RETROSPECTIVE CHART REVIEW OF
SURGICAL MANAGEMENT OF COMPOUND
ELEVATED SKULL FRACTURES

By

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Student Number: 205501695

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for the degree of Master of Medicine in Neurosurgery
in the Department of Neurosurgery
School of Clinical Medicine
College of Health Sciences
University of KwaZulu-Natal
Durban
2019

As the candidate’s supervisor, I have approved this thesis for submission.

Signed:  Name: Basil Enicker   Date: 06/08/2020
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Signed: ____________________________  Date: 06/08/2020
Dedication

I would like to dedicate this thesis to my understanding wife, Ramona, my parents, Parkash and Usha, and my son Pranav.
Acknowledgements

Thanks to Basil Enicker for the assistance and supervision in developing the research idea, conducting the research and composing the manuscript.

I would also like to thank Timothy Craig Hardcastle, Director of Trauma Unit, Inkosi Albert Luthuli Central Hospital for reviewing the manuscript.
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Overview of the thesis

Abstract

Background: Traumatic skull fractures have been traditionally classified into those that involve the base or vault with distinct entities linear or depressed. Compound elevated skull fracture is a newer entity with scanty reports in the literature.

Objective: To describe the clinical presentation, neuro-radiology findings by development of a classification system, medical and surgical management, and complications of patients with compound elevated skull fractures at a busy Neurosurgical Department in Durban, South Africa.

Methods: Medical records of consecutive patients admitted from January 2005 to December 2018 with compound elevated skull fractures at Inkosi Albert Luthuli Central Hospital were retrospectively evaluated. Data was analysed for demographics, clinical presentation, mechanisms of injury, neuro-radiology findings, management and outcomes. Neuro-radiological images were used to develop a classification system.

Results: Eighteen patients were included in this series with a median age of 28 years, median admission Glasgow Coma Scale was 12. Ten patients presented with focal neurological deficits which included hemiparesis [n=8, 44%] and unilateral afferent pupil deficit [n=2, 11%]. Intra-cerebral haematoma was the most common associated neuro-radiological finding [n=10, 55%] followed by acute extradural haematoma [n=4, 22%]. Three distinct neuro-radiological subtypes were identified. All patients underwent surgical debridement and of which 11 [61%] required duroplasty and 10 [55%] re-placement of elevated bone flap. Septic complications included meningitis [n=5, 27%], brain abscess [2, 11%] and surgical site infection [n=1, 5%]. Seventeen patients had favourable outcomes at discharge (Glasgow Outcome Scale 4 or 5).

Conclusion: Compound elevated skull fracture is an additional subtype of skull vault fracture. Use of the originally developed classification system is important and infrequently described type of skull fracture. We recommend early surgical intervention which includes careful management of dura and elevated bone fragment reduces morbidity from septic complications.
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Part 1: The Review of Literature

The entity of compound elevated skull fracture is an unusual type of fracture involving the cranial vault which has been described inadequately in the current literature.\(^1\)

Post-traumatic skull fractures are traditionally classified into fractures of vault or base with skull vault fractures being further sub-divided into linear, comminuted or depressed. Compound elevated skull fracture involves the fractured portion of bone being elevated above level of the intact skull bone.\(^2\)

It has been suggested to include compound elevated skull fracture as subtype into the classification of skull fractures although the current literature only encompasses isolated case reports and short case series.\(^1-6\)

Different mechanisms of injury have been noted in these studies to result in compound elevated skull fractures. The proposed mechanism underlying the development of compound elevated skull fracture in the case of blunt force trauma comprises of a tangential force applied to skull bone which then elevates fractured fragment of bone due to lateral force of the object or rotation of the head.\(^2\) This combination of forces may imitate a formal craniotomy.\(^4\)

Local experience has shown that penetrating injury (like those caused by a machete) may cause an elevated compound skull fracture.\(^7,8\) The mechanism of injury resulting in compound elevated
skull fracture may occur during the assault with a sharp heavy weapon or upon retrieval. This mechanism may mimic a craniotomy flap.\textsuperscript{1} The presenting clinical features depends on site, extent and severity of the underlying brain injury. Computed Tomography (CT) of brain is the investigation of choice for diagnosis in addition to assessing intracranial injury.\textsuperscript{5}

Management principles correspond to those of other compound skull fractures which are early wound debridement with removal of loose bone fragments, evacuation of haematoma (if present), duroplasty and broad spectrum antimicrobial therapy. Complications of compound elevated skull fracture include meningitis, abscess formation or cerebrospinal fluid fistula.\textsuperscript{4,6,9} Timeous neurosurgical management may prevent these complications reducing morbidity and mortality.\textsuperscript{1-6,10,11} Treatment of elevated bone flap has been inconsistently dealt with in the literature as some authors discarded all free or elevated bones whilst others kept the bone flaps in the bone bank. Delayed cranioplasty was advocated either with the autologous bone or synthetic cranioplasty products.\textsuperscript{2} An intact dura was less common but not infrequent\textsuperscript{2,4}, whilst duroplasty (primarily with or without pericranial augmentation) was performed on primary surgery in all reported cases of dural injury.\textsuperscript{1,3,5,6}

In conclusion, compound elevated skull fracture is a rare injury which should be included in the classification of skull fractures. Early detection and prompt neurosurgical management should improve morbidity and mortality however underlying brain injury also plays a significant role in the overall prognosis.
References:


Part 2: A submission ready manuscript.

