# An Epidemiological Analysis of Traumatic Cervical Spine Fractures at a Referral Spinal Unit - A Three-Month Study

By

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I, Natasha Singh, do declare that this dissertation is representative of my own work in both conception and execution (except where acknowledgements indicate to the contrary)

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# DEDICATION

After all the challenges and joys in my life, I sincerely dedicate this dissertation to:

The Lord of the universe, who carried me through all of the hurdles that life threw at me

Those who are responsible for all of my smiles, My Divine Family.

My adoring and compassionate grandparents, Mrs. and the late Mr. Purmasur, my ever-loving, supportive, and nurturing parents, my dad Mr. A.K.J. Singh, and my mum, Veena Singh, my fun-loving, caring and ever-devoted brothers Kaveel and Saiyil, my true and only love, Shekaar, and the Nirahu family for always being the unwaivering pillars of strength in my life.

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# ABSTRACT


### Aim

To determine the profile of traumatic cervical spine fractures with respect to the epidemiology, clinical presentation, types of fractures, conservative and surgical intervention, short-term post-intervention (i.e. post-conservative and post-surgical) complications and short-term post-surgical rehabilitation of patients presenting at the Spinal Unit of King George V Hospital over a 12-week period.

### Methods

Patients who presented to the King George V Hospital Spinal Unit from surrounding hospitals with traumatic cervical spine fractures were evaluated by the medical staff. Data concerning the epidemiology, clinical presentation, types of fractures, conservative and surgical intervention, short-term post-intervention (i.e. post-conservative and post-surgical) complications and short-term post-surgical rehabilitation data were recorded by the researcher. A *p*-value of <0.05 was considered as statistically significant. Appropriate statistical tests were applied to the hypothesis-testing objectives. These involved the Pearson's Chi Square Tests for categorical variables or Fisher's Exact Tests as appropriate where sample sizes were small. Paired *t*-tests were done to compare pre-and-post-surgical Frankel grading and Norton Pressure Sore Assessment scores.

### Results

The number of patients who presented to the Spinal Unit over a 12-week period was 20, of this number 17 were males, three were females and all were black. Eleven patients were treated surgically while nine patients were treated conservatively. The most frequent aetiology of cervical spine fractures was motor vehicle accidents ($n$ = 10) followed by falls ($n$ = 9). The most common co-existing medical conditions were smoking ($n$ = 7), HIV ($n$ = 5), alcohol abuse ($n$ = 3) and obesity ($n$ = 3). The most frequent locations of cervical spine fractures were C2 ($n$ = 6), C1 ($n$ = 4) and the posterior column of C6 ($n$ = 3), while dislocations occurred primarily at the C5-C6 levels ($n$ = 5) of the lower cervical spine. Odontoid fractures ($n$ = 6), Jefferson's fractures ($n$ = 4) and unilateral facet dislocations ($n$ = 6) were the most common fractures and dislocations

observed. Head injuries (*n* = 4) and lower limb fractures (*n* = 3) were the most common extra-spinal fractures. All subjects who sustained head injuries also had associated C1 or C2 fractures. Neurological complications most frequently involved the upper limb where loss of motor function (*n* = 8) and weakness (*n* = 4) were observed. The majority of the patients (*n* = 8) reported a Frankel Grading of E. There were no significant associations between types of fracture and gender with the exception of fracture/dislocation observed in two females. There was a statistically significant difference in the NPSA score ($p = 0.004$). Conservative care utilized included soft collar (*n* = 6), cones calipers (*n* = 6), physiotherapy (*n* = 4), Minerva jacket (*n* = 4) and SOMI (sterno-occipital mandibular immobilization) brace (*n* = 1) while surgical intervention included anterior decompression (*n* = 8), anterior fusion (*n* = 8), allograft strut (*n* = 8), discectomy (*n* = 8), anterior cervical plating (*n* = 8), anterior screw fixation (*n* = 2), a transoral approach (*n* = 1) and a corpectomy (*n* = 1). The short-term post-conservative care complications observed in this study were an occipital pressure sore (*n* = 1), severe discomfort (*n* = 1) as well as severe neck pain (*n* = 1), while the short-term post-surgical complications were severe neck pain (*n* = 2), oral thrush (*n* = 1), pneumonia (*n* = 1), odynophagia (*n* = 1) and hoarseness (*n* = 1). Of the 11 patients who underwent cervical spine surgery, ten were sent for physiotherapy and one for occupational therapy. No significant associations were seen between the type of cervical spine fracture and the age of the subject. There was a significant association between fracture/dislocation and the female gender ($p = 0.016$). There was significant negative association between odontoid fracture and: anterior decompression, anterior fusion, allograft strut, discectomy and anterior cervical plating ($p = 0.006$).

**Conclusion**

The results of this study reflect the presentation and management of cervical spine fractures at a referral spinal unit of a public hospital in KwaZulu Natal. The impact of HIV and other co-existing medical conditions were not determined due to the small sample size in this study. Further epidemiological studies are required to be conducted in the Spinal Units of all South African public hospitals in order to confirm or refute the observation of this study.

# LIST OF ABBREVIATIONS

| | |
|---|---|
| **AF:** | annulus fibrosis |
| **AIDS:** | acquired immune deficiency syndrome |
| **ALL:** | anterior longitudinal ligament |
| **Ant:** | anterior column |
| **AP:** | anteroposterior |
| **CI:** | confident interval |
| **CNS:** | central nervous system |
| **Com:** | complications |
| **CSF:** | cerebrospinal fluid |
| **CT:** | computed tomography |
| **FHSEC:** | Faculty of Health Science ethics committee |
| **FSU:** | functional spinal unit |
| **GCS:** | Glasgow Coma Scale |
| **HIV:** | human immunodeficiency virus |
| **Inst:** | instrument |
| **IL** | interleukin |
| **IVD/s:** | intervertebral disc/s |
| **IVF:** | intervertebral foramina |
| **Mid:** | middle column |
| **MRI:** | magnetic resonance imaging |
| **MVA:** | motor vehicle accident |
| **MVAs:** | motor vehicle accidents |
| **NP:** | nucleus pulposis |
| **NPSA:** | Norton Pressure Sore Assessment |
| **PLL:** | posterior longitudinal ligament |
| **Post:** | posterior column |
| **Post-surg:** | post-surgical |
| **ROM:** | range of motion |
| **SD:** | standard deviation |
| **SOMI:** | sterno-occipital mandibular immobilization |
| **SP:** | spinous process |
| **Surg:** | surgery |

| | |
|---|---|
| **TB:** | tuberculosis |
| **TNF-α:** | tumor necrosis factor-alpha |
| **TMJ:** | temporomandibular joint |
| **TVP:** | transverse process |
| **TVPs:** | transverse processes |
| **VB:** | vertebral body |
| **VC:** | vertebral column |

# LIST OF DEFINITIONS

| | |
|---|---|
| **Abdominal reflex:** | Superficial skin reflex (upper T7–10 and lower T11–12) mediated through the central nervous system and elicited by stroking the skin of the abdomen and inner thigh (Timothy *et al.,* 2004) |
| **Bulbocavernous reflex:** | The bulbocavernous reflex is the contraction of the anal sphincter in response to a tug on a bladder catheter, or to pinching of the penile shaft (Licina and Nowitzke, 2005) |
| **Caudad:** | Directed towards the tail, opposite to cranial or cephalad (Dorland, 2007) |
| **Cephalad:** | Pertaining to the head, or to the head-end of the body (Dorland, 2007) |
| **Corpectomy:** | Removal of an entire vertebral body (Timothy *et al.,* 2004) |
| **Coupled motion:** | A consistent association of one motion about an axis with another motion about a second axis (White and Panjabi, 1990) or complex dual motions which occur simultaneously (Croft, 1995) |
| **Cremasteric reflexes:** | Superficial reflex (T12–L2) mediated through the central nervous system elicited by stroking the skin of the inner thigh (Timothy *et al*., 2004) and raising of the scrotum on the ipsilateral side |
| **Phasic:** | Muscles which cause motion; more rapidly contracting. They are further from the joint that they move, have longer fibers and cross more than one joint. They generally belong to the flexor group (Enoka, 1988) |
| **Priapism:** | Persistent abnormal erection of the penis, usually without sexual desire, and accompanied by pain and tenderness (Dorland, 2007) |
| **Tonic:** | Antigravity postural muscles responsible for stability in the spine; continuous low level of contractile activity that is required to maintain a given posture (Enoka, 1988). |

# LIST OF TABLES

**CHAPTER TWO**



**CHAPTER FOUR**

# LIST OF FIGURES

# LIST OF APPENDICES

# TABLE OF CONTENTS

# CHAPTER ONE

# INTRODUCTION

## 1.1 INTRODUCTION TO THE STUDY

Many patients present at a trauma unit or a spinal unit with cervical spine fractures. The primary aetiology of the majority of these fractures is trauma to the cervical region (Maiman and Cusick, 1982; Walter *et al*., 1984; Hadley *et al*., 1989; Oller *et al*., 1992; Greene *et al*., 1997; Merritt and Williams, 1997; Kirshenbaum *et al*., 1990; Young *et al*., 1999; Preutu, 1999; Inamasu *et al*., 2001; Lenoir *et al*., 2006; Verettas *et al*., 2008). The epidemiological data on cervical spine fractures vary (Walter *et al.,* 1984; Ryan and Henderson, 1992; Vieweg *et al*., 2000; Grauer *et al.,* 2005; Later *et al*., 2005; Lenoir *et al*., 2006; Malik *et al.,* 2008) considerably in the literature while very little data exists on specific cervical spine fractures.

The clinical presentation of these fractures also varies considerably as this depends on the type of cervical spine fracture(s), mechanism of injury, soft tissue and neural tissue injury (Kirshenbaum *et al*., 1990; Oller *et al*., 1992; Inamasu *et al.,* 2001; Timothy *et al*., 2004; Agrillo and Mastronadi, 2006). Several factors (e.g. type of fracture, availability of implements and associated pathological findings) are taken into account in determining the surgical procedure and implements utilized during surgery (Naidoo, 2007). Therefore, the surgical approach to cervical spine fractures may differ depending on the clinical setting.

The development of post-surgical complications is a major concern for spinal surgeons especially if the patient has co-existing medical conditions and/or a depressed immune system (Carragee, 1997; Lin *et al*., 2004; Young *et al*., 2005, King, 2006). Although post-surgical rehabilitation has been shown to be an important component in the overall management of patients with cervical spine fractures, these approaches often differ depending on the clinical setting (e.g. availability of suitably trained staff, availability of rehabilitation equipment and type of rehabilitation required). Patients do sometimes present to chiropractors with neck pain and other clinical features post-trauma (Alcantara *et al.,* 2001; Novicky, 2003; Alpass, 2004; Eriksen, 2005). As a result of this, some researchers have cautioned that chiropractors should be aware of the clinical and radiological presentations of cervical spine fractures even though a patient has already been evaluated by a medical physician (Brynin and Yomtob, 1999).

## 1.2 BACKGROUND TO THE KING GEORGE V HOSPITAL

The King George V Hospital is situated in Springfield in Ward 25 of the eThekwini Health District in the province of KwaZulu-Natal. The Spinal Unit at this hospital is the only tertiary care referral unit in the province providing a service to a spectrum of spinal pathologies. The King George V Hospital serves a population of approximately nine million including those of the Eastern Cape Province. The Hospital is currently undergoing a Revitalization Programme which commenced in 1999 and is scheduled to be completed in 2008/9. The Hospital's vision is to strive to be the centre of excellence to meet the specific health care needs of the people of KwaZulu-Natal through the delivery of accessible, affordable, cost effective health care for designated services. This vision is supported by the hospital's mission and objectives. Specialized services offered by the hospital include (http://www.kznhealth.gov.za/kgv/history.htm):

- Multi Drug Resistant (MDR) and complicated TB
- Orthopaedic spinal surgery, psychiatry, family planning (sterilization)
- Dental Training Facility - attached to the University of KwaZulu/Natal

With respect to the Spinal Unit, there are five to six orthopaedic registrars who are under the supervision of the Head of the Spinal Unit. A Spinal Clinic is held (at the Spinal Unit) once a week where patients are referred from the surrounding hospitals. The purpose of this clinic is to evaluate the patient and to determine whether the patient will be admitted for elective surgical intervention or not (Govender, 2007).

## 1.3 AIMS AND OBJECTIVES OF THE STUDY

The primary aim of this study was to:

- Determine the profile of cervical spine fractures with respect to the epidemiology, clinical presentation, types of fractures, conservative and surgical intervention, short-term post-intervention (i.e. post-conservative and post-surgical) complications and short-term post-surgical rehabilitation of patients presenting at the Spinal Unit of King George V Hospital over a 12-week period.

Several specific objectives were identified and these included:

**1.3.1** To record the demographic data of patients presenting at the Spinal Unit with traumatic cervical spine fractures or dislocations.

**1.3.2** To determine the types of co-existing medical conditions existing in patients who presented at the Spinal Unit with cervical spine fractures or dislocations.

**1.3.3** To record the following data with respect to the cervical spine fractures or dislocations:

i. cause
ii. description
iii. associated fracture/injury
iv. pre-intervention neurological findings
v. pre- and post-surgical Frankel grading

**1.3.4** To determine an association between the age as well as the gender of the patient and the type of cervical spine fracture or dislocation.

**1.3.5** To compare the pre-surgical Norton pressure sore assessment scores with the post-surgical Norton pressure sore assessment scores in order to determine any change in pressure sore status.

**1.3.6** To determine an association between the cause of a cervical spine fracture or dislocation and the type of the cervical spine fracture or dislocation.

**1.3.7** To record the types of cervical spine fractures or dislocations that were treated conservatively.

**1.3.8** To determine an association between the type of cervical spine fracture or dislocation and the conservative treatment utilized.

**1.3.9** To record the following with respect to cervical spine surgery:

i. surgical procedures or approaches used for the specific types of cervical spine fractures or dislocations.
ii. the type of post-surgical bracing used for the specific type of cervical spine fractures or dislocations.
iii. complications that developed during surgery.

**1.3.10** To determine the association between a surgical procedure or approach and the specific type of cervical fracture or dislocation.

**1.3.11** To determine the association between the type of post-surgical brace used and the specific type of cervical fracture or dislocation.

**1.3.12** To record the development of short-term post-intervention (i.e. post-conservative and post-surgical) complications.

**1.3.13** To determine the association between the co-existing medical conditions and the development of short-term post-surgical complications.

## 1.5 HYPOTHESES OF THE STUDY

With respect to the association between the age as well as the gender of the subject and the type of cervical spine fracture, the Null Hypothesis ($H_o$) was set which stated that there would be no significant association between the type of cervical spine fracture and age and gender of the subject.

Based on the reports of Grauer *et al*. (2005), Lakshmanan *et al*. (2005), Later *et al*. (2005), Song *et al*. (2007) and Malik *et al*. (2008), with respect to an association between the cause of a cervical spine fracture or dislocation and the type of the cervical spine fracture or dislocation, the Alternate Hypothesis ($H_a$) was set which stated that there would be a significant association between a fall or motor vehicle accident and the type of cervical spine fracture or dislocation.

Based on the contrasting reports on the conservative management of cervical spine fractures and dislocations, the Null Hypothesis ($H_o$) was set which stated that there would be no significant association between the type of cervical spine fracture or dislocation and the conservative treatment utilized.

Based on the contrasting reports on the many surgical procedures or approaches for cervical spine fractures and dislocations, the Null Hypothesis ($H_o$) was set which stated that there would be no significant association between a surgical procedure or approach and the specific type of cervical fracture or dislocation.

Due to the inconsistent reports by various authors (Brodke and Anderson, 1998; Vieweg *et al*., 2000; Laidlaw *et al*., 2004; Al-Barbarawi and Sekhon, 2005; Agrillo and Mastronadi, 2006; Song and Lee, 2008) on the use of post-surgical braces for different cervical spine fractures, the Null Hypothesis ($H_o$) was set which stated that there would be no significant association between the type of post-surgical instruments used and the specific type of cervical fracture or dislocation.

