to be more prominent drivers of remaining inequality in the post-Apartheid era.[31]

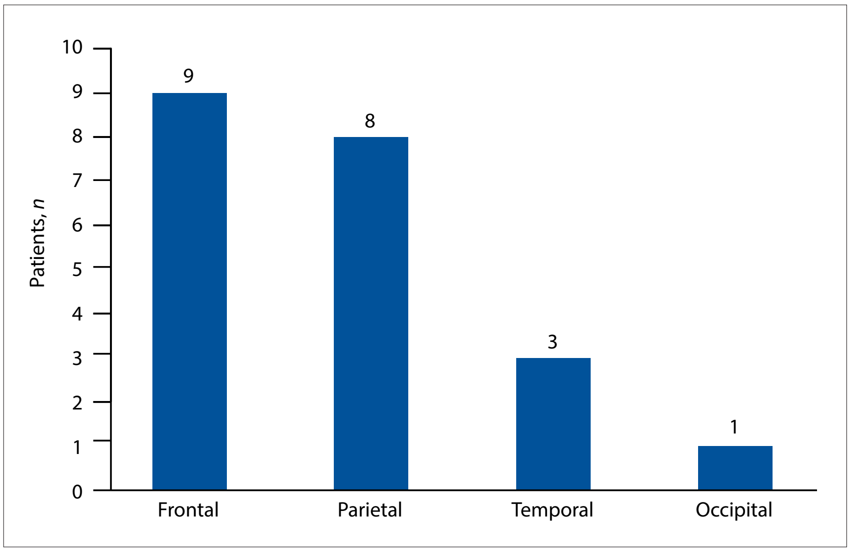

Fig. 2. Fracture location.

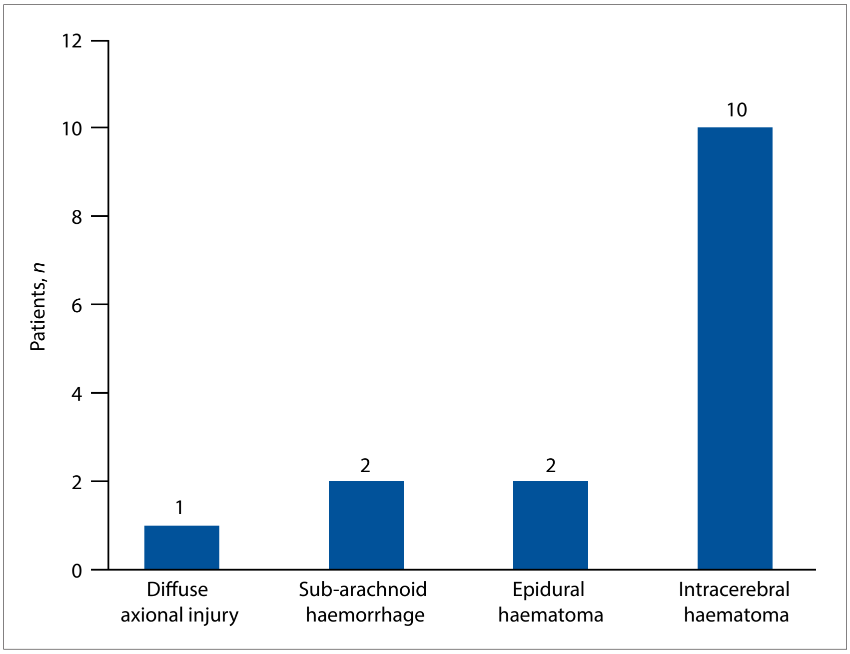

Fig. 3. Intracranial injuries.

Physics principles and injury pattern

The characteristic injury pattern seen in our series can be explained by the physics principles that are used in the design of golf clubs, which aim to maximise the transfer of kinetic energy to a small surface area. The most important principles are moment of inertia (MOI), elasticity and aerodynamics. The MOI is a measure of the resistance to rotational acceleration. Increasing the MOI of the clubhead helps to minimise twisting during collision, reducing the loss of kinetic energy at oblique angles of impact.[32,33] Elasticity in collisions is a measure of the amount of original kinetic energy restored to an object after it impacts with another, and is expressed as the coefficient of restitution (COR). The more elastic a collision, the more energy is transferred.[34]

Golf club heads are made of advanced composites that are both durable and elastic, such as titanium and carbon fibre, with weight distributed peripherally in the club head to maximise MOI.[33] Aerodynamically, the club head is streamlined to reduce turbulence caused by airflow.[35] The club head is attached to a flexible shaft, mounted with a rubber grip, that requires two hands to swing effectively. These factors combined result in the club head being capable of reaching speeds of 145 - 160 km/h in the hands of amateur golfers,[36] with minimal dissipation of kinetic energy at impact, resulting in a focused application of force. This explains the low prevalence of diffuse brain injury and higher number of patients with focally localised injuries in our series.