Compound Elevated Skull Fractures: A Retrospective Descriptive Study

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These authors contributed equally to this work. All authors do not have any financial disclosures.

This work is based on Compound Elevated Skull Fractures: A Case Series from South Africa – a digital poster presentation at the 7-11\textsuperscript{th} October 2017 Congress of Neurological Surgeons Annual Meeting in Boston, Massachusetts, United States of America

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The authors would like to thank Timothy Craig Hardcastle, Director of Trauma Unit, Inkosi Albert Luthuli Central Hospital for reviewing the final manuscript.
Abstract

Background: Traumatic skull fractures have been traditionally classified into those that involve the base or vault with distinct entities linear or depressed. Compound elevated skull fracture is a newer entity with scanty reports in the literature.

Objective: To describe the clinical presentation, neuro-radiology findings by development of a classification system, medical and surgical management, and complications of patients with compound elevated skull fractures at a busy Neurosurgical Department in Durban, South Africa.

Methods: Medical records of consecutive patients admitted from January 2005 to December 2018 with compound elevated skull fractures at Inkosi Albert Luthuli Central Hospital were retrospectively evaluated. Data was analysed for demographics, clinical presentation, mechanisms of injury, neuro-radiology findings, management and outcomes. Neuro-radiological images were used to develop a classification system.

Results: Eighteen patients were included in this series with a median age of 28 years, median admission Glasgow Coma Scale was 12. Ten patients presented with focal neurological deficits which included hemiparesis [n=8, 44%] and unilateral afferent pupil deficit [n=2, 11%]. Intra-cerebral haematoma was the most common associated neuro-radiological finding [n=10, 55%] followed by acute extradural haematoma [n=4, 22%]. Three distinct neuro-radiological subtypes were identified. All patients underwent surgical debridement and of which 11 [61%] required duroplasty and 10[55%] re-placement of elevated bone flap. Septic complications included meningitis [n=5, 27%], brain abscess [2, 11%] and surgical site infection [n=1, 5%]. Seventeen patients had favourable outcomes at discharge (Glasgow Outcome Scale 4 or 5).

Conclusion: Compound elevated skull fracture is an additional subtype of skull vault fracture. Use of the originally developed classification system is important and infrequently described type of skull fracture. We recommend early surgical intervention which includes careful management of dura and elevated bone fragment reduces morbidity from septic complications.
Introduction

Compound elevated skull fracture involves the fractured portion of bone being elevated above level of the intact skull bone. Post-traumatic skull fractures are traditionally classified into fractures of the vault or base with skull vault fractures being further sub-divided into linear or depressed. Compound elevated skull fractures are rare injuries and are not classified in the traditional skull fracture classification. We report a series of this rare type of post-traumatic skull vault fracture which represents the largest study of compound elevated skull fractures, to date, from the Neurosurgical unit at Inkosi Albert Luthuli Central Hospital in Durban, South Africa.

Methods

We undertook a retrospective analysis of data collected from electronic charts of all patients with a diagnosis of open skull vault fracture (ICD code S02.0) resulting from head injuries treated by the Department of Neurosurgery at Inkosi Albert Luthuli Central Hospital, Durban, South Africa from 1st January 2005 to 31st December 2018. This facility is the single provincial neurosurgical referral center for a population of 11 million people in KwaZulu-Natal. We included all patients with clinical and radiological features documented as compound elevated skull fracture or autocraniotomy, and excluded patients with compound depressed or linear skull fractures.

Once the patients were identified, the following data was obtained from the hospital records: neuroradiology images, clinical progress notes, surgical operative notes and outcomes. Demographic details (age, gender) were studied together with the reported circumstances of mechanism of injury, Glasgow Coma Scale (GCS) on admission and neurological examination.
The current unit policy for management of compound skull fractures includes: prompt administration of prophylactic antimicrobials, anti-tetanus toxoid and prophylactic antiepileptic drugs with early surgical debridement and repair of dura when breached.

Classification

The neuro-radiological images were analysed to develop a classification system which would enable accurate description allowing better operative planning.

Details of neurosurgical operation performed with regards to dural and bone management were examined, additionally the baseline neuroimaging (computed tomography) were reviewed noting pattern of injury to the skull vault as well as presence of intracranial haematoma.

Medical management with regards to administration of antimicrobial therapy (therapeutic and prophylaxis) and seizure prophylaxis were noted. The data related to septic complications (post-traumatic meningitis, abscess formation and surgical site infection) and Glasgow Outcome Scale (GOS) on discharge were also captured.
Results

There were 783 patients with open fractures of the skull identified during the study period. Eighteen (2.2%) of these patients were selected with compound elevated skull fracture (also documented as “autocraniotomy”). The details of the patients are summarised in Tables 1A and 1B.