With the exception of alcohol abuse and HIV, the Null Hypothesis ($H_o$) was set which stated that there would be no significant association between the co-existing medical conditions and the development of short-term post-surgical complications. With respect to alcohol abuse and HIV, the Alternate Hypothesis ($H_a$) was however set which stated that there would be a significant association between alcohol abuse or HIV and the development of short-term post-surgical complications. The Alternate Hypothesis ($H_a$) was set based on the reports of Carragee (1997), Tran *et al*. (2000), Delgado-Rodriguez *et al*. (2003), Young *et al*. (2005) and King (2006).

## 1.6 SCOPE OF THE STUDY

In this study 20 patients who presented at the Spinal Unit of the King George V Hospital with traumatic cervical spine fractures or dislocations were observed over a 12-week period. The clinical presentation, types of fractures, conservative and surgical intervention, short-term post-conservative care, short-term post-intervention (i.e. post-conservative and post-surgical) complications and short-term post-surgical rehabilitative care were recorded.  The patients were monitored for three weeks post-intervention for the development of any post-intervention complications. Patients who were discharged from the hospital prior to three-weeks were given a date on which to return for a follow-up consultation. If this date occurred within three weeks post-intervention, the data of this patient was recorded. All patients provided informed consent in order for the researcher to inspect their medical records.

**Note:**

Throughout the write-up of this study the terms ‘patients’ and ‘subjects’ are used interchangeably.

# CHAPTER TWO

# LITERATURE REVIEW

## 2.1 INTRODUCTION

The cervical spine was a common site for orthopaedic-related injuries (Teo and Ng, 2001). Cervical spine fractures were common injuries with 55% occurring in the cervical region (Timothy *et al.,* 2004). The epidemiological data on cervical spine fractures in general varied (Walter *et al.,* 1984; Ryan and Henderson, 1992; Vieweg *et al*., 2000; Grauer *et al.,* 2005; Later *et al*., 2005; Lenoir *et al*., 2006; Malik *et al.,* 2008) in the literature as did the management of these fractures (Perry and Nickel, 1959; Nickel *et al*., 1968; Johnson *et al*., 1977; Koch and Nickel, 1978; Johnson *et al.,* 1981; Ryan and Taylor, 1993; Vieweg *et al*., 2000; Timothy *et al.,* 2004; Eriksen, 2005; Grauer *et al*., 2005). Post-treatment complications were a concerning factor for patients undergoing any type of surgery (Jellis, 1988; Carragee, 1997; Young *et al*., 2005, King, 2006) due to the high prevalence of HIV/AIDS in South Africa (Lin *et al*., 2004; Harling *et al.,* 2008; Littlewood, 2008). The epidemiology, clinical presentation of cervical spine fractures and the development of post-intervention complications has not yet been described in the South African public health-care setting.

## 2.2 AN OVERVIEW OF THE RELEVANT ANATOMY OF THE CERVICAL SPINE AND HEAD

### 2.2.1 The Vertebral Column

The vertebral column (VC), a major component of the axial skeleton, extends from the base of the skull to the tip of the coccyx. In most adults it ranges from 72 to 75 cm in length (Moore and Dalley, 1999). The osseous vertebrae comprises approximately 75% of the VC while the fibrocartilaginous intervertebral discs (IVDs) contributes significantly (about 25%) to its structure (Moore and Dalley, 1999). There are five distinct functional regions in the VC *viz.* the cervical, thoracic, lumbar, sacral and coccygeal areas and two transitional areas *viz*. the cervico-thoracic and thoracolumbar areas. In a typical adult there are usually 33 vertebrae; seven are found in the cervical region, 12 in the thoracic region, five in the lumbar region, five fused vertebrae in the sacrum (Rubin and Safdieh, 2007) and four to five fused segments constitute the coccyx (Moore and Dalley, 1999; Standring, 2005).

### 2.2.2 Curvature of the Vertebral Column

The VC is not a straight, rod-like structure. Rather, there are two types of curvatures in the sagittal plane that are located in distinct areas of the spine (Moore and Dalley, 1999). The cervical and lumbar regions have a curve that is convex anteriorly in the sagittal plane, the lordotic curve, while the thoracic and sacral regions are convex posteriorly resulting in kyphotic curves. The lumbar curvature becomes obvious when an infant begins to walk and assumes an upright posture, while the cervical curvature becomes prominent when the infant begins to lift up its head and neck especially during the crawling phase (Moore and Dalley, 1999). The cervical lordosis contributes to the flexibility of the cervical spine (Bland, 1994). The primary mechanical function of the curvatures of the spine is to serve as a shock absorber, thereby preventing more injury than if the spine were straight (Hirsch and Nachemson, 1954).

### 2.2.3 The Osseous Cervical Spine

The cervical vertebrae which are the smallest of the 24 moveable vertebrae may be divided into two groups i.e. typical and atypical vertebrae.

#### A) Typical Cervical Vertebrae

The typical cervical vertebra has a small, relatively broad vertebral body (VB) with a short bifid spinous process (SP). Each vertebra has two small transverse processes (TVPs) which project laterally and end as the anterior and posterior tubercles (Parke and Sherk, 1989; Standring, 2005). The foramen transversarium is located within each of the

TVPs which serve as a tunnel for the passage of the vertebral arteries. The TVPs of the cervical vertebrae end in two projections i.e. the anterior and posterior tubercles (Moore and Dalley, 1999). The anterior surface of the VB is convex while its posterior surface is either flat or minimally concave. Two uncinate processes arise from the outer circumference of the upper anterior margins of the VB (Parke and Sherk, 1989). The triangular vertebral foramen, which accommodates the cervical enlargement of the spinal cord, is formed by the pedicles projecting posterolaterally and the laminae projecting posteromedially (Standring, 2005).

The superior and inferior articular processes are found at the junction of the lamina and pedicle (Rubin and Safdieh, 2007). The superior articular facets are flat and ovoid (Standring, 2005) and face supero-posteriorly (Moore and Dalley, 1999; Standring, 2005), while the inferior articular facets are directed more anteriorly and inferiorly (Moore and Dalley, 1999) and lie closer to the coronal plane than the superior facets (Standring, 2005).

**B) Atypical Cervical Vertebrae**

**i) The Atlas (C1)**

The atlas is the first cervical vertebra (C1), supported the head (Standring, 2005). It does not possess a VB as it consists of two lateral masses connected by a short anterior and a longer posterior arch. The transverse ligament retains the odontoid of the axis (C2) against the anterior arch (Croft, 1995). This divides the vertebral canal into two compartments, the anterior third of which is occupied by the odontoid process of the axis and the posterior compartment occupied by the spinal cord and its coverings (Standring, 2005). The anterior arch is convex anteriorly and carries the anterior tubercle to which the anterior longitudinal ligament (ALL) attaches. The posterior concave surface of the anterior arch serves as a facet for the odontoid process of C2. The posterior arch, which corresponds to the lamina of a typical vertebra, has a wide groove for the vertebral artery and the first cervical nerve on its superior surface (Moore and Dalley, 1999). The TVPs of the atlas are longer than all cervical vertebrae except the seventh (Standring, 2005). The superior articular processes of the atlas are concave (Moore and Dalley, 1999) and face superiorly and medially in order to receive the occipital condyles, (Bland, 1994). The inferior articular processes are also concave and face inferiorly and medially in order to articulate with the superior articular processes of the axis (Bland, 1994).

**ii) The Axis (C2)**

The axis or the second cervical vertebra acts as a pivot for the rotation of the atlas and head around the odontoid process which is a tooth-like process that projects superiorly from the VB of C2 (Rubin and Safdieh, 2007). In an adult, the odontoid process is approximately 15 mm in length usually with a tilt of 14° posteriorly, or less often, anteriorly, on the body of the axis. The odontoid process can also tilt ten degrees laterally (Standring, 2005). The anterior surface of the odontoid process has an ovoid articular facet for the anterior arch of the atlas (Moore and Dalley, 1999). The superior articular processes of the axis are convex in order to receive the lateral mass of the atlas, while the inferior articular processes are similar to that of the rest of the typical cervical vertebrae (Bland, 1994). The downward anterior border of the VB serves as an attachment site for the ALL (Standring, 2005) while the posterior border of the VB serves as an attachment site for the posterior longitudinal ligament (PLL) and the tectorial membrane (Palastanga *et al.,* 2000). The foramen transversarium is directed laterally as the vertebral artery turns abruptly laterally under the superior articular facet (Standring, 2005). The SP is large, has a bifid tip and a broad base which is inferiorly concave.

**iii) Vertebra prominens (C7)**

This vertebra has a long SP which is visible at the lower end of the nuchal furrow (Moore and Dalley, 1999). It ends in a prominent tubercle for the attachment of the ligamentum nuchae and muscles (Standring, 2005). The thick and prominent TVPs lie behind and lateral to the transverse foramina (Moore and Dalley, 1999). The vertebral arteries do not pass through the foramen transversarium of C7 (Bland, 1994; Moore and Dalley, 1999; Rubin and Safdieh, 2007). Instead, they pass anterior to the TVP of C7 (Moore and Dalley, 1999; Rubin and Safdieh, 2007). The foramen transversarium of C7 allows for the passage of small accessory veins (Moore and Dalley, 1999). The superior and inferior articular processes of C7 are steeply inclined and resemble the articular processes of the thoracic spine (Bland, 1994).

**C) The Zygapophysial Joints**

Zygapophysial or facet joints are synovial, paired, diarthrodial joints of the vertebral arches i.e. between the superior and inferior articular processes of adjacent vertebrae (Bland, 1994; Moore and Dalley, 1999). Their surface area is about two-thirds that of the intervertebral joints. The fibrous capsule is thin and loosely attached to the articular facets of the adjacent levels (Bland, 1994; Standring, 2005). These fibrous capsules which are longer and looser in the cervical region (Standring, 2005) are replaced entirely by the ligamentum flavum in the lumbar spine (Bogduk, 1997). In addition to the intra-articular subcapsular fat, meniscoid structures which could be adipose, collagenous or fibroadipose in nature extends between the crevices of the articular structures (Bogduk, 1997). These joints are innervated by the medial branches of the dorsal primary rami of the spinal nerves which send articular branches to the levels above and below (Moore and Dalley, 1999; Standring, 2005). The superior facets of the joint face anteriorly and inferiorly at an angle of 45° while the inferior facets face posteriorly and superiorly, also at an angle of 45° (Bland, 1994). Complex movement of these joints on lateral flexion and rotation is possible since the curvatures of these facets do not fit each other perfectly (Bland, 1994).

**D) Uncovertebral or Von Luschka's Joints**

The lateral edges of the superior surface of each VB are sharply turned upward to form the uncinate processes that are characteristic of the cervical region (Parke and Sherk, 1989; Standring, 2005). The uncinate processes of the inferior vertebra and the inferior lip of the superior vertebra form the uncovertebral joints or joints of Von Luschka (Greenstein, 1994) which are located between the uncinate processes of C3-C6 (Moore and Dalley, 1999). Hollinshead and Rosse (1985) consider their purpose is to limit lateral flexion and flexion and to provide support to the anterior and lateral aspects of the cervical IVD.

### 2.2.4 An Overview of the Anatomy of the Intervertebral Disc of the Cervical spine

The IVDs which serve as a connection between the articulating surfaces of the adjacent vertebrae (Moore and Dalley, 1999) constitute 20-33% of the height of the VC (Greenstein, 1994). The components of the IVD include the annulus fibrosis (AF), the nucleus pulposus (NP) (Moore and Dalley, 1999) and the cartilaginous endplate (Greenstein, 1994).

The AF is the tough outer component composed of laminated fibrocartilage (Greenstein, 1994; Croft, 1995; Moore and Dalley, 1999) whose outer portion is attached to the vertebra by Sharpey's fibers (Greenstein, 1994; Croft, 1995). This attachment at the periphery which is stronger than the central cartilaginous plate attachment (Panjabi and White, 1978) is clinically significant since hyperextension and hyperflexion forces produce avulsion of the annulus occurring in this area (Croft, 1995). The cartilaginous endplates are composed of both hyaline cartilage (Greenstein, 1994) and fibrocartilage (Standring, 2005) which, with increasing age are eventually replaced by bone (Greenstein, 1994). The IVDs are generally scantly innervated (Cassinelli *et al*., 2001) with sensory fibers in the peripheral annulus (Mendel *et al.,* 1992).

The gelatinous central mass of the IVD is the avascular NP (Greenstein, 1994; Moore and Dalley, 1999) which receives its nourishment *via* diffusion from blood vessels at the periphery of the annulus fibrosis (Moore and Dalley, 1999). The NP is composed of 70-90% of water (Greenstein, 1994) and its main function is to evenly distribute stresses applied to the spine.

### 2.2.5 Ligamentous Anatomy

There are many important ligaments in the cervical spine responsible for static stabilization (Bland, 1994; Croft, 1995; Moore and Dalley, 1999; Dean and Mitchell, 2002; Standring, 2005).

The skull and C1 are connected by the anterior and posterior atlanto-occipital membranes which extend from the anterior and posterior arches of C1 to the anterior and posterior margins of the foramen magnum (Croft, 1995). The ALL is a strong band that extends from the base of the occiput to the anterior tubercle of C1 and the front of the body of C2 caudally to the sacrum (Moore and Dalley, 1999; Standring, 2005). It attaches to the anterior aspect of the vertebral bodies and IVDs. The PLL runs on the posterior aspects of the vertebral bodies from C2 to the sacrum. It forms the tectorial membrane cranially and is thicker in the thoracic spine.

The transverse ligament of the atlas is diamond-shaped and firmly holds the odontoid process to the anterior arch of the atlas. It is the primary ligament involved in preventing subluxation of the odontoid process (Bland, 1994). It is made up of two bands. The first passes up to the occiput and the other passes down to the body of the axis completing the cruciate ligament of the atlas (Bland, 1994). The apical ligament runs from the tip of the odontoid process to the anterior aspect of the foramen magnum. The alar ligaments extend from the sides of the odontoid process to the lateral aspects of the foramen magnum (Moore and Dalley, 1999). Together these ligaments check the motion of rotation of the head (Moore and Dalley, 1999).

The nuchal ligament or ligamentum nuchae is a fibroelastic, intermuscular septum which extends from the external occipital protuberance and posterior border of the foramen magnum (Moore and Dalley, 1999) to the SP of C7 (Moore and Dalley, 1999; Standring, 2005). There is a midline attachment to the posterior spinal dura at the atlanto-occipital and atlanto-axial levels (Dean and Mitchell, 2002). The intertransverse ligaments attach to adjacent TVPs (Moore Dalley, 1999; Standring, 2005) and are poorly developed in the cervical region (Croft, 1995). The interspinous ligament is a poorly developed fibroelastic septum in the cervical spine, extending from the external occipital protuberance to C7, where it is largely replaced by the ligamentum nuchae (Croft, 1995). The supraspinous ligament on the other hand, is a strong fibrous cord connecting the tip of C7 SP to the sacrum (Standring, 2005).

The paired ligamenta flava runs between the inferior aspect of the posterior arch of the atlas to the lamina of the axis below (Croft, 1995) and connects the laminae of adjacent vertebrae in the vertebral canal (Standring, 2005). The ligaments are thin, broad and long in the cervical region, thicker in the thoracic region but thickest in the lumbar region (Moore and Dalley, 1999; Standring, 2005). The ligamenta flava helps to preserve the normal curvatures of the vertebral column by facilitating the restoration of the body to an erect posture after flexion, possibly protecting IVDs from injury (Moore and Dalley, 1999; Standring, 2005).

### 2.2.6 The Intervertebral Foramina

This is the foramen where the dorsal and ventral spinal nerve roots unite to form the spinal nerve (Rubin and Safdieh, 2007). The boundaries of the intervertebral foramen (IVF) are as follows (Rubin and Safdieh, 2007):

- superiorly by the pedicles of the vertebrae above
- inferiorly by the pedicles of the vertebrae below
- anteriorly by the ivds and by the facet joints
- posteriorly by the facet joints

Compression and inflammation of a nerve root/s in close proximity to the neuroforamen results in cervical radiculopathy (Abbed and Coumans, 2007). Common causes include IVD herniation and spondylosis which occur with or without myelopathy (Polston, 2007).

### 2.2.7 Muscles of the Head and Neck

The related musculature of the head and the cervical spine is presented in **Table 2.1**.