Additionally, the vertical angle at which the club head is moving prior to impact, known as the angle of attack, influences the collision characteristics with the object it impacts. A steep angle of attack, or downward blow, can cause the leading edge of the golf club to dig into the surface of impact, whereas a shallow angle of attack, or upward blow, can result in a skimming collision. In our series of compound skull fractures, most patients presented with significantly depressed fractures (mean depth of 13 mm), and fewer with elevated fracture fragments, which is likely accounted for by the variations in angle of attack. The lack of right and left disparity in location of the fractures may be due to the need to grip the club with two hands to swing effectively, negating the impact of the hand dominance of the assailant seen in other cranial assault patterns.[37-39]

Septic complications

Compound skull fractures result in the exposure of underlying intracranial contents to commensal scalp organisms

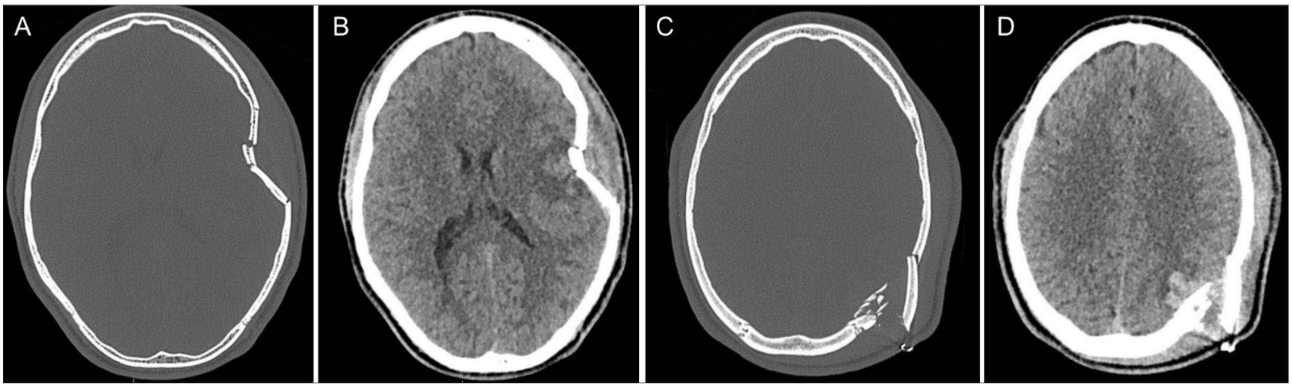

Fig. 4. Examples of depressed and elevated skull fractures. A: Axial computed tomography brain (CTB) bone window demonstrating the depressed fracture. B: Axial CTB demonstrating the cranial injury (contusion). C: Axial CTB bone window demonstrating the elevated skull fracture. D: Axial CTB with an elevated bone fracture and intracranial haemorrhagic contusion.