<table>
<thead>
<tr>
<th>Patient Age</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
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<tr>
<td>Male</td>
<td>36</td>
<td>13</td>
<td>25</td>
<td>28</td>
<td>25</td>
<td>49</td>
<td>40</td>
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<tr>
<td>Admission GCS</td>
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<td>11</td>
<td>15</td>
<td>14</td>
<td>14</td>
<td>15</td>
<td>10</td>
<td>11</td>
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<tr>
<td>Focal Neurological Deficit</td>
<td>Right pupil deficit</td>
<td>No</td>
<td>Left hemiplegia</td>
<td>Left hemiplegia</td>
<td>Left hemiplegia</td>
<td>No</td>
<td>Right hemiplegia</td>
<td>Right hemiplegia</td>
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</tr>
<tr>
<td>Mechanism Location on CT Scan Fracture Type</td>
<td>Machete</td>
<td>Frontal</td>
<td>Occipital</td>
<td>Frontal</td>
<td>Parietal</td>
<td>Frontal</td>
<td>Parietal</td>
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<tr>
<td>Dural Injury Surgical Management of fractured elevated bone</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Antimicrobial</td>
<td>Yes</td>
<td>Y</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<td>Yes</td>
</tr>
<tr>
<td>Anti-epileptics Post-traumatic meningitis</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<td>No</td>
<td>No</td>
<td>Yes</td>
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<td></td>
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<tr>
<td>SSI/Abcess Associated intracranial haematomas</td>
<td>No</td>
<td>No</td>
<td>No</td>
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<td>No</td>
<td>No</td>
<td>No</td>
<td>Abscess</td>
<td>SSI</td>
</tr>
<tr>
<td>GOS on Discharge</td>
<td>ICH</td>
<td>ICH</td>
<td>ICH</td>
<td>ICH</td>
<td>ICH</td>
<td>AEDH</td>
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The majority of the patients were male (94%), with a median age of 28 years. The most common mechanism of injury was that of assault with machete (n=7), followed by blunt cranial injury from motor vehicle collision (n=5), and assault with an axe (n=4). Fall from a bicycle and blunt assault each occurred in one patient. The median GCS was 12 with only two patients in coma (GCS <9). Only 10 of the 18 patients presented with focal neurological deficits, 8 with a hemiparesis and 2 with afferent pupil defect.

Upon review of neuro-radiology imaging, fractures were located in the parietal [n=9], frontal [n=8] and occipital [n=1] regions.
Three distinct types were identified: Type 1 – fractured segment with minimal loss of contact with rest of the cranial vault, Type 2 – fractured segment with complete loss of contact with rest of the cranial vault but retained attachment with scalp tissues, Type 3 – fractured segment with complete loss of contact with rest of the cranial vault and scalp tissues. The compound elevated fracture subtypes are shown in Table 2 and Figures 1, 2 and 3.

Table 2. Results of Subtypes of Compound Elevated Skull Fractures

<table>
<thead>
<tr>
<th>Type</th>
<th>Subtype Description</th>
<th>Percentage</th>
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<tr>
<td><strong>Type 1</strong></td>
<td>Fractured segment with minimal loss of contact with rest of cranial vault</td>
<td>22.2% (n=4)</td>
</tr>
<tr>
<td><em>(Figure 1)</em></td>
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<tr>
<td><strong>Type 2</strong></td>
<td>Fractured segment with complete loss of contact with cranial vault but retained attachment with scalp</td>
<td>55.6% (n=10)</td>
</tr>
<tr>
<td><em>(Figure 2)</em></td>
<td></td>
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<tr>
<td><strong>Type 3</strong></td>
<td>Fractured segment with complete loss of contact with cranial vault and scalp</td>
<td>22.2% (n=4)</td>
</tr>
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<td><em>(Figure 3)</em></td>
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Figure 1 – Type 1 with elevated fractured segment (arrow) with minimal loss of contact with cranial vault
Figure 2 – Type 2 with elevated fractured segment (arrow) with complete loss of contact with cranial vault but retained attachment to scalp

Figure 3 – Type 3 with elevated fractured segment which has complete loss of contact with cranial vault and scalp
Regarding underlying brain injury, most patients had associated underlying intracranial haemorrhage (55% intracerebral, 22% extradural). Surgical intervention was undertaken in all patients with the majority (n=11) requiring duroplasty. The bone flap was debrided and re-placed in 55% (n=10) of cases whilst discarded in the rest due comminution or extensive contamination.

With regards to sepsis, two patients developed post-traumatic brain abscesses and one patient who was assaulted with a machete developed wound sepsis. Post-traumatic meningitis occurred in 5 patients. Post-traumatic meningitis occurred in 36% with dural injury versus 14% without. Time from injury to surgery were all within 24 hours. Bone replacement did not result in any acute sepsis or long-term osteitis.

Two patients had an injury to the superior sagittal sinus (anterior third). Ninety-four percent (n=17) of the patients in the series had favourable outcomes, Glasgow Outcome Scale 4-5.