**Table 2.1 Muscles of the head and neck**

| ***Intrinsic mm – upper c/s** | **Intrinsic mm – Lower c/s** $^{\alpha}$ | **Accessory mm** $^{\alpha}$ | **Large flexors**$^{\alpha}$ | **Large extensors**$^{\alpha}$ |
|---|---|---|---|---|
| Rectus capitis anterior minor (Kapandji, 1974) | Longus colli | Mylohyoid | Sternocleidomastoid | Trapezius |
| Rectus capitis anterior major (Kapandji, 1974) | Longissimus cervicis | Digastric (ant. belly) | Anterior scalene | Splenius capitis |
| Longus capitits | **Transversospinalis:** | Sternohyoid | Middle scalene | Splenius cervicis |
| Rectus capitis lateralis | | Sternothyroid | Posterior scalene | Levator scapulae |
| **Suboccipital mm**: | Semispinalis cervicis | Omohyoid | Scalenus minimus | Semispinalis capitis |
| Rectus capitus posterior major | Semispinalis capitis | | | Longissimus |
| Rectus capitis posterior minor | Rotatores | | | Iliocostalis cervicis |
| Obliquus capitis inferior | Multifudus | | | Spinalis |
| Obliquus capitis superior | | | | |

**mm = muscles; c/s = cervical spine; ant = anterior**
***These refer to muscles that have their origin and insertion on the skull and the cervical spine (Croft, 1995)**
$^{\alpha}$ **from Croft (1995)**

The muscles of the cervical spine are responsible for providing support to the head as well as in the initiation of motion in the cervical spine (Eriksen, 2005). According to Moskovich (2001), muscle strength and control are vital in maintaining the balance between the head and neck. He added that a significant amount of load was observed in the cervical spine during flexion especially in the lower cervical segments (Moskovich, 2001). The most common motion seen in the cervical spine is that of forward flexion of the head where the posterior musculature of the cervical spine acts to lower the head eccentrically (Lehmkuhl and Smith, 1983). The larger muscles of the cervical spine which are further away from the spine are considered phasic while those closer and smaller to the cervical spine are considered tonic in nature (Enoka, 1988; Gowitzke and Milner, 1988). Intrinsic muscles of the cervical spine are responsible for posture control of the VC (Greenstein, 1994).

### 2.2.8 Anatomy of the Skull

The skull is the most complex osseous structure in the body (Standring, 2005). It is subdivided into the cranium and the mandible portions (Palastanga *et al.,* 2000). Most of the bones of the skull articulate by relatively fixed joints (synarthrodial joints) with the exception of the mandible which can be easily detached from the temporomandibular joint (TMJ). The skull is composed of 28 separate bones most of which are paired and flat. The primary function of the skull is to serve as protection for the brain, the organs of special sense and the cranial parts of the respiratory and digestive systems (Standring, 2005). In addition to this it also provides attachments for many muscles of the head and neck allowing for movement (Standring, 2005).

### 2.2.9 Brain

The brain was composed of the cerebrum, cerebellum and brainstem. The brainstem could be further divided into the midbrain, pons and medulla oblongata (Moore and Dalley, 1999).

The brainstem which is located in the posterior cranial fossa is the site of termination of many ascending and descending tracts. Almost all the canial nerve nuclei are located in the brainstem, except the first two nuclei which are evaginations of the brain itself (Waxman and DeGroot, 1995). Damage to the brainstem is often devastating and life-threatening (Standring, 2005) since this is the area that houses the cardiorespiratory centers of the brain.

The corticospinal tract or pyramidal tract is the most important pathway in the central nervous system (CNS) (FitzGerald *et al.,* 2007). It originates from the motor cortex which is situated in the precentral gyrus. Thereafter, it descends through the corona radiata, internal capsule and midbrain, and travels to the caudal end of the brainstem before it crosses over to the opposite side of the spinal cord (FitzGerald *et al*., 2007). This tract is important in its function of voluntary motion. Any disruptions of this tract lead to paresis (weakness) or motor paralysis. Also, it extends the entire length of the CNS, rendering it vulnerable to disease on one side and to spinal cord disease or trauma on the other side (FitzGerald *et al*., 2007).

### 2.2.10 The Basal Ganglia

The basal ganglia refer to a collection of masses of gray matter which are situated in each cerebral hemisphere (Snell, 1997). The basal ganglia receives input from the cerebral cortex (Rubin and Safdieh, 2007), thalamus, subthalamus, brainstem and substantia nigra (Snell, 1997). After processing the information is relayed *via* the thalamus back to the cerebral cortex (Rubin and Safdieh, 2007). The structures involved include the striatum which consist of the caudate nucleus, putamen of the lentiform nucleus and nucleus accumbens. The globus pallidus of the lenitform nucleus is made up of the pallidum where a lateral and medial segment is present.

### 2.2.11 The Cerebellum

The cerebellum lies dorsal to the pons and medulla (Waxman and DeGroot, 1995; Moore and Dalley, 1999) and ventral to the posterior part of the cerebrum (Moore and

Dalley, 1999). It lies in the posterior cranial fossa (Waxman and DeGroot, 1995; Snell, 1997; Moore and Dalley, 1999) and also forms the roof of the fourth ventricle (Waxman and DeGroot, 1995). The cerebellar hemispheres are separated by a middle portion called the vermis (Waxman and DeGroot, 1995; Snell, 1997; Moore and Dalley, 1999). The cerebellum is involved in co-ordination of skilled voluntary movement, controlling equilibrium (Waxman and DeGroot, 1995; Snell, 1997) and muscle tone *via* the vestibular system (Waxman and DeGroot, 1995).

### 2.2.12 The Spinal Cord

The spinal cord is located within the VC in the upper two-thirds of the vertebral canal. It is normally 42-45cm long in adults and is continuous with the brainstem at its upper end (Standring, 2005). The spinal cord controls the functions of and receives afferent input from the trunk and limbs. Afferent and efferent connections travel in 31 pairs of segmentally arranged spinal nerves (Standring, 2005; Moore and Dalley, 1999). These are attached to the cord as dorsal and ventral rootlets which unite to form the spinal nerves proper. The dorsal roots carry the primary afferent nerve fibres from the cell bodies located in dorsal root ganglia. Ventral roots carry the efferent fibers from cell bodies located in the spinal grey matter (Moore and Dalley, 1999).

The conus medullaris is the conical distal end of the spinal cord. The filum terminale which extends from the tip of the conus is attached to the distal dural sac (Palastanga *et al*., 2000) and consists of pia and glial fibers and often a vein (Standring, 2005). Even though the spinal cord ends at the L1 vertebra, the nerve roots corresponding to a cord segment form a spinal nerve exiting the IVF at the corresponding level (Darby, 2005). The more inferior rootlets tend to exit at an oblique angle with the lumbosacral roots being the longest and most oblique and are referred to as the cauda equina (Darby, 2005).

Internally, the spinal cord is differentiated into a central core of grey matter surrounded by white matter. The grey matter is configured in a characteristic “H”, or butterfly-shape which has dorsal and ventral horns (Palastanga *et al.,* 2000). Generally, neurons situated in the dorsal horn are primarily concerned with sensory functions and those in the ventral horn are concerned with motor activity (Standring, 2005). A small lateral horn can be additionally present at certain levels marking the location of the cell bodies of preganglionic sympathetic neurons (Standring, 2005). The central canal which is a vestigial component of the ventricular system, lies at the centre of the spinal grey matter and runs the length of the cord. The white matter of the spinal cord consists of ascending and descending axons which link spinal cord segments to one another and the spinal cord to the brain (Standring, 2005). The spinal cord is widened in two regions: the cervical enlargement and the lumbar enlargement (Palastanga *et al.,* 2000). The lumbar enlargement tapers off to form the conus medullaris. The nerves of the brachial plexus originate at the cervical enlargement while the nerves of the lumbosacral plexus arise from the lumbar segment (Palastanga *et al.,* 2000).

The two major ascending somatic sensory pathways are referred to as the posterior column-medial lemniscal and spinothalamic pathways (FitzGerald *et al.* (2007). The posterior column-medial lemniscal pathway is made up of the fasciculus gracilis (which receives information from the lower limb and trunk) and fasciculus cuneatus (which receives information from the upper limb and upper trunk) whose nucleus is present in the medulla and functions in determining discriminative touch, joint position sense and vibration from the legs and arms, respectively. The nucleus of the spinothalamic pathway is found in the thalamus and functions in pain and temperature sensation discrimination. Unilateral section of the spinothalamic tract can lead to a loss of sensation on the contralateral side to a level that is one segment below the level of the lesion because of its fibers which cross in an oblique fashion (Rubin and Safdieh, 2007). The posterior and anterior spinocerebellar tracts have their nucleus present in the cerebellum and serve to provide proprioceptive input from muscle and skin receptors. The spinoreticular tract contributes to the emotional experience of pain and the destination of this tract is the reticular formation in the brainstem (Rubin and Safdieh, 2007).

The rubrospinal tract controls proximal muscles especially flexors and begin at the contralateral red nucleus (Rubin and Safdieh, 2007). The nucleus of the lateral vestibulospinal tract is found in the ipsilateral lateral vestibular nucleus and is involved in posture control (FitzGerald *et al.,* 2007; Rubin and Safdieh, 2007). Muscle spindle state is controlled by the lateral and medial reticulospinal tracts. The nucleus of this tract is found in the ipsilateral and contralateral reticular formation (FitzGerald *et al.,* 2007; Rubin and Safdieh, 2007).

**2.2.13 The Spinal Nerves**

There are 31 pairs of spinal nerves (Moore and Dalley, 1999; Ramani, 2004); eight cervical, 12 thoracic, five lumbar, five sacral and one coccygeal (Moore and Dalley, 1999). The dorsal and ventral roots of the mixed spinal nerves are made up from rootlets which arise from the dorsal and ventral aspects of the spinal cord (Moore and Dalley, 1999). The dorsal roots carry afferent or sensory fibers from skin, subcutaneous tissue and viscera while the ventral roots carry efferent or motor fibers to skeletal muscle and contain presynaptic autonomic fibers (Moore and Dalley, 1999). The ventral rami of C5–C8 nerves and the ventral ramus of T1 contribute to the formation of the brachial plexus (Moore and Dalley, 1999).

**2.2.14 Arterial Supply to the Spinal Cord and Vertebrae**

The aorta and its branches are largely responsible for blood supply to the spinal cord. The spinal cord in the cervical region receives its branches from the vertebral arteries *viz*. the anterior and posterior spinal arteries (Darby, 2005; Rubin and Safdieh, 2007). The anterior spinal artery supplies the anterior two-thirds of the spinal cord while the posterior spinal artery supplies the posterior spinal columns (Rubin and Safdieh, 2007). The anterior spinal artery and posterior spinal artery anastomose at the level of the conus medullaris forming a loop or basket (Lazorthes *et al.,* 1971). Here, the artery of the filum terminale branches off and courses the ventral surface of the filum terminale (Djindjian *et al.,* 1988).

Spinal arteries receive additional supply from the radicular arteries off the aorta (Rubin and Safdieh, 2007) which branch into anterior and posterior radicular arteries and which supply the anterior spinal artery and posterior spinal arteries respectively (Rubin and Safdieh, 2007). Each anterior and posterior artery supplies radicular branches to the neighbouring roots, and the posterior radicular arteries in particular supply branches to the dorsal root ganglion (Darby, 2005).

#### 2.2.15 Venous Drainage of the Spinal Cord and Vertebra

The veins of the spinal cord are situated in the pia mater and consist of two median longitudinal veins, one of which is present anterior to the anterior median fissure and the other posterior to the posterior median septum of the spinal cord (Middleditch and Oliver, 2005). These channels run behind the ventral and dorsal roots respectively and drain into the internal vertebral venous plexus (Middleditch and Oliver, 2005).

The external vertebral venous plexus is made up of the anterior and posterior external venous plexuses which lie anterior and posterior to the vertebral bodies and vertebral laminae, respectively (Middleditch and Oliver, 2005; Rubin and Safdieh, 2007). The plexus of veins in the epidural space of the spinal cord are referred to as the internal vertebral venous plexus (Rubin and Safdieh, 2007) also known as Batson’s plexus (Batson, 1940). The internal and external vertebral venous plexuses as well as the veins of the spinal cord drain into the intervertebral veins (Middleditch and Oliver, 2005) which exit the spinal canal *via* the IVF (Middleditch and Oliver, 2005; Rubin and Safdieh, 2007).

#### 2.2.16 Cranial Meninges

The brain and spinal cord are enveloped by three concentric membranes *viz.* the meninges. The function of the meninges includes protection and support of the brain and spinal cord. The outermost meningeal layer is the dura mater, beneath which lies the arachnoid mater (Palastanga *et al.,* 2000). The inner-most layer is the pia mater. The dura mater is separated from the arachnoid mater by the subdural space. Beneath the arachnoid mater lies the subarachnoid space which contains CSF secreted by the choroid plexus (Standring, 2005).

### 2.2.17 Blood Supply to the Brain

The common carotid, internal and external carotid arteries are the major source of blood to the neck (Standring, 2005) while additional arteries arise from branches of the subclavian artery, especially the vertebral artery (Moore and Dalley, 1999; Standring, 2005). The common carotid artery is divided into the external and internal carotid arteries at the level of C3-C4 i.e. level of the upper border of the thyroid cartilage of the larynx (Standring, 2005).

The internal carotid arteries ascend vertically to the base of the skull (Snell, 1997; Moore and Dalley, 1999) and enter the cranial cavity through the carotid canals which are situated in the temporal bones (Snell, 1997; Moore and Dalley, 1999; Standring, 2005). The internal carotid artery supplies most of the ipsilateral cerebral hemisphere, eye, accessory organs, forehead and in part, the nose (Standring, 2005). Each internal carotid artery pierces the roof of the cavernous sinus and enters the subarachnoid space, where it gives off the ophthalmic, posterior communicating and anterior choroidal arteries before dividing into the anterior and middle cerebral arteries (FitzGerald *et al.,* 2007). The internal carotid artery and its branches are referred to as the anterior circulation of the brain (Moore and Dalley, 1999).

The anterior cerebral artery supplies the medial and superior surfaces of the brain as well as the frontal pole (Moore and Dalley, 1999). Close to the anterior communicating artery, it gives off the medial striate artery (recurrent artery of Heubner), which contributes to the blood supply of the internal capsule (FitzGerald *et al.,* 2007). Cortical branches supply the medial surface of the hemisphere as far back as the parietooccipital sulcus (Snell, 1997; FitzGerald *et al.,* 2007). The branches overlap onto the orbital and lateral surfaces of the hemisphere (FitzGerald *et al*., 2007).

The middle cerebral artery is essentially a continuation of the internal carotid (Snell, 1997; FitzGerald *et al.,* 2007), receiving 60-80% of the carotid blood flow (FitzGerald *et a*l., 2007). It supplies the lateral surface of the brain (Moore and Dalley, 1999) by entering the lateral sulcus and supplying two-thirds of the lateral surface of the hemisphere (Moore and Dalley, 1999; FitzGerald *et al.,* 2007). The posterior cerebral artery, a branch of the basilar artery (FitzGerald *et al*., 2007) supplies the inferior surface of the brain and the occipital pole (Moore and Dalley, 1999). Injury to the middle meningeal artery, a branch of the external carotid artery, from head trauma could cause an epidural hematoma leading to death as a result of herniation of brain structures (Rubin and Safdieh, 2007).

The right subclavian artery arises from the brachiocephalic trunk while the left one arises from the aortic arch (Standring, 2005). The subclavian artery gives off three branches: first, the vertebral artery, which arises from the root of the neck (Moore and Dalley, 1999) as the first branch of the first part of the subclavian artery (Moore and Dalley, 1999; Standring, 2005); second, the thyrocervical trunk and third, the costocervical trunk, bilaterally. The vertebral arteries pass through the transverse foramen of all of the cervical vertebrae except the seventh; curves medially behind the lateral mass of the atlas and enters the cranium via the foramen magnum (Standring, 2005). They are usually unequal in size, the left being larger than the right (Moore and Dalley, 1999). They unite at the caudal border of the pons to form the basilar artery (Moore and Dalley, 1999) which is divided at the upper border of the pons into the two posterior cerebral arteries (FitzGerald *et al*., 2007; Snell, 1997). The vertebrobasilar arterial system and its branches contribute to the posterior circulation of the brain (Moore and Dalley, 1999).