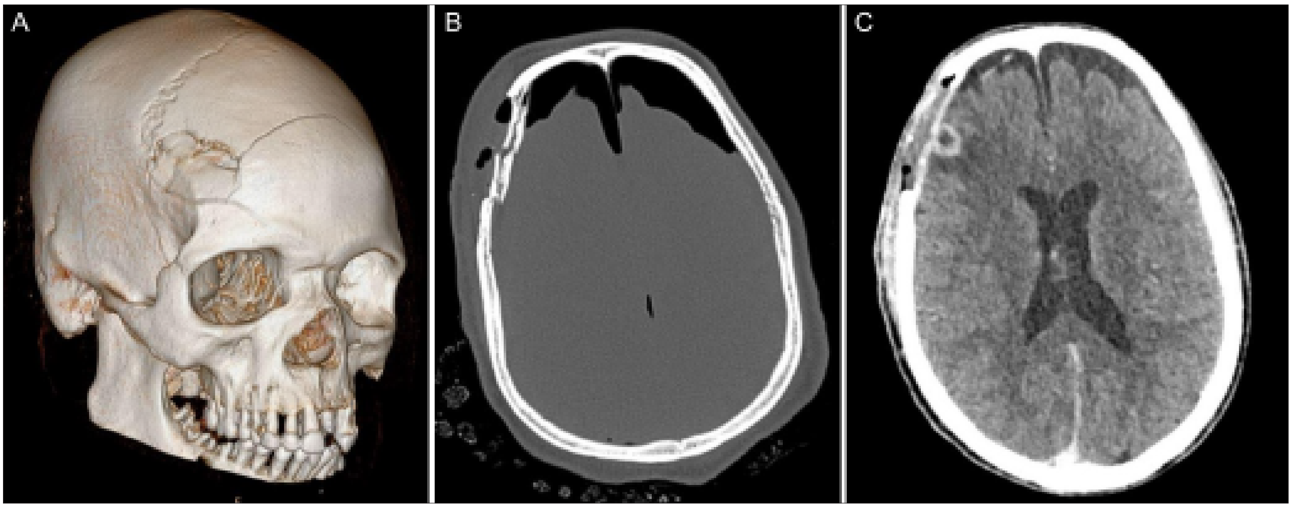

Fig. 5. A: Three-dimensional reconstruction of computed tomography brain (CTB) images demonstrating a depressed frontal skull fracture. B: Pre-operative CTB (bone window) axial image showing the Mount Fuji sign associated with tension pneumocephalus. C: Postoperative CTB (soft-tissue window) axial image demonstrating craniectomy and new rim enhancing lesion indicating abscess formation.

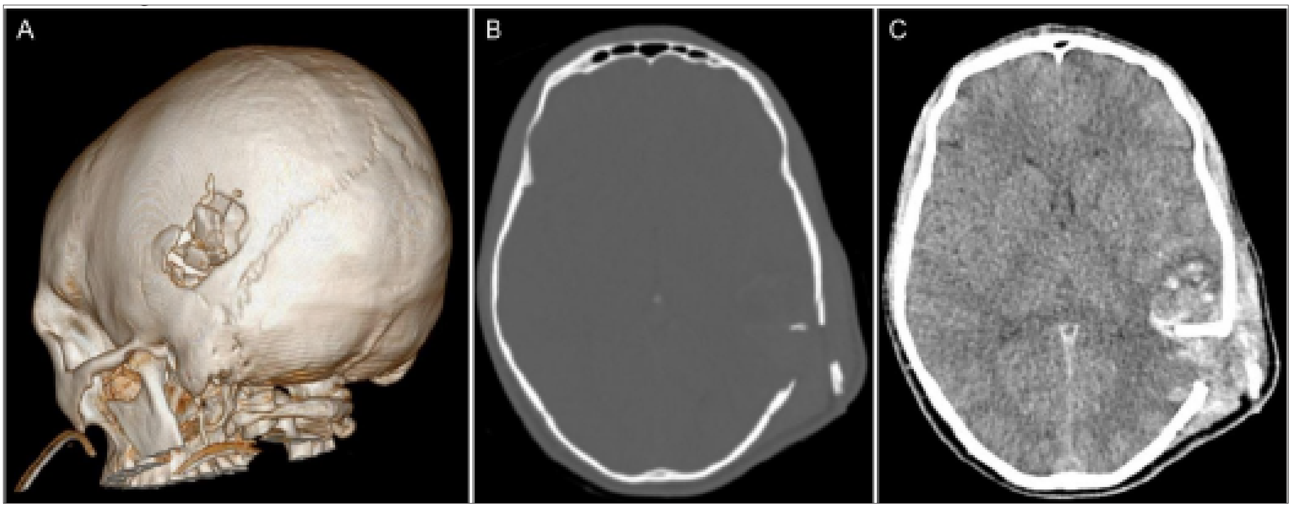

Fig. 6. A: Three-dimensional reconstruction of a computed tomography brain (CTB) scan demonstrating a compound depressed fracture of the left parietal bone. B: Preoperative axial images (bone window) of the same patient, showing the elevated component. C: Preoperative CTB axial (soft-tissue window) showing underlying haemorrhagic contusion.

and those introduced by the implement that caused the injury, with subsequent risk of developing septic complications, such as superficial wound sepsis, meningitis, subdural empyema and brain abscesses.[40] Delay to definitive surgery and wound care, free bone fragments, wound contamination and evidence of dural injury are known risk factors for developing septic complications.[8,9,41] Our

Table 2. Top countries according to number of golf courses compared with income inequality and serious assault rate

Country	Golf courses, *n*[28]	Gini coefficient[30]	Serious assault rate[29]*
USA	16 156	0.42	246.84
Japan	3 140	0.33	19.07
UK	3 101	0.35	87
Canada	2 564	0.33	150.81
Germany	1 054	0.33	164.48
France	811	0.32	375.63
South Korea	810	0.31	103.31
China	617	0.38	3.47
Spain	493	0.34	39.18
South Africa	477	0.63	293.55

*Per 100 000 population.