The single patient who died in the series, was assaulted with a machete presenting with a GCS 7/15 and right dilated non-reactive pupil. The patient was intubated on arrival. He was taken to theatre and found intra-operatively to have an injury to the superior sagittal sinus with an associated acute extradural hematoma. Post-operatively, the patient was managed in the neurosurgical intensive care unit for assisted ventilation and monitoring of ICP. He developed an early ventilator associated pneumonia and cerebrospinal fluid confirmed post-traumatic meningitis (*Enterococcus faecalis*). Despite ventilation and appropriate antimicrobial therapy, he developed septic shock refractory to therapy.
Discussion

The entity of compound elevated skull fracture is an unusual type of fracture involving the cranial vault, the current literature has been limited to case reports and small case series.\(^1\)\(^-\)\(^6\),\(^10\),\(^11\) We present the largest series, to date, of compound elevated skull fractures as well as provide a descriptive analysis regarding aspects of clinical presentation, mechanisms of injury, neuroimaging and management.

Clinical Presentation

The presenting clinical features which include GCS and focal neurological deficit are dependent on site, extent and severity of the underlying brain injury, in addition to the mechanism of injury.

Mechanism of Injury

The mechanisms of injury have not been consistent in the current literature, both blunt as well as penetrating force have been shown to be responsible which is confirmed by the presented series of patients.\(^2\),\(^3\),\(^5\),\(^12\),\(^13\) The proposed mechanism underlying the development of compound elevated skull fracture in the case of blunt force trauma comprises of a tangential force applied to skull bone which then elevates fractured fragment of bone due to lateral force of the object or rotation of the head.\(^2\) This combination of forces may imitate a formal craniotomy as in Figure 4 and Figure 5.\(^4\)
Figure 4 – Intra-operative picture showing Type 3 compound elevated skull fracture with intact dura (arrow) as a result of blunt force trauma due to involvement in a motor vehicle collision.

Figure 5 – Elevated fracture segment (arrow) from patient in Figure 4 brought to emergency department in saline soaked gauze for re-placement in operating theatre.
With regards to our experience, penetrating neurosurgical trauma comprises a significant portion of the local case load.\textsuperscript{7,8} This may occur when a sharp heavy weapon is used in an assault or upon retrieval of the weapon elevating the fractured segment. The outcome may mimic a craniotomy flap.\textsuperscript{1}

**Neuroimaging**

Computed Tomography (CT) scan of the brain is the investigation of choice for diagnosis in addition to assessing extent of injury to underlying parenchyma and intracranial haematomas.\textsuperscript{5} Performing coronal, sagittal and three-dimensional reconstructions will be of value (see Figure 6) in evaluating the grade. The proposed grading system is important in consistently providing an accurate description of the extent of elevated skull fracture. Contrasted CT Brain scan is recommended when post-traumatic sepsis or brain abscess formation is suspected. Management is in accordance with standard Surviving Sepsis guidelines.\textsuperscript{15}

![Coronal CT Brain scan showing elevated fractured segment](image_url)

Figure 6 – Coronal CT Brain scan showing elevated fractured segment
Surgery

Surgical principles include early wound debridement with removal of loose bone fragments, evacuation of haematoma (if present), duroplasty and broad spectrum antimicrobial therapy. Management of the elevated bone flap is dependent on intra-operative assessment of the elevated bone fragment for possible contamination. Treatment of elevated bone flap was inconsistently dealt with in the literature; some authors discarded the elevated bone flap\(^6,16\) whilst others kept the bone flap in the bone bank\(^2,4\) or performed immediate re-placement\(^1,3,12,13,16\) as in Figure 7. In our unit, we favour immediate re-placement of bone flap for protection of the underlying brain and for cosmesis. In the scenario where the bone flap is severely comminuted or contaminated we discard it. In these cases, we prefer a delayed cranioplasty with synthetic cranioplasty products.\(^2\)

Figure 7 – Intra-operative picture showing re-placement of elevated fractured segment from Figures 4 and 5
Dural penetration

An intact dura was less common but not infrequent\textsuperscript{2,4}. In our unit, we prefer primary dural closure or augmentation with peri-cranium.

Morbidity and Mortality

Complications of compound elevated skull fracture include surgical site infection, meningitis, brain abscess formation or cerebrospinal fluid (CSF) fistula. In comparison to compound depressed skull fractures where infection rates have been reported from 1.9 - 10.6\%\textsuperscript{17}, the infection rate with compound elevated skull fractures are significantly higher (44\%). This is thought to be as a result of the large surface area exposure following elevation of bone fragment with exposure or injury to underlying dura. Timeous neurosurgical management as seen in Figure 8 may prevent these complications thus reducing morbidity and mortality.\textsuperscript{1-6,10,11}

Figure 8 – Intra-operative picture from Figure 6 showing elevated fractured segment (arrow) at risk for secondary septic complications.
The majority of authors describe favorable outcomes \(^1\text{-}^6\) in congruence with our study. The few case reports with poor outcome are due to development of post-traumatic brain abscess, primary brain injury or associated intracranial haematoma. \(^2\text{-}^3\)

Neurological morbidity compared to depressed skull fractures (11\%)\(^17\) were significantly higher (55\%). Association with intracranial haematoma was also much higher (77\%) when compared to compound depressed skull fractures (23.6\%)\(^18\).