The cerebral arterial circle (Circle of Willis) which lies at the base of the brain in the interpeduncular fossa (Snell, 1997) is completed by a linkage of the posterior communicating artery with the posterior cerebral on each side, and by linkage of the two anterior cerebral arteries by the anterior communicating artery (FitzGerald *et al.,* 2007). The Circle of Willis allows blood that enters by either internal carotid or vertebral arteries to be distributed to any part of both cerebral hemispheres. Although the cerebral arteries anastomose with one another at the Circle of Willis and by means of branches on the surface of the cerebral hemispheres, once they enter the brain substance, no further anastomoses occurs (Snell, 1997).

### 2.2.18 Venous Drainage of the Neck and Brain

Dural venous sinuses are venous channels lined by mesothelium which lie between the inner and outer layers of dura. The superior sagittal sinus drains blood from the skull, scalp, meningeal and cerebral veins. Clinically, a thrombosis from possible head trauma could cause an increase in intracranial pressure leading to a backup of venous drainage (Rubin and Safdieh, 2007). The inferior sagittal sinus drains the deeper veins (Rubin and Safdieh, 2007). If the cavernous sinus, which drains the superior ophthalmic vein and empties into the petrosal sinuses, has a thrombosis, the result will be cranial nerve damage and venous backup in the retina (Rubin and Safdieh, 2007). The superior and inferior petrosal sinuses drain blood from the cavernous sinus and drain into the transverse and internal jugular veins respectively. The straight sinus drains the inferior sagittal sinus and the great cerebral vein. The internal jugular vein receives blood from the skull, brain, superficial parts of the face and much of the neck (Standring, 2005).

### 2.2.19 Ventricular system

The ventricles of the brain are the lateral, third ventricle and the fourth ventricle (Snell, 1997, Moore and Dalley, 1999). The lateral ventricles are the largest cavities of the ventricular system (Moore and Dalley, 1999). They form a C-shaped cavity from which the CSF exits *via* the paired interventricular foramen also known as the foramen of Monro (Snell, 1997; Moore and Dalley, 1999; Rubin and Safdieh, 2007). The third ventricle is a thin, slit-like structure found between the thalamus which communicates with the fourth ventricle *via* the tube-like cerebral aqueduct (of Sylvius) (Snell, 1997; Moore and Dalley, 1999). The fourth ventricle is a rhomboid-shaped structure that circulates CSF to the pons and medulla (Snell, 1997; Rubin and Safdieh, 2007).

### 2.2.20 Cerebrospinal fluid

The CSF is a clear, colourless fluid which in solution possesses inorganic salts similar to those in blood plasma (Snell, 1997). It is formed in the choroid plexus in the lateral ventricles, third ventricle and fourth ventricle and exit the ventricular system in the medulla *via* the foramina of Luschka and Magendie (Moore and Dalley, 1999; Rubin and Safdieh, 2007). The CSF serves as a cushion between the CNS and the surrounding bones during any trauma (Snell, 1997; Moore and Dalley, 1999). The CSF is absorbed into the blood *via* the arachnoid granulations (Snell, 1997; FitzGerald *et al*., 2007).

### 2.2.21 Cervical sympathetic trunk

The sympathetic trunk begins at C1 and lies on the prevertebral fascia in the anterolateral aspect of the VC (Moore and Dalley, 1999; Standring, 2005). It is not connected directly to any spinal nerves, but is associated with cervical sympathetic ganglions (Standring, 2005) *viz*. the superior, middle and inferior cervical ganglion (Moore and Dalley, 1999; Standring, 2005). The sympathetic ganglia can be divided into paravertebral or prevertebral ganglia (Benarroch *et al.*, 1999).

A lesion in the cervical sympathetic trunk can result in a condition known as Horner's syndrome where ptosis (drooping of the eyelid) (Moore and Dalley, 1999), enophthalmos (sunken eyeball), meiosis (constricted pupil) and anhydrosis (vasodilatation and lack of thermal sweating on the affected side (Standring, 2005) may be observed.

### 2.2.22 Lymph nodes

All lymph nodes in the cervical spine eventually end up draining into the deep cervical chain of lymph nodes. The superficial structures drain into the superficial cervical lymph nodes (Moore and Dalley, 1999) which eventually drain into the inferior deep cervical lymph nodes (Moore and Dalley, 1999) and into the supraclavicular nodes. At the superior and inferior aspects of the sternocleidomastoid muscle lie the tonsillar and supraclavicular nodes respectively (Bickley and Szilagyi, 2003). The prelaryngeal, pretracheal, paratracheal and retropharyngeal nodes are other deep cervical nodes that may be found (Moore and Dalley, 1999; Standring, 2005). The jugular trunk is formed by efferents of the deep cervical nodes (Moore and Dalley, 1999; Standring, 2005).

### 2.2.23 Viscera of the neck

The cervical viscera can be divided into layers. In the most superficial layer of cervical viscera, the thyroid, parathyroid and salivary glands are found. The middle layer is made up of the larynx and the trachea, while the deepest and final layer is composed of the pharynx and esophagus (Moore and Dalley, 1999).

The thyroid gland lies between the levels of C5–T1 vertebrae, deep to the sternothyroid and sternohyoid muscles (Moore and Dalley, 1999). The pharynx extends from the base of the skull to the inferior border of the cricoid cartilage anteriorly and the inferior border of C6 vertebra posteriorly. The larynx is found at the C3-C6 levels of the vertebral bodies of C3–C6 vertebra. The trachea which is a fibrocartilaginous tube extends from the inferior end of the larynx at the level of T6 vertebra and ends at the level of the sternal angel or the T4-T5 IVD. The oesophagus begins posterior to the cricoid cartilage at the level of C6 (Moore and Dalley, 1999).

## 2.3 SYNOPSIS OF THE BIOMECHANICS OF THE CERVICAL SPINE

### 2.3.1 Range of Motion of the Cervical Spine

#### A) Cranio-cervical junction

The two distinct sections of the cervical spine are; the superior occipital segment containing the atlas and axis which join the occiput, and the inferior segment extending from the inferior aspect of the axis to the superior aspect of the first thoracic segment. Thus, the superior segment is made up of the atlantoaxial and atlanto-odontoid segment while the subaxial spine constitutes the inferior segment.

There is essentially no primary rotation at the atlanto-occipital segment (Werne, 1958; Mow and Hayes, 1991; Croft, 1995). Lateral flexion occurs at the atlanto-occipital and lower cervical spine joints. At C2 there are two degrees of coupled axial rotation for every three degrees of lateral flexion (Moskovich, 2001). Atlanto-occipital rotation occurs secondary to atlanto-axial rotation. The ROM between the atlas and occiput is about eight degrees lateral flexion and 13° of flexion-extension (Werne, 1958; Mow and Hayes, 1991; Croft, 1995; Moskovich, 2001).

On secondary rotation, there is displacement of the facets depending on the direction of rotation i.e. on left rotation there is anterior displacement of the right occipital facet with posterior rotation of the left occipital facet. The tension in the ligaments however, tends to pull the ipsilateral facet medially. This causes a linear displacement of two to three millimeters and lateral flexion to the contralateral side of rotation (Moskovich, 2001). Flexion is limited by contact of the odontoid process and the anterior margin of the foramen magnum while extension is limited by contact between the occiput and the posterior arch of C1 and C2 SP and the tectorial membrane (Croft, 1995). Extension of the skull results in all the vessels taking on a wavy and relaxed form allowing for maximal filling with blood (Breig, 1978). During flexion these vessels straighten and appear to have a decreased blood supply because of a narrowing of the lumen (Breig, 1978). In addition, flexion of the spine increases the strain on the spinal cord due to elongation (Harrison *et al*., 1999) which in turn places strain on the longitudinal vessels of the cord especially the posterior spinal arteries (Harrison *et al*., 1999). During cervical acceleration/deceleration trauma the cervical spine is placed under great degrees of strain which in addition to bony injury, results in vascular complications.

**B) Atlanto-axial and Atlanto-odontoid Segments**

This mobile area is composed of the atlanto-axial joint with the odontoid serving as a pivot and the two atlanto-axial joints which are found on either side (Moskovich, 2001). The inelastic transverse ligament does not permit more than two to three millimeters of anterior subluxation of C1 on C2 (Fielding *et al*., 1974) causing the C1-C2 lateral masses to articulate with some sliding and rolling during flexion and extension (Moskovich, 2001). Rotation at C1-C2 occurs with vertical translation along the Y-axis as well as a degree of AP displacement (Werne, 1957). According to Dvorak and Panjabi (1987), Penning and Wilmink (1987) and Dvorak *et al.* (1988), active axial rotation in one direction was 27°- 49° with a mean of 39° while the range of passive rotation was 29°- 46°. The atlantoaxial articulation permitted 47° of rotation in one direction, and 10° of flexion and extension (Croft, 1995). According to Dankmeijer and Rethmeier (1943) lateral flexion measured was about five degrees, but Croft (1995) reported that there was essentially no lateral flexion at this joint. Seventy percent of the total axial rotation of the cervical spine occurred between the occiput and C2 level (Moskovich, 2001).

Stretching or kinking of the vertebral arteries on extreme ranges of motion occurs at the C1-C2 segments (Croft, 1995). Extension and rotation of the neck to one side could alter blood flow in that particular artery (Noyes *et al.*, 1974) resulting in the target areas of that artery being deprived of blood supply.

**C) Subaxial Spine**

The cardinal movements in the lower cervical spine are flexion and extension (Bogduk and Mercer, 2002). Zygapophysial joints and uncovertebral joints are the major contributors to coupled motion in the lower cervical spine especially during lateral flexion and axial rotation (Yoganandan *et al.,* 2000, Moskovich, 2001). These could occur due to the oblique orientation of the zygapophyseal joints and the presence of the uncinate processes in the cervical spine (Milne, 1993). Coupled motion is defined as a consistent association of one motion about an axis with another motion about a second axis (White and Panjabi, 1990). When axial rotary and lateral flexion loads are applied to the cervical spine, the uncinate processes decreases motion coupling and cervical motion (Moskovich, 2001). In the subaxial spine the coupling pattern is such that during lateral flexion to the left, the SP moves to the right, and during lateral flexion to the right side, the SP moves to the left side (Lysell, 1969; Moroney *et al*., 1988). Each motion segment between C2-C7 vertebra averages from four to eight degrees rotation (Mimura *et al*., 1989). The majority of axial rotation occurs between C3-C7 (Croft, 1995) while rotation is about 45° to each side of neutral (Moskovich, 2001). The range of flexion is about 40° while that of extension is 24° (Moskovich, 2001).

Moskovich (2001) reported that the combined flexion and extension motion mean (± SD) of the cervical spine was 122° (± 18°) while total axial mean (± SD) rotation was 144° (± 20°). However, previous studies (Hole *et al*., 1995, Trott *et al.,* 1996 and Feipel *et al*., 1999) reported that the axial motion ranged from 139°- 149°. The combined mean (± SD) lateral flexion ROM was found to be 88° (± 16°) (Moskovich, 2001). Haynes and Edmonston (2002) reported a range of 80°- 93° for lateral flexion.

### 2.3.2 Functional Spinal Unit and Kinematic Chain

The spine is a mechanical structure which is made up of different types of living tissue including bones, ligaments and muscle as well as the IVDs. The cervical spine in particular, serves to support the skull, protect the brainstem, spinal cord and neurovascular structures and acts as a shock absorber for the brain (Moskovich, 2001). The kinematic chain refers to the collection of several connecting rigid body segments linked together in a linear fashion (Zatsiorsky, 2002; Wheeless, 2008). In the cervical spine, the kinematic chain is open at the cephalad end and closed at the caudal end. At the cephalad end lies the skull which houses the brain and is supported by the cervical spine (Moskovich, 2001). Therefore, any trauma or injury that occurs to the skull affects the brain as well as the cervical spine on which it rests.

The building block of the spinal column is the functional spinal unit (FSU) (Hall, 1999; Moskovich, 2001). The FSU is made up of the two adjacent vertebrae, the IVD in between as well as the ligaments surrounding the vertebrae (Moskovich, 2001). A VB consists of a central trabecular bone which is surrounded by a thin cortical shell (Schultz and Ashton-Miller, 1991). The principle function of the central portion of the VB is to resist compression and shear loading forces (Schultz and Ashton-Miller, 1991). According to Brinckmann *et al*. (1983) several studies report that endplate defects occur under compressive loads due to weakening in the central vertebral trabecular bone. The other structure carrying significant amount of compressive loads due to muscular and gravitational forces is the IVD (Schultz and Ashton-Miller, 1991).

An increase in pressure within the NP occurs when a load is applied to the IVD (Kumaresan *et al*., 1999) which helps to resist the axial load (Schultz and Ashton-Miller, 1991; Kumaresan *et al*., 1999). Of particular significance in the cervical spine is the weight of the head which is three times the weight of the neck and places a compressive force on the C2-T1 IVDs (Yoganandan *et al*., 2001). Since the head is eccentrically placed with respect to the cervical column, the IVDs not only resist pure loading (Pintar *et al.,* 1995; Yoganandan *et al*., 1997) but moment as well (Yoganandan *et al*., 2001). The VBs in the cervical spine either translate or rotate (Croft, 1995) in each of three orthogonal planes. This occurs for a total of six degrees of freedom (Panjabi *et al*., 1981).

### 2.3.3 Soft Tissue Biomechanics

The ligaments of the cervical spine are uniaxial structures that resist tensile forces (White and Panjabi, 1990). They are most effective when distracted along the direction of the fibers (Myklebust *et al.,* 1988). The ALL is most active during extension (Myklebust *et al.,* 1988) while the PLL and interspinous ligament are most effective during flexion. The PLL which lies closer to the center of rotation responds with less resistance to force than the ALL or the interspinous ligament (Yoganandan *et al*., 2001). A person who sustains a cervical spine fracture/injury may have concomitant ligament and muscle damage. A disruption of the anterior and even posterior muscular and osseoligamentous complexes is seen in injuries such as a traumatic spondylolisthesis where the mechanism of injury is hyperextension of the cervical spine (Timothy *et al.,* 2004). A hyperflexion strain can produce disruption of the posterior ligamentous complex (Timothy *et al.,* 2004). In a bilateral facet dislocation, there is disruption of all ligamentous structures with the exception of the ALL (Timothy *et al.,* 2004).

The ligamentum flavum affects the size of the spinal canal during flexion and extension (Breig, 1978; White and Panjabi, 1990; Holmes *et al.,* 1996). According to Nachemson and Evans (1968) the elasticity of the ligamentum flavum prevents it from protruding into the spinal canal during extension. In full extension of the spine there is a decrease in length of the ligamentum flavum (13%) which results in compression (3%) of this ligament. This has the potential of bulging into the canal (White and Panjabi, 1990). In healthy spines this degree of compression and up to one millimeter of disc bulge is insufficient to cause compression of the spinal cord or nerve roots (Harrison *et al.,* 1999). During flexion the spinal canal diameter is increased as a result of the slack being taken out of the soft tissues surrounding the canal. On extension, the AP width of the spinal canal is reduced, but this is usually less than one millimeter (Holmes *et al.,* 1996). This reduction is due to deformation of the IVD and the ligamentum flavum (Breig, 1978; White and Panjabi, 1990; Holmes *et al.,* 1996).

### 2.3.4 The Three Column Theory

The three column theory which was developed by Denis (1983) is an aid in describing spinal stability (Timothy *et al.,* 2004). It consists of the anterior column which is made up of the ALL, VB (White and Panjabi, 1990), the IVD and the PLL. The posterior column consists of all skeletal and ligamentous structures posterior to the PLL while the middle column consists of the posterior one-third of the VB, the AF and the PLL (Denis, 1983).

Major spinal injuries are classified into four different categories based on this theory (Denis, 1983). The compression fracture results in injury to the anterior column (Eismont and Kitchel, 1994) with an intact middle column (Patel *et al*., 2002). Loading of the spinal column during flexion occurs until failure which results in compression of the anterior portion of the VB. As compression increases there is an increased likelihood of associated ligamentous injury leading to instability and chronic deformity (Eismont and Kitchel, 1994).

Burst fractures are caused by either axial loading or a combination of axial loading and flexion forces (Eismont and Kitchel, 1994). The burst fracture indicates failure under compression of both the anterior and middle columns with a possible retropulsion of bone into the spinal canal (Eismont and Kitchel, 1994; Patel *et al*., 2002). As a result of the involvement of at least two columns, the burst fracture is an acutely unstable fracture (Eismont and Kitchel, 1994).