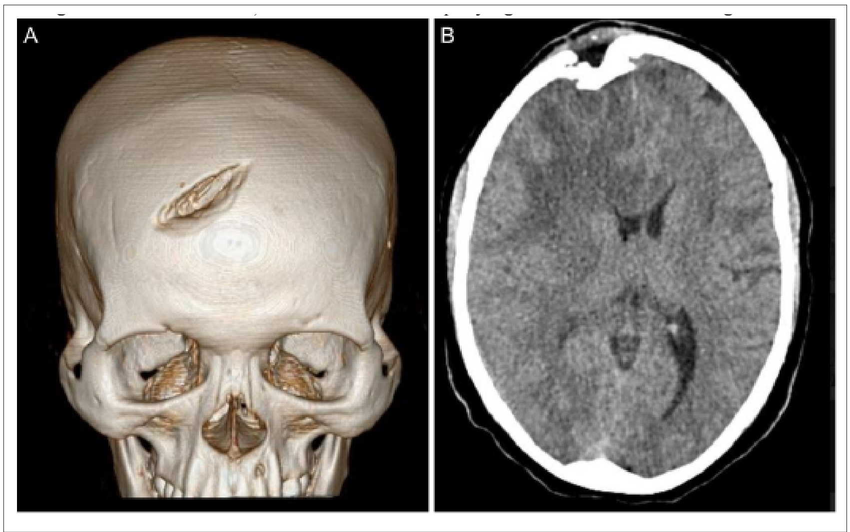

Fig. 7. A: Three-dimensional reconstruction of a computed tomography brain image demonstrating the depressed skull fracture in the right frontal bone. B: Axial view of accompanying soft-tissue window images.

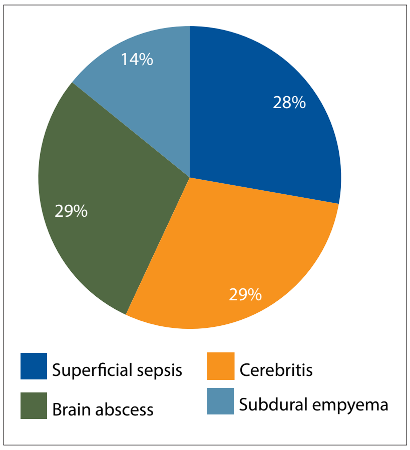

Fig. 8. Septic complications.

series had a high septic rate compared with other compound skull fracture series reported in similarly resourced settings.[42-44] This may be due to the club head probably being contaminated by soil, and a high rate of dural injury (57%). The 108.2-hour delay to surgery may also be a contributing factor to development of sepsis.[45] In addition, the high rate of local pneumocephalus (76%) confirms exposure of intracranial contents to the external environment.

The use of prophylactic antibiotics has remained controversial in compound skull fractures. In an international survey performed in 2021, it was found that one-third of European centres do not offer prophylactic antibiotics as part of the management of compound skull fractures.[46] Three important studies on compound skull fractures, performed in Liverpool in 2002,[47] Rotterdam in 1972[41] and Glasgow in 1972,[48] demonstrated low sepsis rates with variable use of prophylactic antibiotics. These studies included mainly paediatric patients (52%) involved in road traffic accidents, and failed to demonstrate a reduction in septic complications with the use of prophylactic antibiotics.

Harrington *et al.*,[49] in a series of 192 cranial stab wounds, demonstrated that prophylactic antibiotic use had a significant impact on the incidence of cranial sepsis. The mechanism of injury in their study is similar to our series, with contaminated weapons creating open intracranial pathology secondary to interpersonal violence. Despite the variations in practice and inconclusive findings in the existing literature, the Brain Trauma Foundation guidelines currently recommend the use of broad-spectrum antibiotic prophylaxis.[40]

Study limitations

This study was conducted in a single centre that serves a population with a unique sociodemographic background, and had the aim of describing a specific mechanism of injury, which may limit its generalisability. The study had a retrospective design with a small sample size, which introduces biases and limits the statistical power of the findings.

Conclusion

Golf club assault-related compound skull fractures in adults are a rare phenomenon, with few previous reports, and their prevalence in SA is correlated with income inequality, assault rates and the popularity of golf. Golf club assault produces a unique injury pattern, with a high rate of septic complications, owing to the physics principles involved in golf club design and the high rate of dural injury and wound contamination. Awareness of this mode of injury is important to guide treatment and prevent complications. Future study opportunities are quantification of biomechanical characteristics relevant to forensic sciences, and a prospective trial evaluating the role of pre-emptive antibiotic treatment to reduce septic complications.

Data availability. Available from the authors on request.

Declaration. The research for this study was done in partial fulfilment of the requirements for RG's MMed (Neurosurgery) degree.

Acknowledgements. None.

Author contributions. RG: data collection, ethical and institutional approval, manuscript writing and editing; EMG: data presentation, manuscript writing; AJV: manuscript editing and study supervision.

Funding. This study was self-funded.

Conflicts of interest. None.

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Received 27 May 2024; accepted 22 July 2024.