**Conclusion**

Compound elevated skull fracture represents an additional subtype of skull vault fracture which is rarely reported in the literature. This study builds on the 40 years of literature with the largest series of patients with compound elevated skull fractures to date describing this clinico-pathological entity. Surgical principles and medical management remain standard of care in line with current practice. The novel neuro-radiology classification the authors propose provide a consistent method of description of compound elevates skull fractures.

**Disclosure statement**

The authors report that they have no conflicts of interest.
References


Appendix 1: The final Study Protocol

**Retrospective Chart Review of surgical management of compound elevated skull fractures**

Principle Investigator: Prashanth Maharaj

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11. Exclusion criteria
12. Data collection methods and tools
13. Statistical analysis
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15. Ethical approval
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18. Data collection sheet
1. Introduction

Post-traumatic skull fractures are traditionally classified into fractures of vault or base with skull vault fractures being sub-divided into linear, comminuted or depressed. Compound elevated skull fracture involves the fractured portion of bone being elevated above level of the intact skull bone. It has been suggested to include compound elevated skull fracture as subtype into the classification of skull fractures although the current literature only encompasses isolated case reports and short case series. This rare type of post-traumatic skull vault fracture has yet to be studied in South Africa.

2. Research Questions

a. What are the outcomes of patients with compound elevated skull fractures at the Department of Neurosurgery at Inkosi Albert Luthuli Central Hospital (IALCH) situated in the province of Kwa Zulu Natal (KZN), South Africa?

b. What mechanisms of injuries are associated with compound elevated skull fractures?

c. What surgical management options are used to treat patients with compound elevated skull fractures?

3. Aim of study

To review the presentations, complications, management strategies and outcomes of patients who present following head injuries with compound elevated skull fractures by the Department of Neurosurgery at Inkosi Albert Luthuli Central Hospital.
4. Objectives

   a. To review the total admissions of all patients with head injuries treated at the Department of Neurosurgery at IALCH from 1\textsuperscript{st} January 2005 to 31\textsuperscript{st} December 2018, so as to select those with compound elevated skull fractures.

   b. To review the medical records for information on demographics, clinical presentation, and medical/surgical treatment.

   c. To review neuroradiology reports/images.

   d. To review medical records of hospital-stay, complications, Glasgow Outcome Scale and mortality.
5. Literature review

The entity of compound elevated skull fracture is an unusual type of fracture involving the cranial vault which has been described inadequately in the current literature.¹

Post-traumatic skull fractures are traditionally classified into fractures of vault or base with skull vault fractures being sub-divided into linear, comminuted or depressed. Compound elevated skull fracture involves the fractured portion of bone being elevated above level of the intact skull bone.²

It has been suggested to include compound elevated skull fracture as subtype into the classification of skull fractures although the current literature only encompasses isolated case reports and short case series.¹⁻⁶

The mechanisms of injury have not been consistent in these studies involving both blunt as well as penetrating force. The proposed mechanism underlying the development of compound elevated skull fracture in the case of blunt force trauma comprises of a tangential force applied to skull bone which then elevates fractured fragment of bone due to lateral force of the object or rotation of the head.² This combination of forces may imitate a formal craniotomy.⁴

With regards to local experience, penetrating neurosurgical trauma comprise of a significant portion of the case load.⁷,⁸ However, a penetrating mechanism may also result in compound elevated skull fracture where a sharp heavy object which elevates the fractured portion of skull bone or the elevation may occur upon retrieval of the object in question (which may be a weapon). This mechanism may mimic a craniotomy flap.¹
The presenting clinical features is heavily dependent on site, extent and severity of the underlying brain injury. Computed Tomography (CT) of brain is the investigation of choice for diagnosis in addition to assessing extent of injury to underlying parenchyma and intracranial haematomas.\textsuperscript{5}

Management principles correspond to those of other compound skull fractures which are early wound debridement with removal of loose bone fragments, evacuation of haematoma (if present), duroplasty and broad spectrum antimicrobial therapy. Complications of compound elevated skull fracture include meningitis, abscess formation or cerebrospinal fluid fistula. Timeous neurosurgical management may prevent these complications reducing morbidity and mortality. \textsuperscript{1-6,10,11} Treatment of elevated bone flap was inconsistently dealt with in the literature as some authors discarded all free or elevated bone whilst others kept the flap in the bone bank. Delayed cranioplasty was advocated either with the autologous bone or synthetic cranioplasty products.\textsuperscript{2} An intact dura was less common but not infrequent\textsuperscript{2,4}, whilst duroplasty (primarily with or without pericranial augmentation) being performed on primary surgery in all reported cases of dural injury. \textsuperscript{1,3,5,6}

In conclusion, compound elevated skull fracture is a rare injury which should be included in the classification of skull fractures. Early detection and prompt neurosurgical management should improve morbidity and mortality however underlying brain injury also plays a significant role in the overall prognosis.

6. Rationale for study

Evidence and description of surgical management of compound elevated skull fractures is limited to case reports and small case series. Despite the large caseload of patients with traumatic brain injury at our institution, the entity of compound elevated skull fracture has presented rarely with no clearly defined
surgical management strategy. The development of surgical site infection, post-traumatic abscess formation is known complications of compound skull fractures in general and may worsen outcomes. The presence of intracerebral haematoma may also be a contributing factor to poorer neurological outcome.