Fractures with bony injury to the anterior column with ligamentous or IVD injury in the middle and posterior columns are acutely unstable (Eismont and Kitchel, 1994). In fracture dislocations or flexion-distraction injuries (Patel *et al*., 2002) there is failure of all three columns fail due to forces acting to various degrees from one or another direction. Involvement of two or more columns results in an unstable spine (Bhattacharjee and Poonnoose, 2003).

### 2.3.5 Examples of Conditions Affecting the Cervical Spine Curvatures

Certain conditions such as aging, degeneration, trauma and surgical procedures can lead to a loss of the normal cervical lordosis (Stemper *et al*., 2005). According to Abel (1962), Deburge *et al.* (1996), Kessinger and Boneva (2000), and Vaccaro and Silber (2001) major and minor trauma can cause injury and possibly cervical spine deformity. Surgical procedures such as single and multi-level laminectomies are shown to alter spinal curvatures (Mikawa *et al.,* 1987; Batzdorf and Batzdorff, 1988; Butler and Whitecloud, 1992; Guigui *et al.*, 1998; Baisden *et al*., 1999).

Curvatures influence the load-carrying capacity of the cervical spine (Stemper *et al.,* 2005). According to Portnoy *et al*. (1972), Maiman *et al.* (1983), Yoganandan *et al*. (1986), Liu and Dai (1989) and Maiman *et al.* (2002) the severity of injury, mechanisms of injury and classification of fracture largely depend on the posture of the cervical spine at the time of loading.

During traumatic injuries such as whiplash the spine undergoes three kinematic phases: the S-curvature, C-curvature and a rebound after the head makes contact with the restraint (Stemper *et al.,* 2005). The S-shaped curve results from the head lagging behind the thorax and are characterized by flexion in the upper segments and extension in the lower segments which places abnormal loads on the cervical spine (Stemper *et al.,* 2005). The C-shaped curve describes overall extension of the head and neck (Stemper *et al.,* 2005). Croft (1995) suggested that the C5-C7 region may be predisposed to greater injury from acceleration/deceleration trauma due to the increased motion. He further suggested that this may be the reason why a high incidence of cervical spondylosis is reported in this region of the spine (Prasad *et al.,* 1974; Macnab, 1975).

The area of the brainstem where the cardiac and respiratory nuclei are present deforms during postural rotations and axial translations (Harrison *et al*., 1999) resulting in strain to some nerve roots (Harrison *et al*., 1999). If these occur over a prolonged period, it can may lead to ligamentous ossification or hypertrophy (Fukuyama *et al*., 1995) resulting in abnormal motion and abnormal alignment of the spine. The rate of osteophyte formation will be increased (Jones *et al.*, 1988; Zagra *et al*., 1988) and IVD degeneration may also occur (Brickley-Parsons and Glimcher, 1983). In the geriatric population the IVD height decreases due to degeneration (Macnab, 1975) which will lead to a decrease in lordosis of the cervical spine (Gore *et al.,* 1986). When this occurs, uncovertebral joints come into contact with each other forming osteophytes. The anterior aspect of the IVD is affected more severely in the later stages of degeneration which leads to a loss or even reversal of the lordotic curve (Stemper *et al.,* 2005).

## 2.4 EPIDEMIOLOGY AND DESCRIPTION OF CERVICAL SPINE FRACTURES

The cervical spine is a common site for orthopaedic-related injuries (Teo and Ng, 2001). According to Timothy *et al.* (2004) approximately 55% of spinal injuries occur in the cervical region, 15% in the thoracic region, and 15% in the thoracolumbar region while 15% occur in the lumbo-sacral region. In children below the age of seven, injuries in the craniocervical region account for 75% of cervical spine injuries (Timothy *et al*., 2004). A retrospective study by Lin *et al.* (2003) over a four-year period at a major teaching hospital reported 68 patients with a discharged diagnosis of cervical spine fractures.

Walter *et al*. (1984) reported that the average age of patients with acute cervical fractures presenting at two community hospital emergency departments was 39 years. Ryan and Henderson (1992) and Vieweg *et al.* (2000) on the other hand reported an average age of 47 years and 30 years respectively. Later, Grauer *et al*. (2005) and Lenoir *et al.* (2006) reported average ages of 62 and 49 years respectively. The studies of Vieweg *et al.* (2000) and Lenoir *et al.* (2006) were conducted in a university hospital. Later *et al.* (2005) conducted a study over a ten-year period (1995-2005) at York Hospital where 135 geriatric patients were enrolled with a mean age of 78.6 years. More recently, a study conducted by Malik *et al*. (2008) in a similar cohort of 107 subjects in a tertiary spinal unit over a shorter period of approximately four and half years reported a mean age of 74 years.

With respect to paediatric patients, Brown *et al.* (2001) reported a mean age of 10.3 years while Hackl *et al*. (2001) reported similar findings in a study conducted on 3 083 patients in a university hospital. Vieweg *et al*. (2000), Grauer *et al*. (2005), Daffner *et al*. (2006), Lenoir *et al.* (2006) and Malik *et al*. (2008) reported that males were more likely to experience cervical spine injuries or fractures. The description of the types of cervical spine fractures is summarised in **Table 2.2**. The vertebral levels involved however, were variable and were inconsistent in the various studies (Ryan and Henderson, 1992; Vieweg *et al*., 2000; Daffner *et al.,* 2006).

**Table 2.2 Description of specific cervical spine fractures**

| Reference | Fracture type | Description |
|---|---|---|
| Anderson and D'Alonso (1974), Timothy *et al*. (2004), Davenport *et al*. (2008) | Odontoid fracture | Type I consists of an oblique fracture at the upper portion of the odontoid process. Type II consists of a fracture which crosses the base of the odontoid process at the junction with the axis body, while Type III consists of a fracture through the cancellous portion of the body of the axis |
| Timothy *et al*. (2004), Ianuzzi *et al*. (2006), Davenport *et al*. (2008) | Cervical flexion teardrop fracture | Fracture of antero-inferior aspect of the VB; posterior ligamentous disruption due to flexion and vertical axial compression |
| Davenport *et al*. (2008) | Extension teardrop fracture | Displacement of the antero-inferior aspect of the VB due to a hyperextension injury |
| Timothy *et al.* (2004), Davenport *et al*. (2008) | Bilateral facet dislocation | Extreme form of anterior displacement of vertebrae resulting from dislocation of the facet joints |
| Davenport *et al*. (2008) | Burst fracture of the vertebral body | Compression trauma to the vertebra causing it to shatter outward |
| Effendi *et al*. (1981), Timothy *et al. (*2004), Davenport *et al*. (2008) | Hangman's fracture | Fracture through the pars interarticularis of the C2 pedicles due to hyperextension |
| Davenport *et al.* (2008) | Atlas fractures | Type I and Type II fractures refer to anterior and posterior arch fractures respectively; Type III – fracture through the lateral mass of C1; Type IV – Jefferson fracture |
| Timothy *et al.* (2004), Davenport *et al*. (2008) | Jefferson's fracture | Burst fracture of anterior and posterior arches of C1 due to compression trauma |
| Timothy *et al*. (2004) | Combined C1 and C2 fractures | Combination of C1 and Type II odontoid fracture is most frequent |
| Davenport *et al*. (2008) | Rotatory atlantoaxial dislocation | Specific type of unilateral facet dislocation |
| Davenport *et al*. (2008) | Atlantoaxial subluxation | Transverse ligament disruption during flexion of the upper cervical spine causing an anterior dislocation at this joint |
| Timothy *et al*. (2004), Davenport *et al*. (2008) | Unilateral facet dislocation | The inferior articular process of the vertebra above lies anterior to the superior articular process of the vertebra below |
| Davenport *et al*. (2008) | Simple wedge compression fracture | Fracture of the anterior VB |
| Davenport *et al*. (2008) | Articular pillar fracture | Articular pillars are fractured |
| Davenport *et al*. (2008) | Fracture of the posterior arch of C1 | Fracture of posterior arch occurs when the head is hyperextended |
| Graber and Kathol (1999), Davenport *et al.* (2008) | Clay shoveler's fracture | Oblique fracture of the base of the spinous process |
| Timothy *et al*. (2004), Davenport *et al*. (2008) | Atlanto-occipital dislocation injuries | Disruption of all ligaments between occiput and atlas resulting in dislocation between the atlas and occiput |
| Timothy *et al.* (2004), Davenport *et al*. (2008) | Occipital condyle fracture | Type I – comminution of occipital condyle with minimal or no displacement into the foramen magnum; Type II – part of basilar skull fracture; Type III – avulsion of occipital condyle by the alar ligament |
| Willis *et al.* (1994), Weller *et al*. (1999), Veras *et al.* (2000) | Transverse foramen fractures | Fracture through the transverse foramen of the cervical vertebrae |

**VB = Vertebral body**

The primary aetiology of cervical spine fractures reported in the literature (Maiman and Cusick, 1982; Walter *et al*., 1984; Hadley *et al*., 1989; Oller *et al*., 1992; Greene *et al*., 1997; Merritt and Williams, 1997; Kirshenbaum *et al*., 1990; Young *et al*., 1999; Preutu, 1999; Inamasu *et al*., 2001; Lenoir *et al*., 2006; Verettas *et al*., 2008) is trauma to the cervical spine. Falls and motor vehicle accidents (MVAs) account for the majority of the traumatic causes of cervical spine injuries (Song *et al*., 2007; Malik *et al*. 2008). Geriatric patients sustain injuries primarily due to low energy forces such as falls, while injuries to the younger population are largely due to higher energy forces (Grauer *et al.*, 2005; Lakshmanan *et al*., 2005). High-energy forces are reported as reliable predictors of cervical spine fractures (odds ratio = 11.6, 95% CI: 5.4-25.0) by Blackmore *et al*. (1999). Later *et al*. (2005) reported that 39% of geriatric patients' sustained fractures due to falls from standing, 38% due to motor vehicle accidents (MVA), 19% from falls from more than five feet, while 3% were pedestrians who were struck by vehicles. Ersmark and Kalen (1987) reported that 22% of MVAs occurred when the driver was under the influence of drugs or alcohol. According to Jurkovich *et al.* (1992) 40% of patients involved in motor vehicle collisions and falls are intoxicated at the time of injury. Thompson *et al.* (2008) reported that globally alcohol abuse is responsible for 20% of MVAs. Johnston and McGovern (2004) reported that alcohol-related falls are often associated with craniofacial injury. Skeletal fractures in epileptic patients are reported to be two to six times greater than in the general population (Mattson and Gidal, 2004). Vestergaard *et al.* (1999) reported that the relative risk for spinal fractures in epileptic individuals is significantly greater than that of normal individuals. Anti-epileptic drugs are known to decrease bone mineral density which is a significant contributing factor to the development of fractures (Pack and Morrell, 2001).

Other types of trauma to the cervical spine include assaults, ballistic trauma and diving into shallow water (Merritt and Williams, 1997; Inamasu *et al*., 2001; Lenoir *et al*., 2006). In a case report by Haku *et al*. (2008) a patient presented with a C6 burst fracture which occurred as a result of a diving accident. Allen *et al*. (1982) reported that the mechanisms of injury of the highly unstable cervical flexion teardrop fracture include MVAs and shallow diving.

The mechanism of injury of unilateral facet dislocations is flexion and a rotation (Kricun, 1988; Pathria, 1995; Daffner, 1996) while the mechanism of injury of bilateral facet dislocation or locked facets is hyperflexion (Payer and Tessitore, 2007) and axial loading or an upward blow to the occiput region (Kricun, 1988; Pathria, 1995). This hyperflexion trauma frequently causes tetraplegia (Sonntag, 1981; Lu *et al*., 1998; Razack *et al*., 2000).

Traumatic bilateral facet dislocation is mostly caused by MVAs and affects the levels C5-C6 and C6-C7 (Sonntag, 1981; Maiman *et al*., 1986; Wolf *et al*., 1991; Lu *et al*., 1998 and Razack *et al*., 2000). Rupture of the interspinous ligament and the facet capsule on the affected side (Kricun, 1988; Pathria, 1995; Daffner, 1996) results in unilateral facet dislocations where the inferior facets of the superior VB slide anteriorly over the superior facets of the inferior VB (Kricun, 1988; Pathria, 1995; Daffner, 1996). Unilateral dislocations are less common than bilateral facet dislocations and are associated with a decreased chance of any neurological complications (Pasciak and Doniec, 1993). In a review of 292 patients who sustained acute spinal injury, Pasciak and Doniec (1993) reported 183 spinal fractures, 77 bilateral facet and 32 unilateral facet dislocations. Kim and Yoon (1997) reported that 44.3% and 55.7% of 61 patients with facet interlocking presented with unilateral facet dislocations and bilateral facet interlocking respectively. A possible reason for the decreased prevalence of unilateral facet dislocations was that they were often misdiagnosed and treated as instability or a subluxation (Braakman and Vinken, 1967; Braakman and Vinken, 1968; Rorabeck *et al.,* 1987).

The occipito–atlanto–axial (C0–C1–C2) joint complex is a significant area of the spine since this region is highly susceptible to traumatic impact injury (Teo and Ng, 2001). In the study by Malik *et al.* (2008) on 107 geriatric patients, atlantoaxial involvement was found in 44 cases while subaxial involvement was found in 52 cases. Odontoid fractures **(Table 2.2)** were common injuries (Pepin *et al*., 1985; Hadley *et al.*, 1985; Hadley *et al.*, 1989; Harrop *et al*., 2001; Kirkpatrick *et al.*, 2004; Grauer *et al.*, 2005) and accounted for 1 - 2% percent of all vertebral fractures (Maiman *et al.,* 1983; Amling *et al.,* 1995). There was however, no agreement on the prevalence of odontoid fractures. Lee *et al.* (1984), Subach *et al.* (1999) and Vaccaro *et al.* (2000) reported a range of 9 -15% while Pepin *et al*. (1985), Hadley *et al.* (1985), Hadley *et al.* (1989) and Kirkpatrick *et al.* (2004) provided a higher range of 7 - 29% for all fractures in the cervical spine and Maiman *et al.* (1983), and Amling *et al.* (1995) suggested that these fractures accounted for 10% of cervical fractures. Later *et al*. (2005) in their study reported that odontoid fractures accounted for 68% of 181 cervical spine fractures in geriatric patients. In a recent study, Perri *et al*. (2007) reported that fractures of the odontoid process accounted for 18 - 20%

of all cervical spine injuries. According to Hadley *et al.* (1985), Hadley *et al.* (1989), and Greene *et al.* (1997) Type III fractures accounted for 18 - 23% of odontoid fractures.

A hangman's fracture **(Table 2.2)** also known as a traumatic spondylolisthesis (Timothy *et al*., 2004) may be classified into three types based on the mechanism of injury (Effendi *et al*., 1981) as shown in **Table 2.3**.

**Table 2.3 Classification of the hangman's fracture according to the mechanism of injury**

| Type | Mechanism of injury |
|---|---|
| Type I | Axial loading and hyperextension |
| Type II | Hyperextension and rebound flexion |
| Type III | Primary flexion and rebound extension |

Occipital condyle fractures which may occur during trauma to the head and neck are also classified into three types (Anderson and Montesano, 1988) as shown in **Table 2.4**.