7. References


8. Study methodology

The study will be a retrospective analysis of data collected from electronic charts of all patients with a diagnosis of compound elevated skull fracture resulting from head injuries treated by the Department of Neurosurgery at Inkosi Albert Luthuli Central Hospital from 1\textsuperscript{st} January 2005 to 31\textsuperscript{st} December 2018.

9. Study location

This study will be performed in a single center which is the Department of Neurosurgery unit at Inkosi Albert Luthuli Central Hospital situated in Durban, South Africa.

10. Inclusion criteria

All patients with the diagnosis of compound elevated skull fracture diagnosed by clinically and CT Brain scans, which were referred and treated at the Department of Neurosurgery at IALCH from 1\textsuperscript{st} January 2005 to 31\textsuperscript{st} December 2018.

11. Exclusion criteria

Patients with head injuries referred to IALCH Department of Neurosurgery with no radiological features of compound elevated skull fracture will be excluded.
12. Data collection methods and tools.

Data will be collected from electronic charts of all patients with a diagnosis of compound elevated skull fracture resulting from head injuries treated by the Department of Neurosurgery at Inkosi Albert Luthuli Central Hospital from 1st January 2005 to 31st December 2018. Due to the unusual nature of compound elevated skull fractures, cases will be selected within the bank of patients with traumatic brain injury. Clinical details including clinical presentation, operative notes and discharge outcomes will be extracted from electronic note keeping system at Department of Neurosurgery at Inkosi Albert Luthuli Central Hospital. Neuro-radiology findings will be reviewed on PACS systems (Plaza Web®). Data will be collected using Microsoft® Excel®.

13. Statistical analysis

Statistical analysis will be performed with the assistance of the biostatistician Yuesentha Balakrishna (SAMRC). Data will be analysed using Stata version 14 (StataCorp®, 2015). Frequencies and medians/means will be used to describe the data.

14. Study limitations

Study will not include patients with diagnosis of compound elevated skull fracture who are not referred to Department of Neurosurgery at Inkosi Albert Luthuli Central Hospital will be included in study (e.g. those who attend private healthcare facilities in the province of Kwa Zulu Natal).
15. Ethical approval

Ethical approval will be sought from the Biomedical Research Ethics Committee (BREC) of the University of KwaZulu-Natal.

16. Ethical considerations

The study will be conducted in full accordance with the principles of the Declaration of Helsinki, good clinical practice and regulations of BREC of the University of KwaZulu-Natal. This is a retrospective study and there will be no direct contact with patients. The details of patients will be kept confidential in a password protected computer program.

17. Outcomes and significance

The data gathered will be analysed and will be the subject of a publication in a peer reviewed journal. The information will help us better understand this rare type of skull fracture and describe surgical methods used for management.
# Data collection sheet

**Numerical identifier:** ……………………………..

## 1. Age

<table>
<thead>
<tr>
<th>2. Gender</th>
<th>I. Male</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>II. Female</td>
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</tbody>
</table>

## 3. Mechanism of injury

| I. Fall              |                                                                 |
| II. Motor vehicle accident as passenger |                                                                 |
| III. Pedestrian vehicle accident |                                                                 |
| IV. Bicycle accidents |                                                                 |
| V. Assault with blunt object |                                                                 |
| VI. Assault with Machette |                                                                 |
| VII. Assault with knife or axe |                                                                 |

## 4. Signs on clinical examination

| I. Hemiparesis / hemiplegia |                                                                 |
| II. Pupil defect |                                                                 |

## 5. GCS on admission

| I. 13-15                                                                 |
| II. 9-12                                                              |
| III. 3-8                                                             |

## 6. **CT scan findings:** Location of Fracture and underlying injury

<p>| I. Frontal |                                                                 |
| II. Parietal |                                                                 |
| III. Temporal |                                                                 |
| IV. Occipital |                                                                 |</p>
<table>
<thead>
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<tr>
<td>V.</td>
<td>Does extradural cross suture line</td>
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<td>VI.</td>
<td>ASDH</td>
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<td>VII.</td>
<td>ICH</td>
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<td>VIII.</td>
<td>AEDH</td>
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<td>7.</td>
<td>Surgical management</td>
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<td>8.</td>
<td>Medical management</td>
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<td>9.</td>
<td>ICU stay</td>
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<td>10.</td>
<td>ICU complications</td>
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<td>11.</td>
<td>Length of ICU stay</td>
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<tr>
<td>13.</td>
<td>Surgical complications</td>
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<td>14.</td>
<td>Length of stay in hospital</td>
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<td>15.</td>
<td>Mortality</td>
</tr>
<tr>
<td>16.</td>
<td>GOS at discharge</td>
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Appendix 2: The Guidelines for Authorship for the Journal selected for submission of the manuscript -

British Journal of Neurosurgery

(as adapted https://www.tandfonline.com/action/authorSubmission?journalCode=ibjn20&page=instructions#style)

_In British Journal of Neurosurgery_, original research is published in an international, peer-reviewed journal. Please consult the journal's Aims & Scope for details on its focus and peer-review policy. Note that submissions must be in English.