**Table 2.4 Types of occipital condyle fractures**

| Type | Description |
|---|---|
| Type I | Comminution of the occipital condyle with minimal or no displacement of fragments into the foramen magnum |
| Type II | Part of basilar skull fractures |
| Type III | Avulsion fractures of the occipital condyle by the alar ligament |

Type I and Type II occipital condyle fractures are stable while Type III fractures may be unstable. Atlas fractures account for approximately 4-6% of spinal fractures (Young *et al.,* 1999). Injuries of the atlas comprise approximately 25% of all injuries to the atlanto-axial complex (Levine and Edwards, 1986). However, isolated atlas fractures account for 5 - 10% of cervical spine injuries (Timothy *et al.,* 2004). According to Young *et al.* (1999), the most common of the atlas fractures are the posterior arch fractures **(Table 2.2)** which comprise of 50% of all atlas fractures. Eighty-percent of posterior arch fractures are associated with additional cervical spine fractures (Sherk and Nicholson, 1970; Gehweiler *et al.,* 1980; Landells and Peteghem, 1988; Yochum and Rowe, 2004). Thereafter the Jefferson's fracture **(Table 2.2)** accounts for one-third of atlas fractures (Young *et al.,* 1999). This is the most significant of the atlas fractures since neurological impairments are often associated with this type of fracture (Timothy *et al.,* 2004; Davenport *et al.,* 2008). Fractures of the anterior arch of the atlas are less common accounting for less than 2% of all cervical fractures (Landells and Peteghem, 1988; Yochum and Rowe, 2004). These fractures are also found with odontoid fractures (Landells and Peteghem, 1988). Furthermore, atlas fractures are reported as complications to odontoid fractures in the geriatric population (Asfora *et al.,* 1992; Apostolides *et al*., 1997). High levels of mortality and morbidity are associated with combination C1-C2 fractures than with isolated fractures of these vertebrae (Timothy *et al.,* 2004). Fractures of the lateral mass of the atlas are rare with low morbidity rates (Young *et al*., 1999).

Lin *et al.* (2003) evaluated the lower cervical spine fractures and reported a C6-C7 fracture-dislocation, a bilateral C6 pedicle fracture, a C6 facet fracture and five clay shovelers' fractures. Fractures involving the atlantoaxial complex in the elderly population comprise 23 - 29% of all cervical spine fractures (Bohlman, 1979; Sonntag and Hadley, 1986; Loembe *et al.,* 1988). Ryan and Henderson (1992) observed that C1 and C2 fractures, especially those involving the odontoid process are more common in the elderly. Pedicle fractures of the axis are not common and are rarely reported in the literature (Hadley *et al.,* 1985; Signoret *et al.,* 1986; Craig and Hodgson, 1991).

According to the National Emergency X-radiography Utilization Study (NEXUS), the most common area of fracture distribution is at C2 (23.9%) then C6 (20.25%) followed closely by C7 (19.08%) and then C5 (14.98%) (Goldberg *et al.*, 2001). In addition, the most common dislocation/subluxation levels are C5-C6 (25.11%) followed by C6-C7 (23.77%) and C4-C5 (16.96%) (Goldberg *et al.* 2001). Daffner and Daffner (2002) also reported that facet dislocations occur most commonly at the C5-C6 levels. Besides this region being the most mobile of the subaxial spine, the posterolateral-facing superior articular facets in this region also account for this finding (Daffner and Daffner, 2002).

According to Saboe *et al.* (1991) 47% of patients with trauma to the spine sustain associated injuries. Head injuries account for 26%, chest injuries account for 24%, long bone injuries account for 23% of these associated injuries, while the rest are due to abdominal and chest injuries (Saboe *et al.,* 1991). Facial and skull fractures are reported to be associated with cervical spine fractures especially if the upper cervical spine is involved (Kirshenbaum *et al*., 1990; Oller *et al*., 1992; Merritt and Williams, 1997; Meyer *et al*., 2005). According to Timothy *et al*. (2004) approximately 5% of the primary head-injured patients have an associated spinal injury. However, 25% of patients with primary spinal injury have at least a mild head injury (Timothy *et al.,* 2004). Severe head injuries are reported to be predictors of cervical spine injuries (odd ratio = 8.5, 95% CI: 4.0-17.0) by Blackmore *et al*. (1999). The mortality of coincident head injury and cervical spine injury is 14% (Timothy *et al.,* 2004). Earlier, Holly *et al.* (2002) reported that 4 - 8% of patients presenting with head and brain trauma have cervical spine fractures. Cervical vertebral fractures (Shaha *et al*., 1993), cranial trauma (Morandi *et al*., 1999a), atlanto-axial dislocation (Inamasu *et al*., 2001), atlanto-occipital dislocation (Ochoa, 2005), thoracolumbar, and clavicle fractures (Song *et al*., 2007) were reported to be associated with odontoid fractures. Verettas *et al*. (2008) reported a case of an individual with a hangman's fracture who also had bimaleolar ankle fractures following an MVA. In a study conducted by Aslam *et al.* (2008) on patients presenting to a trauma service at St. Michael's Hospital over a ten-year period, a total of 124 patients with cervical spine injuries drawn from a cohort of 3356 patients with craniomaxillofacial fractures were considered. The incidence of cervical spine injury was 3.7%. Upper one-third facial and skull fractures were associated with cervical spine injury in 0.53% of cases, middle one-third facial fractures were associated with 1.13% of cervical spine injuries while the lower one-third facial fractures were associated with 1.51% of cervical spine injuries. Fractures involving two or more facial thirds were however, associated with 7.1% of cervical spine injuries. Recently Song and Lee (2008) reported that cerebral contusion, multiple extremity fractures, multiple rib fractures, pulmonary contusions, haemothorax and other areas of spinal injury were associated with cervical spine injury.

Despite these reports on the epidemiology of cervical spine fractures and their associated injuries and fractures, it is very difficult to predict the associated fractures with cervical spine fractures due to differences in the types of trauma, force of trauma, mechanism of injury and patient profile.

## 2.5 CLINICAL PRESENTATION OF CERVICAL SPINE FRACTURES

The pathological and clinical findings associated with cervical spine fractures vary considerably. The majority of the findings include neurological aberrations such as intracranial haemorrhage (Kirshenbaum *et al*., 1990), spinal cord injury (Oller *et al*., 1992), spinal cord compression (Payer and Tessitore, 2007), selective paralysis of the limbs (Inamasu *et al.,* 2001), brainstem injuries which may lead to cardiac arrest (Meyer *et al*., 2005), motor weakness in the limbs and tetraparesis (Agrillo and Mastronadi, 2006; Payer and Tessitore, 2007), poor Frankel grading (Lenoir *et al*., 2006) and neck pain (Payer and Tessitore, 2007). Focal neurological deficits are reported as predictors of cervical spine fractures (odd ratio = 58, 95% CI: 12, 283) by Blackmore *et al*. (1999). Many patients with cervical spine fractures sustain an associated spinal cord injury (Timothy *et al.*, 2004). According to Balanga and Levi (2000) the primary injury occurs at the scene of the accident while the secondary injury occurs due to disruption of microcirculation, loss of autoregulation, edema, anoxia as well as ischemia. It may be extremely difficult to perform an adequate clinical assessment in these patients as they may be unconscious on presentation (Timothy *et al.,* 2004). The clinical signs of spinal cord damage include priapism, low blood pressure (Timothy *et al.,* 2004), loss of the bulbocavernous reflex, loss of motor function, flaccid paralysis below the level of the lesion and loss of autonomic reflex activity (Licina and Nowitzke, 2005). Bowel and bladder dysfunction as a result of disruption of the autonomic nervous system following cervical spine injuries was reported by Glickman and Kamm (1996), Goodrich *et al.* (2008) and Davenport *et al*. (2008). The loss of autonomic reflex activity has implications on the blood pressure of the patient (White and Likavec, 1999) as it can drop to dangerously low levels. According to Timothy *et al.* (2004) spinal shock which refers to the transient loss of all neurological function below the level of injury precipitates microcirculatory cord injury (Timothy *et al*., 2004). These patients need to be monitored in an intensive care setting in order to maintain a stable condition. Constant haemodynamic monitoring is necessary but volume replacement is done with caution since fluid redistribution can precipitate congestive cardiac failure and pulmonary edema (Timothy *et al*., 2004).

Autonomic dysreflexia due to fractures and dislocations in the lower cervical spine, occurs as a result of a generalized sympathetic discharge where the blood pressure of the patient can reach dangerously high levels causing severe headache, nausea, chills, anxiety and sweating (Goodrich *et al.*, 2008). On the other hand, if the patient sustains severe trauma, blood loss could cause hypovolaemia leading to hypotension (Timothy *et al.,* 2004). When spinal cord injury occurs the sympathetic nervous system is interrupted resulting in the parasympathetic system being unopposed causing a bradycardia (Timothy *et al.*, 2004). Also, skeletal or smooth muscle paralysis below the level of injury can cause loss of muscle tone leading to hypotension (Timothy *et al.*, 2004).

A detailed or complete neurological assessment should be done in all cases of cervical spine trauma (Nykoliation *et al.,* 1986). Several studies have reported that cervical spine fractures cannot be ruled out on the basis of a normal neurological examination (Nykoliation *et al.,* 1986; Munro, 1990; Troyanovich, 1994; Plezbert and Oestreich, 1994; Crowther, 1995; Hadida and Lemire, 1997; Brynin and Yomtob, 1999) or on the basis of lack of pain or negative orthopaedic findings (Brynin and Yomtob, 1999). Woodring and Lee (1993) reported that 5% of fractures may be asymptomatic, and Bresler and Rich (1982), Mace (1985), Haines (1986), and Cadoux and White (1986) also stated the possibility of painless cervical spine fractures. In the study by Walter *et al.* (1984) the majority of patients, even those with acute cervical spine fractures had no history of loss of consciousness or any neurological deficit. Nagashima *et al.* (2001) reported two cases of kyphotic elderly females, one who sustained a fall and the other who could not recall any history of trauma. One female complained only of neck pain and a bruise in her occipital region while the other only experienced neck pain. Both were neurologically intact. One was found to have sustained a Type III odontoid fracture as well as a fracture of the posterior arch of atlas while the other sustained a Type II odontoid fracture. In a review of cases of cervical spine fractures, Malik *et al.* (2008) reported that of 107 elderly patients, who sustained cervical spine injuries, four patients had complete neurology, 27 had incomplete neurology and the remaining 76 had no neurological deficit. Brachial plexus injuries were found in 12% of patients who sustained spinal injury (Webb *et al.,* 2002). Mortality rate of acute axis fractures was 25 – 40% at the scene of the accident (Hadley *et al.,* 1989).

The neurology after spinal cord injury was attributed to swelling of the spinal cord (Timothy *et al.,* 2004). According to Ditunno *et al.* (2004), spinal shock could be due to the loss of background excitatory input from the supraspinal axons and may be considered the spinal cord's first phase of response to spinal cord injury (Licina and

Nowitzke, 2005). Later, there may be hyperreflexia and spasticity (Licina and Nowitzke, 2005). Return of the spinal reflexes and the bulbocavernous reflex signify the end of spinal shock (Licina and Nowitzke, 2005). The bulbocavernous reflex may return within 24 hours of injury but could extend for longer periods (Licina and Nowitzke, 2005). A rectal examination is pertinent in establishing whether or not a lesion present in the spinal cord is complete or incomplete (Licina and Nowitzke, 2005).

The first report of a neurological scale to characterise patients with acute spinal cord injuries was provided by Frankel *et al.* (1962). Frankel grading (Frankel *et al.,* 1962) was a component of the neurological examination which was utilized in order to determine whether the patient's condition had improved or deteriorated post-surgery. The grading of this neurological scale which ranges from A-E is shown in **Table 2.5** (Timothy *et al.,* 2004). Later, in 1984 the American Spinal Injury Association developed guidelines on how a neurological assessment should be performed (**Figure 2.1** and **Table 2.5**).

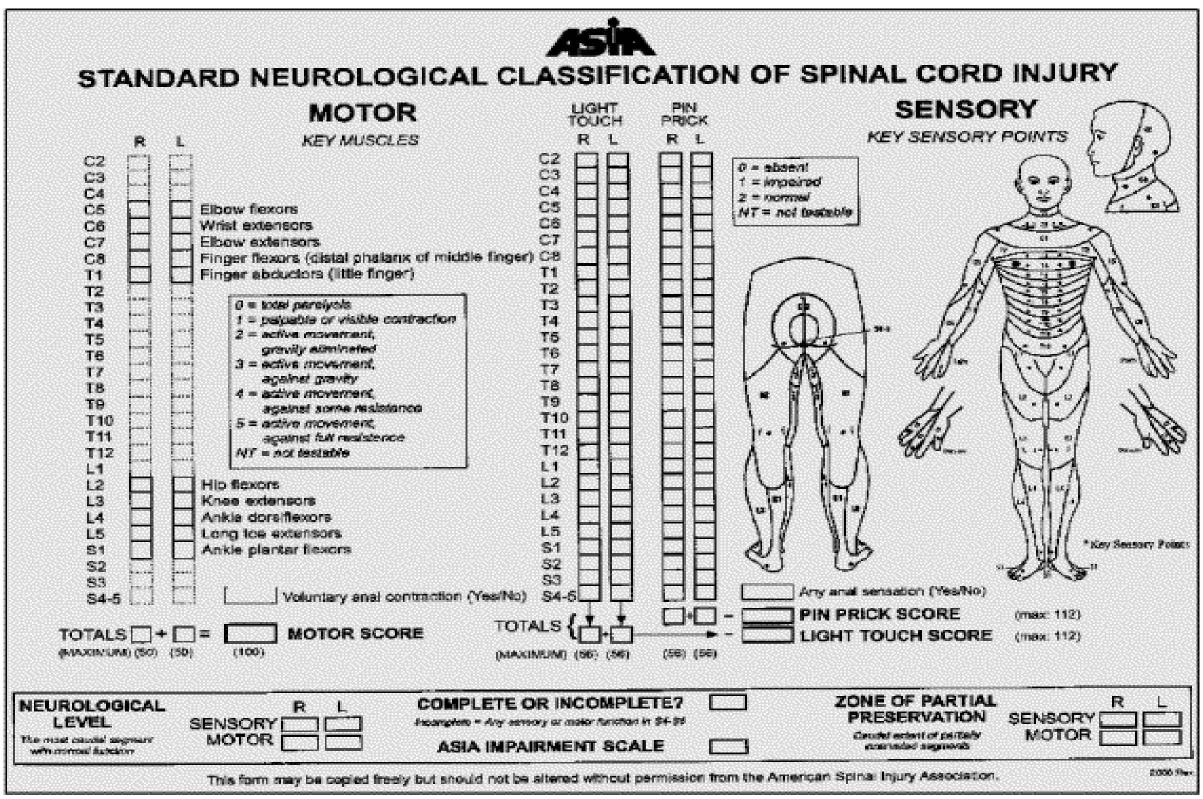


**Figure 2.1 Standard neurological classification of spinal cord injury**

**Table 2.5 Frankel grading**

| Frankel grading | Neurological status | Description |
|---|---|---|
| A | Complete | No motor or sensory function is preserved in the sacral segments S4-S5. |
| B | Incomplete | Sensory but not motor function is preserved below the neurological level and includes the sacral segments S4-S5. |
| C | Incomplete | Motor function is preserved below the neurological level, and more than half of key muscles below the neurological level have a muscle grade less than 3. |
| D | Incomplete | Motor function is preserved below the neurological muscles below the neurological level have a muscle grade of 2 or more. |
| E | Normal | Motor and sensory functions are normal. |
| **Clinical syndromes**<br>Central cord<br>Brown-Sequard<br>Anterior cord<br>Conus medullaris<br>Cauda equina | | |

**ASIA Neurological assessment and impairment scale (American Spine Injury Association (ASIA). International Standards for Neurological Classification of SCI, revised 2002, *American Spine Injury Association booklet*. ASIA)**

The preservation of the abdominal and cremasteric reflexes indicates a neurologically intact state (Timothy *et al.,* 2004). In the abdominal reflex, umbilical deviation toward the stimulated side indicates a neurologically intact response, while in the cremasteric reflex contraction of the scrotum on the stimulated side is considered as neurologically intact (Timothy *et al.,* 2004).

According to White and El-Khoury (2002) patients with transected cords have a grave prognosis. Patients with spinal cord edema fare better than patients with hemorrhagic cord injuries while patients with a normal spinal cord state have the best prognosis. Although rare, arterial injury that may occur during spinal trauma has the potential to cause serious neurological complications (Choi *et al.,* 1986; Willis *et al.,* 1994). Although the vertebral arteries may be frequently injured during cervical spine trauma, neurological symptoms as a result of their injury are rare (White and El-Khoury, 2002). If neurological symptomatology does occur, it is extremely serious (Woodring and Lee, 1993; Willis *et al.*, 1994; Harrop *et al.*, 2001). Injury to the vertebral artery is likely to occur during transverse foramen fractures (Cothren *et al.*, 2003) and during cervical spine subluxations, dislocations, burst and compression fractures (White and El-Khoury, 2002). Various studies have suggested that transverse foramen fractures (Willis *et al.,* 1994; Weller *et al.,* 1999, Veras *et al.,* 2000; Cothren *et al*., 2003), subluxations of greater than three millimeters (Friedman *et al*., 1995) and dislocations of the zygapophysial joints (Giacobetti *et al.*, 1997; Veras *et al.*, 2000; Parbhoo *et al.*, 2001), are predictive of vertebral artery injury. Parbhoo *et al.* (2001) reported that 30% of patients who sustained unilateral facet dislocations have vertebral artery injury.