_British Journal of Neurosurgery_ accepts a range of article types: Original Articles, Short Reports, and Case Reports, Review Articles, and Letters to the Editor.

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All authors submitting to medicine, biomedicine, and health sciences journals should conform to the Uniform Requirements for Manuscripts Submitted to Biomedical Journals, prepared by the International Committee of Medical Journal Editors (ICMJE).

**Structure**

Your paper should follow this order: title page; abstract; keywords; main text introduction, materials and methods, results, discussion; acknowledgments; declaration of interest statement; references; appendices (if applicable); table(s) with caption(s) (on separate pages); figures; figure captions (as a list).

**Word Limits**

Please include a word count for your paper. There are no word limits for papers in this journal.

**Style Guidelines**

Please refer to these quick style guidelines when preparing your paper, rather than any published articles or a sample copy.

Please use British (-ise) spelling style consistently throughout your manuscript.

Please use single quotation marks, except where a quotation is “within” a quotation. Please note that long quotations should be indented without quotation marks.

XXXIV
**Formatting and Templates**

Papers may be submitted in Word format. Figures should be saved separately from the text. To assist you in preparing your paper, we provide formatting template(s).

**Checklist: What to Include**

1. **Author details.** Please ensure everyone meeting the International Committee of Medical Journal Editors (ICMJE) requirements for authorship is included as an author of your paper. All authors of a manuscript should include their full name and affiliation on the cover page of the manuscript. Where available, please also include ORCiDs and social media handles (Facebook, Twitter or LinkedIn). One author will need to be identified as the corresponding author, with their email address normally displayed in the article PDF (depending on the journal) and the online article. Authors’ affiliations are the affiliations where the research was conducted. If any of the named co-authors moves affiliation during the peer-review process, the new affiliation can be given as a footnote. Please note that no changes to affiliation can be made after your paper is accepted. Read more on authorship.

2. Should contain a structured abstract of 300 words. A structured abstract should cover (in the following order): the purpose of the article, its materials and methods (the experimental system and procedures used), the results and conclusions.

3. **Graphical abstract** (optional). This is an image to give readers a clear idea of the content of your article. It should be a maximum width of 525 pixels. If your image is narrower than 525 pixels, please place it on a white background 525 pixels wide to ensure the dimensions are maintained. Save the graphical abstract as a .jpg, .png, or .gif. Please do not embed it in the manuscript file but save it as a separate file, labelled GraphicalAbstract1.

4. You can opt to include a video abstract with your article. Find out how these can help your work reach a wider audience, and what to think about when filming.

5. Read making your article more discoverable, including information on choosing a title and search engine optimization.

6. **Funding details.** Please supply all details required by your funding and grant-awarding bodies as follows:
   - For single agency grants
     This work was supported by the [Funding Agency] under Grant [number xxxx].
   - For multiple agency grants
     This work was supported by the [Funding Agency #1] under Grant [number xxxx]; [Funding Agency #2] under Grant [number xxxx]; and [Funding Agency #3] under Grant [number xxxx].

7. **Disclosure statement.** This is to acknowledge any financial interest or benefit that has arisen from the direct applications of your research. Further guidance on what is a conflict of interest and how to disclose it.

8. **Biographical note.** Please supply a short biographical note for each author. This could be adapted from your departmental website or academic networking profile and should be relatively brief (e.g. no more than 200 words).

9. **Data availability statement.** If there is a data set associated with the paper, please provide information about where the data supporting the results or analyses presented in the paper can be found. Where applicable, this should include the hyperlink, DOI or other persistent identifier associated with the data set(s). Templates are also available to support authors.

10. **Data deposition.** If you choose to share or make the data underlying the study open, please deposit your data in a recognized data repository prior to or at the time of submission. You will be asked to provide the DOI, pre-reserved DOI, or other persistent identifier for the data set.
11. **Supplemental online material.** Supplemental material can be a video, dataset, fileset, sound file or anything which supports (and is pertinent to) your paper. We publish supplemental material online via Figshare. Find out more about supplemental material and how to submit it with your article.

12. **Figures.** Figures should be high quality (1200 dpi for line art, 600 dpi for grayscale and 300 dpi for colour, at the correct size). Figures should be supplied in one of our preferred file formats: EPS, PS, JPEG, GIF, or Microsoft Word (DOC or DOCX). For information relating to other file types, please consult our Submission of electronic artwork document.

13. **Tables.** Tables should present new information rather than duplicating what is in the text. Readers should be able to interpret the table without reference to the text. Please supply editable files.

14. **Equations.** If you are submitting your manuscript as a Word document, please ensure that equations are editable. More information about mathematical symbols and equations.

15. **Units.** Please use SI units (non-italicized).

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Please include a disclosure statement, using the subheading “Disclosure of interest.” If you have no interests to declare, please state this (suggested wording: The authors report no conflict of interest). For all NIH/Wellcome-funded papers, the grant number(s) must be included in the declaration of interest statement. Read more on declaring conflicts of interest.