Odontoid, compression, Jefferson and comminuted fractures are also associated with vertebral artery injury (Willis *et al.*, 1994; Giacobetti *et al.*, 1997; Weller *et al.*, 1999; Veras *et al.*, 2000; Parbhoo *et al.*, 2001). The mechanisms of injury to the vertebral artery are distractive flexion (Veras *et al.*, 2000), flexion distraction or flexion compression injury (Giacobetti *et al.*, 1997). Brachial plexopathy as well as cervical radiculopathy are also associated with transverse process fractures (Woodring and Lee, 1993) as a result of the close association of these structures with the TVPs of the cervical spine vertebrae.

Multiple clinical features which relate to vertebral artery injury (Sue and Brant-Zawadzki, 1992; Mascalchi *et al.*, 1997; Leclerc *et al*., 1999) include:

- neck pain and stiffness
- headaches
- vomiting
- tinnitus
- hemiparesis
- diplopia
- ataxia
- dizziness
- hemiparaesthesiae
- dysmetria
- dysphagia
- dysphonia
- Horner's syndrome
- nystagmus
- hypoaesthesia
- aphasia
- facial weakness
- dysnomia
- basilar transient ischemic attacks

The arteries that arise from the vertebral arteries are at risk of injury during injury of the vertebral artery. The posterior inferior cerebellar arteries, the anterior and posterior spinal arteries and radicular arteries may cause neurological deficits when injured especially if there is a lack of collateral circulation (White and El-Khoury, 2002). According to Vishteh *et al*. (1999) vertebral artery injury also results in the basilar artery being potentially at risk for the development of thrombosis resulting in infarction to the brainstem. This was verified in the study by Rommel *et al.* (1999) where Doppler ultrasound demonstrated internal carotid artery dissection resulting in cerebral ischemia, and thromboses in vertebral and basilar arteries were observed after cervical spine injury.

According to Timothy *et al.* (2004) central cord syndrome is the most common spinal cord syndrome that usually results from a hyperextension injury which causes greater loss of gray matter. Upper limb motor impairment occurs more than lower limb impairment in this syndrome as well as sacral sparing (Meyer *et al.,* 1976; Morse, 1982; Cooper, 1986; Timothy *et al*., 2004). The anterior cord syndrome can result from a fracture-dislocation, flexion injury or a burst fracture causing principle damage to the anterior two-thirds of the spinal cord (Timothy *et al.,* 2004) or the anterior spinal artery (Errico, 1993). This leads to spinothalamic and corticospinal tract dysfunction resulting in both sensory and motor symptoms (Errico, 1993). Brown-Sequard syndrome is caused as a result of injury to one half of the spinal cord and presents as ipsilateral loss of motor and proprioception with sparing of pain and temperature on the contralateral side (Errico, 1993; Timothy *et al.,* 2004). According to Timothy *et al.* (2004) anterior cord syndrome has the worst prognosis unless there is preservation of the spinothalamic tract (Errico, 1993) while Brown-Sequard syndrome has the best prognosis (Timothy *et al.,* 2004). According to Weir (1975), Fielding and Hawkins (1976), and Cooper (1986) posterior cord syndrome is the most rare cord syndrome which results from injury to the posterior column leading to a loss of proprioception and vibration sense following extension injury.

An incomplete spinal cord lesion is defined as any residual motor or sensory function more than three segments below the level of injury (Timothy *et al.,* 2004). Sensation (including proprioception) or voluntary movement in the lower extremities, sacral sparing, sensation around the anus, voluntary rectal sphincter contraction or voluntary toe flexion are signs of an incomplete lesion while no motor and/or sensory function more than three segments below the level of the injury is defined as a complete spinal cord lesion (Timothy *et al.,* 2004). About 3% of patients with complete injures on initial examination develop some recovery within 24 hours (Timothy *et al.,* 2004). According to Lomoschitz *et al.* (2002) 24% of patients with cervical spine injuries present with complete spinal cord injuries.

According to Kreipe *et al.* (1989) palpation may reveal neck pain and tenderness as well as deformity (Cadoux, 1987). Deformity may be caused as a result of fracture-dislocation and caution needs to be taken for a possible unstable lesion (Brynin and Yomtob, 1999). According to Greene *et al*. (1997) the clinical presentation of patients with axis fractures varies from neck pain to paralysis and even death. In a study on 107 cases of axis fractures Hadley *et al.* (1985) observed that 91 (85%) patients complained of neck pain, 11 (10%) complained of paresthesias, eight (7%) complained of specific motor weakness, and 14 (13%) had some paralysis at the time of presentation. Cervical myelopathy, tetraplegia, monoparesis (Przybylski *et al.,* 2002), spinal stenosis (Daentzer *et al.,* 2003) and paresthesias (Hadley *et al.,* 1985) were observed in patients who sustained cervical spine fractures and dislocations, especially the odontoid fractures. In their follow-up study of ten atlas and 85 axis fractures Ersmark and Kalen (1987) reported that radiating cervical spine pain indicated a mild demyelinating process of the medulla as a result of trauma to this region. Spinal cord compression with tetraplegia or tetraparesis was observed in patients who sustained unilateral facet dislocations (Pasciak and Doniec, 1993).

Payer *et al.* (2005) reported a rare case of a 64-year old patient with vertical atlanto-occipital dislocation. There was significant ligamentous damage since the mechanism of this injury was hyperextension followed by lateral flexion and/or hyperflexion. Rupture of the tectorial, alar, apical dental ligament and vertical bands of the cruciate ligament (Cohen *et al.,* 1991; Hladky *et al.,* 1991; Houle *et al.,* 2001; Kenter *et al.,* 2001; Labbe *et al.,* 2001) lead to instability of the C0-C1 and C1-C2 regions (Payer *et al.,* 2005). Although this type of injury is usually fatal, clinically this patient presented with hypotension, bradycardia, pinpoint pupils, absent corneal reflexes, diminished gag reflex, flaccid paralysis of arms and legs and absent deep tendon reflexes.

Patton and Renshaw (2006) reported a case of a 47 year-old patient who sustained a severe blow to the vertex of the cranium presenting with severe occipital neuralgia and upper cervical spine pain. On examination the patient demonstrated focal upper cervical tenderness and was neurologically intact (Patton and Renshaw, 2006). Radiographic examination however, showed a fracture through the lateral mass of the atlas. Hsieh *et al. (article in press)* presented a case of a 49 year-old patient who complained of sudden neck pain with no recollection of a traumatic event. Except for an elevated blood pressure and hypoaesthesia in his left hand, the clinical examination findings were unremarkable. Radiological findings however revealed a Type III odontoid fracture.

Amirjamshidi *et al*. (2008) reported a case of a 31 year-old male who presented with a traumatic rotatory posterior dislocation of the atlas on the axis without a fracture following a head-on collision with a truck. The patient was unconscious with a Glasgow Coma Scale (GCS) of 10, a forehead wound and no lateralising neurological deficit. A computed tomography (CT) scan revealed diffuse brain contusion and oedema which was localised to the frontal lobes bilaterally.

Non-neurological pathological and clinical findings included subclavian and carotid bruits possibly as a result of vessel dissection which occurred during extreme hyperextension and rotation of the neck or vessel laceration by adjacent bony fractures (Crissey and Bernstein, 1974), lumbar spine pain and scoliosis (Eriksen, 2005), tracheal rupture, subcutaneous emphysema and pneumomediastinum (Verettas *et al*., 2008).

Prognosis of recovery from spinal cord injury depends on the levels involved as patients with spinal cord injury in the higher cervical spine area become tetraplegic, while patients with spinal cord injury in the lower cervical spine with preservation of the upper limb function rehabilitate better and are able to live a more independent life (Timothy *et al.,* 2004).

## 2.6 DIAGNOSTIC IMAGING OF THE CERVICAL SPINE

The radiograph was the initial diagnostic modality of choice pre-surgically (Kirshenbaum *et al*., 1990; Preutu, 1999; Inamasu *et al*., 2001; Eriksen, 2005; Rowell*,* 2006; Lenoir *et al.,* 2006; Agrillo and Mastronadi, 2006; Verettas *et al*., 2008) as well as post-surgically (Vieweg *e*t *al*., 2000; Laidlaw *et al.,* 2004; Agrillo and Mastronadi, 2006). Since approximately 20% of spinal fractures were missed on radiographs (Woodring and Lee, 1993) advanced imaging modalities e.g. computed tomography (CT) scan and magnetic resonance imaging (MRI) were often utilized to view the cervical spine fractures and associated soft tissue and bony injuries both pre-surgically (Merritt and Willliams, 1997; Inamasu *et al.,* 2001; Agrillo and Mastronadi, 2006; Rowell, 2006; Lenoir *et al.,* 2006; Verettas *et al.,* 2008) and post-surgically (Vieweg *et al*., 2000; Laidlaw *et al*., 2004; Hong Cho *et al*., 2005; Agrillo and Mastronadi, 2006; Rowell, 2006).

## 2.7 CONSERVATIVE TREATMENT OF CERVICAL SPINE FRACTURES

Not all patients with cervical spine fractures are treated surgically. Conservative treatment is implemented for a variety of fracture types as shown in **Table 2.6**. Some fracture types e.g. an isolated C1 isthmus fracture requires no surgery with the patient wearing a neck collar for a few weeks (Vieweg *et al*., 2000). According to Timothy *et al.* (2004) spinal orthoses is primarily used to support the spinal column and musculature during treatment. These orthoses include (Perri *et al.* (2007):

A) Cervical collars:

- Soft
- Philadelphia
- Miami-J
- Aspen collars

These limit flexion-extension motions but permit axial rotation and lateral flexion. The collar immobilization is associated with the least loss of range of motion of the cervical spine while cervical fusion is associated with the greatest loss of range of motion (Ersmark and Kalen, 1987). Twenty percent of patients treated with a collar report residual symptoms such as pain compared to 40% of patients who are treated surgically (Ersmark and Kalen, 1987).

B) Poster-type orthoses:

- Gilford orthosis
- SOMI brace

These do not limit lateral flexion and axial rotation but are considered more supportive than the cervical collars (Timothy *et al.,* 2004).

C) Cervicothoracic orthosis:

- Yale orthosis
- Minerva jacket
- Halo vests

These limit cervical spine flexion-extension and axial rotation with little restriction to lateral flexion. Halo vests which are the most effective in limiting motion of the upper cervical spine are considered as rigid bracing while bracing such as Aspen and Philadelphia collars are referred to as non-rigid immobilizers (Perri *et al.* (2007). The halo is used extensively to stabilize the cervical spine (Perry and Nickel, 1959; Nickel *et al*., 1968; Johnson *et al*., 1977; Koch and Nickel, 1978; Johnson *et al*., 1981) and is generally used in displaced atlas fractures, odontoid fractures, axis fractures and combined C1-C2 fractures (Timothy *et al.,* 2004).

Treatment in the elderly is difficult due to the poor tolerance of the halo-vest immobilization (Pepin *et al.,* 1985; Timothy *et al*., 2004). Elderly patients with odontoid fractures and especially those with respiratory ailments do not tolerate these halo vests well since they alter respiratory function and therefore treatment with collars is preferred although it is not the optimum (Timothy *et al.,* 2004). Pepin *et al.* (1985) reported a 54% non-union rate and an increased rate of morbidity were observed in elderly patients who presented with Type II odontoid fractures (Perri *et al.,* 2007). This however, rarely contributes to late neurological worsening (Bachs *et al.,* 1955; Govender and Grootboom, 1988). Increased morbidity and mortality was observed in patients who were treated by the halo vest compared to those who were treated surgically (Tashjian *et al.,* 2006). The halo is attached to the skull *via* four pins and requires tightening every two to seven days to prevent loosening (Timothy *et al.,* 2004). This procedure leads to pin-site pain which is extremely uncomfortable for the patient (Timothy *et al.,* 2004). The halo vest is worn by the patient for between two to three months after which time union of the fracture is expected. Thereafter a soft collar is worn and the patient is referred for physical therapy (Kim *et al.*, 2008). If there is non-union of the fracture then surgical intervention is considered (Timothy *et al*., 2004). Despite there being a high rate of non-union with the use of a halo vest, this still remains the most frequent choice of treatment for Type II odontoid fractures (Kim *et al.,* 2008).

The non-union rate for odontoid fractures is 4 - 64% (Schweigel, 1987). The reason for this large range is that union of odontoid fractures depends on the site of the fracture as well as the method of treatment (Song *et al.,* 2007). According to Ryan and Taylor (1993) the SOMI brace or simple collar is the optimum management for patients over the age of 75 years. Cones calipers, which are a type of skull traction are indicated in the conservative management of cervical spine fractures and dislocations (Department of Orthopaedic Surgery, University of Stellenbosch, 2008).

**Table 2.6 Conservative treatment of cervical spine fractures**

| Type of fracture | Reference | Conservative treatment |
|---|---|---|
| Odontoid fractures | | |
| Unspecified | Anderson and D'Alonso (1974), Subach *et al*. (1999) | Cervical collar immobilization |
| Odontoid Type I | Weller *et al.* (1997), Forster *et al*. (2002) | Philadelphia collar |
| Odontoid Type II | Weller *et al.* (1997) | Philadelphia collar |
| | Richman (1998) | Gardner-Wells tongs, halo ring traction |
| | Vieweg *et al*. (2000) | Stiff neck collar, halo |
| | Forster *et al.* (2002) | Philadelphia collar |
| | Malik *et al*. (2008) | Cervical orthosis, halo |
| Odontoid Type III | Hsieh *et al.* (*in press*) | Rigid neck collar |
| Type II and Type III odontoid fractures | Nagashima *et al*. (2001) | Philadelphia collar, cervical hard orthosis |
| Body of C2 avulsion | Maiman (1997) | Halo |
| C2 pedicle fracture | Cockluk *et al. (*2005) | Philadelphia collar |
| Axis pedicle fractures | Cockluk *et al.* (2005) | Philadelphia collar |
| Traumatic spondylolisthesis of C2 | Buchowski and Riley (2005) | Reduction without traction, halo |
| Traumatic spondylolisthesis Type I | Timothy *et al.* (2004) | Philadelphia collar |
| Traumatic spondylolisthesis Type II and Type III | Timothy *et al.* (2004) | Immobilization |
| Isolated fracture of the atlas | Timothy *et al.* (2004) | Rigid collar, SOMI brace, halo |
| Jefferson's fracture (unstable) | Haus and Harris (2008) | Cervical collar |
| Jefferson's fracture | Weller *et al.* (1997), Vieweg *et al*. (2000), | Halo |
| | Haus and Harris (2008) | Cervical collar |
| Isolated C1 isthmus fracture | Vieweg *et al*. (2000) | Stiff neck collar |

| | | |
|---|---|---|
| Anterior arch of C1 | Forster *et al.* (2002) | Philadelphia collar |
| C7 compression fracture | Brynin and Yomtob (1999) | Philadelphia collar |
| Type II odontoid and posterior arch of atlas | Nagashima *et al.* (2001) | Philadelphia collar |
| Type III odontoid and posterior arch of atlas | Nagashima *et al*. (2001) | Cervical hard orthosis, cervical collar |
| Atlantoaxial cases and subaxial cases | Malik *et al.* (2008) | Cervical orthosis, halo |
| Combined C1-C2 fractures | Vieweg *et al*. (2000) | Halo |
| C1-odontoid Type II | Weller *et al.* (1997) | Halo |
| C1-odontoid Type III | Weller *et al.* (1997) | Halo |
| C7 compression fracture | Brynin and Yomtob (1999) | Philadelphia collar |
| Simple wedge fracture | Davenport *et al*. (2008) | Cervical orthosis |
| Clay shoveler's fracture | Davenport *et al*. (2008) | Cervical immobilization with orthotic device |
| Unilateral facet dislocation | Pasciak and Doniec (1993) | Skull traction, Minerva plaster, halo |

Odontoid fractures are treated using both conservative as well as surgical interventions **(Table 2.6)**. Conservative treatment of unspecified odontoid fractures includes external mobilization (Grauer *et al.,* 2005; **Table 2.6**) and cervical collar immobilization (Anderson and D'Alonso, 1974; Subach *et al.,* 1999; **Table 2.6**). Although the cervical collar and the halo-vest are used to provide support by Song *et al.* (2007) to patients who sustain Type II odontoid fractures, surgical treatment is preferred as it provides a higher fusion rate. The rate of non-union during conservative treatment is approximately 25% (Fujii *et al.,* 1988) as the halo-vest and cervical collar are not able to provide stable support (McGraw and Rusch, 1973). The odontoid Type II and Type III fractures sustained by patients in the study by Weller *et al.* (1997, **Table 2.6**) were displaced as well as nondisplaced respectively. However, due to the patients being elderly and unable to tolerate halo device immobilization or surgical fusion as a result of medical debility, a Philadelphia collar was the chosen treatment of choice (Weller *et al.,* 1997) **(Table 2.6)**.