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In order to be published in a Taylor & Francis journal, all clinical trials must have been registered in a public repository at the beginning of the research process (prior to patient enrolment). Trial registration numbers should be included in the abstract, with full details in the methods section. The registry should be publicly accessible (at no charge), open to all prospective registrants, and managed by a not-for-profit organization. For a list of registries that meet these requirements, please visit the WHO International Clinical Trials Registry Platform (ICTRP). The registration of all clinical trials facilitates the sharing of information among clinicians, researchers, and patients, enhances public confidence in research, and is in accordance with the ICMJE guidelines.

**Complying with Ethics of Experimentation**

Please ensure that all research reported in submitted papers has been conducted in an ethical and responsible manner, and is in full compliance with all relevant codes of experimentation and legislation. All papers which report in vivo experiments or clinical trials on humans or animals must include a written statement in the Methods section. This should explain that all work was conducted with the formal approval of the local human subject or animal care committees (institutional and national), and that
clinical trials have been registered as legislation requires. Authors who do not have formal ethics review committees should include a statement that their study follows the principles of the Declaration of Helsinki.

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Appendix 3: Ethical approvals

Included hospital and provincial approvals as well as the BREC approval (or waiver if appropriate).
To:
Professor J. Tsoka-Gwegweni
Biomedical Research Ethics Committee
University of KwaZulu-Natal
Westville Campus
Govan Mbeki Building
Private Bag X54001
Durban
4000

07 February 2017

Re: Ethical approval for study titled: “Retrospective Chart Review of surgical management of compound elevated skull fractures” for degree purposes (Master of Medicine in Neurosurgery) under class approval BREC reference number: BCA 219/15.

Dear Professor J. Tsoka-Gwegweni

Dr. Prashanth Maharaj, a registrar in the Department of Neurosurgery is currently registered for a MMed. (Neurosurgery) with the University of KwaZulu-Natal. The title of his study is “Retrospective Chart Review of surgical management of compound elevated skull fractures” and is for higher degree purpose.

The Department of Neurosurgery has BREC class approval to maintain a database of admissions and procedures performed in this unit for research purposes (BREC reference number: BCA 219/15).
We request permission to perform this study under the existing class approval using the database in our unit.

Yours Sincerely

[Signature]

Dr. Basil Enicker (Class approval / database primary administrator)
Consultant Neurosurgeon
Department of Neurosurgery
Inkosi Albert Luthuli Central Hospital (IALCH)
800 Bellair Road
Mayville
Durban, South Africa
4091
Telephone: +27 31 240 1135
Cell: 079 892 6711
E-mail: basilenicker@yahoo.com

* KINDLY RETURN ALL DOCUMENTATION WHEN REPLYING
26 April 2017

Dr P Maharaj (205501695)
Discipline of Neurosurgery
School of Clinical Medicine
drpmaharaj@gmail.com

Dear Dr Maharaj

Protocol: Retrospective chart review for surgical management of compound elevated skull fractures.
Degree: MMED
BREC reference number: BE088/17

A sub-committee of the Biomedical Research Ethics Committee has considered and noted your application received on 28 February 2017.

The study was provisionally approved pending appropriate responses to queries raised. Your response received on 18 April 2017 to BREC letter dated 10 April 2017 have been noted by a sub-committee of the Biomedical Research Ethics Committee. The conditions have now been met and the study is given full ethics approval and may begin as from 26 April 2017.

This approval is valid for one year from 26 April 2017. To ensure uninterrupted approval of this study beyond the approval expiry date, an application for recertification must be submitted to BREC on the appropriate BREC Form 2-3 months before the expiry date.

Any amendments to this study, unless urgently required to ensure safety of participants, must be approved by BREC prior to implementation.


BREC is registered with the South African National Health Research Ethics Council (REC-290408-009). BREC has US Office for Human Research Protections (OHRRP) Federal-wide Assurance (FWA 678).

The sub-committee’s decision will be RATIFIED by a full Committee at its next meeting taking place on 09 May 2017.

We wish you well with this study. We would appreciate receiving copies of all publications arising out of this study.

Yours sincerely

Professor Joyce Tsoka-Gwegweni
Chair: Biomedical Research Ethics Committee

cc supervisor: basilenicker@yahoo.com
cc postgraduate administrator: jantiles@ukzn.ac.za

Biomedical Research Ethics Committee
Professor J Tsoka-Gwegweni (Chair)
Westville Campus, Govan Mbeki Building
Postal Address: Private Bag X54001, Durban 4000
Telephone: +27 (0) 31 260 2406 Facsimile: +27 (0) 31 260 4609 Email: brec@ukzn.ac.za
### Appendix 4: Glasgow Outcome Scale

<table>
<thead>
<tr>
<th>Glasgow Outcome Scale</th>
<th>Interpretation</th>
</tr>
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<tbody>
<tr>
<td>1 – Dead</td>
<td>Dead</td>
</tr>
<tr>
<td>2 – Vegetative State</td>
<td>Absence of awareness of self and environment</td>
</tr>
<tr>
<td>3 – Severe Disability</td>
<td>Needs assistance with activities of daily living</td>
</tr>
<tr>
<td>4 – Moderate Disability</td>
<td>Independent, can partially resume work/school/social activities</td>
</tr>
<tr>
<td>5 – Good Recovery</td>
<td>Full recovery or minor symptoms which do not affect daily life</td>
</tr>
</tbody>
</table>