Those patients who sustained a combination of C1 and odontoid fractures were immobilized conservatively due to the severity of their associated injuries. According to Timothy *et al.* (2004) it was rare for Type III odontoid fractures to be associated with neurological injury which could be the reason why the treatment of choice for this injury was conservative therapy (Hsieh *et al.* (*in press*); **Table 2.6)**. Due to the lack of neurological deficit and increased age the elderly patients with a combination of C1 and odontoid fractures were treated conservatively (Nagashima *et al.,* 2001; **Table 2.6**). A combination of C1- Type II and Type III odontoid fractures (Weller *et al*., 1997) and an avulsion fracture of the body of C2 (Maiman, 1997) were treated conservatively **(Table 2.6)**.

Jefferson's fractures are treated conservatively using different modalities (Weller *et al.,* 1997, Vieweg *et al.*, 2000; Haus and Harris, 2008; **Table 2.6**). Isthmus fractures of C1 as well as anterior arch of C1 fractures are also successfully treated conservatively **(Table 2.6).** An atlas fracture is treated surgically (Sharma *et al.,* 2001), while a combination of C1 and C2 fractures are treated conservatively (Weller *et al.,* 1997; Vieweg *et al.,* 2000) as well as surgically (Weller *et al.,* 1997; Vieweg *et al.,* 2000 and Nagashima *et al.,* 2001). The treatment of unstable Jefferson fractures is varied. External immobilizations with halo traction, halo vest or surgical approaches have been successful (Haus and Harris, 2008). The authors **(Table 2.6)** also reported a case of an unstable Jefferson fracture which was successfully treated conservatively.

Type I traumatic spondylolisthesis is a stable fracture while the Type II and Type III fractures are unstable (Timothy *et al*., 2004). Despite the instability, Types II and III may be treated conservatively **(Table 2.6)**. If, however, healing does not occur, surgical options include anterior C2-C3 interbody fusion or posterior C1-C3 fusion procedures. With respect to atlas fractures, these occur in combination with fractures of C2 or the occipital condyle (Timothy *et al.,* 2004). If seven millimeters or more lateral displacement of the lateral masses occur, it is assumed that transverse ligament disruption has occurred (Sonntag and Dickman, 1992; Polin *et al.*, 1996; Von Gumpenberg and Harms, 1997; Timothy *et al.*, 2004). Treatment of combined anterior and posterior arch fractures of the atlas depends on the integrity of the transverse ligament (Timothy *et al.,* 2004). Isolated anterior arch, posterior arch, or lateral mass fractures are effectively treated with external cervical immobilization devices such as rigid collars, SOMI braces and halo ring-vest orthosis. If the transverse ligament is intact (implying C1–2 stability), the patient is managed without a halo (Timothy *et al*., 2004). If the ligament has been disrupted, the patient is treated conservatively **(Table 2.6)** or *via* surgical C1–2 stabilization (Timothy *et al.,* 2004). Although no studies describe the conservative treatment of extension teardrop fractures, Wheeless (2008) reported that a cervical collar and refraining from excessive activity were appropriate conservative protocols for this type of fracture.

Simple wedge compression fractures are considered stable fractures since the posterior column remains intact. Treatment in this case requires the use of cervical orthoses

(Brynin and Yomtob, 1999; Davenport *et al*., 2008 **Table 2.6**). In the study by Malik *et al.* (2008) C2 injuries were the most common and patients were managed in an orthosis however, the unstable injuries required external immobilization or rigid stabilization. No specific reason was provided as to why the treatment of choice was conservative in the study by Brynin and Yomtob (1999). The authors did however state that there was no comminution or displacement of the fracture and that the soft tissues were within normal limits. Cockluk *et al.* (2005) preferred a conservative approach in the treatment of a unilateral undisplaced fracture of the pedicle of the axis as they considered this to be a stable fracture **(Table 2.6)**. Conservative treatment of unilateral facet dislocation **(Table 2.6)** is unsatisfactory in 75% of cases therefore surgical intervention should be employed as the treatment of choice (Pasciak and Doniec, 1993).

## 2.8 POST-CONSERVATIVE TREATMENT COMPLICATIONS OF CERVICAL SPINE FRACTURES

Complications that occur after conservative treatment include loss of reduction due to halo and Minerva loosening (Malik *et al.,* 2008), non-union and delayed union (Nagashima *et al.,* 2001; Malik *et al.,* 2008). Respiratory complications are also observed specifically in patients in whom the halo was utilized (Lind *et al.,* 1987; Hanigan *et al.*, 1993) and is most likely due to a reduction in vital capacity as a result of the restriction by the halo-vest (Lind *et al*., 1987). Although this reduction of vital capacity may not be symptomatic in normal healthy adults, it should not be overlooked in the elderly as this population group may possess other co-existing medical conditions such as pulmonary disease or associated thoracic spine trauma (Weller *et al.,* 1997). Local infection at the screw entry point in the halo and pseudoarthrosis after the use of a stiff neck collar was observed by Vieweg *et al*. (2000).

Cervical spine traction performed in order to reduce a fracture or dislocation needs to be carefully monitored as overdistraction may lead to spinal cord necrosis (Timothy *et al.*, 2004). Cervical traction may require the patient to have eight to 12 weeks of bed-rest and during this time complications such as deep vein thrombosis (DVT), pneumonia, atelectasis, decubitus ulcers, loss of lean body mass (Timothy *et al.,* 2004) and gastrointestinal bleeding (Goodrich *et al.,* 2008) may occur. Occipital pressure sores have been reported as complications of cones calipers which is a type of skull traction (Department of Orthopaedic Surgery, University of Stellenbosch, 2008).

## 2.9 SURGICAL MANAGEMENT OF CERVICAL SPINE FRACTURES

In the event of an accident, spinal immobilization must be commenced at the scene where rescue workers are likely to utilize a rigid cervical collar in order to immobilize the patient along with supportive blocks. The patient should be placed on a rigid backboard with straps to secure the body (Timothy *et al.,* 2004). Axial traction, cervical Minerva jacket as well as restriction of movement are necessary (Maldonado, 1997). Cardiopulmonary resuscitation, endotracheal ventilation or tracheotomy may be necessary and the development of spinal shock is a pertinent issue that needs to be constantly monitored (Maldonado, 1997).

Pre-surgical treatment such as cervical traction is necessary in order to reduce a fracture or dislocation if instability in the cervical spine is noted (Timothy *et al.*, 2004; Goodrich *et al.*, 2008). This procedure has to be carefully monitored as over-distraction may lead to spinal cord necrosis (Timothy *et al.,* 2004). During cervical traction, fracture union is expected to be obtained between eight to 12 weeks. During this procedure the patient is required to be completely confined to the bed leading to possible complications such as deep vein thrombosis (DVT), pneumonia, atelectasis, decubitus ulcers, loss of lean body mass (Timothy *et al.,* 2004) and gastrointestinal bleeding (Goodrich *et al*., 2008). Gardner-Wells tongs are the most commonly used type of cervical traction (Timothy *et al.,* 2004; Goodrich *et al*., 2008). They have been the standard criteria for many years since they are easy to apply and are able to withstand great weight until reduction is obtained (Goodrich *et al*., 2008). Careful pre-operative treatment of the cervical spine patient is crucial as there is a risk in the development of pulmonary conditions secondary to concomitant injuries (Goodrich *et al.*, 2008). The risk of developing DVT is as high as 95% and is clinically relevant in 35% of patients (Goodrich *et al*., 2008).

The time at which surgical intervention may be performed is not clearly determined (Timothy *et al.,* 2004; Licina and Nowitzke, 2005; Goodrich *et al.,* 2008). Life threatening injuries require immediate attention (Licina and Nowitzke, 2005). Increased mortality rates and neurological deterioration when the operation was performed within five days was reported by Goodrich *et al.* (2008). One to two weeks post-injury was therefore suggested as the best time for surgery. According to Rosenfeld *et al. (*1998), Mirza *et al.* (1999), Papadopoulos *et al*. (2002), Timothy *et al.* (2004) and Goodrich *et al*., (2008) if decompression of the spinal cord is required, early surgical intervention is optimum. Kaya *et al*. (2005) reported that patients with spinal cord compression must undergo surgery as early as possible, most within 24 hours after admission even though these are not emergency cases. Benzel and Larson (1987) observed neurological recovery in patients soon after decompressive surgery. Early surgery means a shorter period of immobilization for the patient, decreased hospital stay and unnecessary surgery later on (Timothy *et al.,* 2004). Rapid decompression of the spinal cord results in the patient being mobile sooner preventing the development of complications (Timothy *et al.,* 2004; Goodrich *et al*., 2008).

Surgical treatment of the cervical spine is considered if the spine is unstable in order to reduce deformity and improve any neurological deficit (Timothy *et al*., 2004; Licina and Nowitzke, 2005). The surgical procedure and the implements utilized are evidence-based i.e. they depend on the type/s and complexity/ies of the cervical spine fracture/s, the availability of the implements and associated pathological and clinical findings (Naidoo, 2007).

The literature reports on the surgical procedures/implements utilized for the different cervical spine fractures are summarized in **Table 2.7**.

**Table 2.7 Surgical procedures/instrumentation utilized for cervical spine fractures**

| **Fracture type** | **Reference** | **Surgical procedures/instrumentation** |
|---|---|---|
| Odontoid fractures | | |
| Unspecified | Gallie (1939), Brooks and Jenkins (1978), Geisler *et al*. (1989), Jeanneret and Magerl (1992), Coyne *et al.* (1995), Harms and Melcher (2001) | Posterior fusion or anterior screw fixation |
| | Shaha *et al.* (1993) | Transoral or transpharyngeal exposure |
| | Nagashima *et al.* (2001) | Posterior atlantoaxial arthorodesis |
| | Eriksen (2005) | Brooks C1-C2 posterior fusion, Songer cables and iliac bone graft |
| | Grauer *et al*. (2005) | External immobilization, anterior screw fixation, posterior atlantoaxial fusion |
| Type II | Geisler *et al.* (1989), Montesano *et al*. (1991), Apfelbaum *et al.* (2000), Vieweg *et al.* (2000), Koivikko *et al*. (2004), Ochoa (2005), Min *et al.* (2006), Song *et al*. (2007), Ben-Galim and Reitman (*in press*) | Anterior screw fixation |
| Type II and Type III | Wang *et al*. (1984), Hadley *et al.* (1985), Dunn and Seljeskog (1986), Fujii *et al.* (1988), Geisler *et al.* (1989), Etter *et al*. (1991), Apfelbaum (1992), Subach *et al*. (1999), Kim *et al.* (2000) | C1-C2 posterior fusion as the primary intervention |
| Atlantoaxial and subaxial cases | Malik *et al.* (2008) | Posterior stabilization, anterior cervical fusion |
| C1 and C2 fractures | Weller *et al*. (1997) | Halo immobilization, Philadelphia collar and then posterior cervical fusion |
| Combined C1-C2 fractures | Vieweg *et al.* (2000) | Anterior screw fixation or dorsal atlantoaxial fusion in conjunction with a stiff neck collar |
| | Nagashima *et al.* (2001) | Atlantoaxial fusion |
| | Agrillo and Mastronadi (2006) | Anterior screw fixation and transarticular screw fixation |
| C1-C2 instability | Coyne *et al.* (1996) and Kaminski *et al*. (2008) | Transarticular screw fixation |
| Complex C2 fractures | Vieweg *et al*. (2000) | Dorsal atlantoaxial screw fixation |
| Transpedicular fractures of C2 with C2-C3 dislocation | Sharma *et al.* (2001) | Anterior cervical plating with screw fixation, C2-C3 discectomy |
| Chance-type fracture C6-C7 | Rowell (2006) | Discectomy with fusion of C6-C7 |
| Bilateral facet dislocation | Payer and Tessitore (2007) | Anterior approach (anterior discectomy), posterior approach with lateral mass screw insertion and anterior approach using the anterior cervical plate |

Spinal fusion is performed by operating under traction where the SP wiring is first done which proceeds to fusion (Rogers, 1942). This procedure was first introduced by Rogers (1942) and lateral mass screws and plates were later introduced by Camille *et al.* (1979). Anterior cervical discectomy and fusion were reported by Smith and Robinson in 1955 while the technique of circular graft with anterior cervical fusion was reported by Cloward in 1959. During cervical spine surgery the patient who was placed in traction or a halo for the purpose of reduction of the fracture or dislocation was required to have these devices intact in the operating theatre (Timothy *et al.,* 2004; Goodrich *et al.*, 2008). Depending on the surgical procedure required, the patient is moved from supine to prone positions where great care is required in the change of positions (Goodrich *et al.*, 2008). In the anterior approach the following muscles are encountered during the surgeon’s incision: the platysma, sternocleidomastoid, sternothyroid, sternohyoid and longus colli muscles (Timothy *et al.,* 2004). It is during this procedure that damage to recurrent laryngeal nerve occurs leading to possible vocal cord palsy (Timothy *et al.,* 2004). Difficulties in swallowing due to damage to the superior laryngeal nerve are also observed (Timothy *et al.,* 2004).

According to Timothy *et al*. (2004) the anterior approach is less painless compared to the posterior approach due to the relative lack of muscle dissection which make it more tolerated and less painful than the posterior approach. Often in an anterior column fracture the entire vertebral body is disrupted which necessitates its removal i.e. a corpectomy or vertebrectomy is required (Timothy *et al.,* 2004). During injury involving the anterior column the Smith-Robinson approach (which was an anterior approach), is utilized (Kaya *et al*., 2005; Goodrich *et al.,* 2008). This procedure permits anterior decompression after which an allograft, autograft iliac crests or fibular is placed in the IVD space. This is followed by placement of the anterior locking plates which serves to stabilize the cervical spine (Timothy *et al.,* 2004; Goodrich *et al.,* 2008). The Synthes Anterior Cervical Spine Locking Plate or Aesculap ABC dynamic plating may also be used (Timothy *et al.,* 2004). The advantage of the Synthes Anterior Cervical Spine Locking Plate is that the screws maintain rigid alignment of the bone grafts. The dynamic plating which permits vertical translocation but restricts lateral and AP translocation allows the bone graft to collapse into the bodies which reduce the likelihood of the screws loosening as the construct matures (Timothy *et al.,* 2004). If fracture reduction does not occur especially in cases of bilateral locked facets a posterior approach is necessary (Timothy *et al.,* 2004; Payer and Tessitore, 2007) and sometimes a dual approach is required (Goodrich *et al.,* 2008; Payer and Tessitore, 2007) as in the case of odontoid fractures (Grauer *et al*., 2005; **Table 2.7**) and bilateral facet dislocations (Payer and Tessitore, 2007; **Table 2.7)**. In the case of odontoid fractures the anterior approach maintains rotation at the atlantoaxial joint while the posterior approach reduces rotation of the spine at this joint (Timothy *et al.,* 2004).

Although the posterior approach is considered relatively easy and reliable (Kato and Itoh, 1998) it requires muscle retraction off the cervical spine as far lateral as to the facet joints bilaterally (Timothy *et al.,* 2004; Goodrich *et al.,* 2008). This approach necessitates exposure of the facet joints leading to severe post-operative pain, devascularisation and atrophy of the posterior cervical muscles (Timothy *et al.,* 2004). Spinous process wiring techniques are used in the posterior approach and posterior fusion. The disadvantages associated with these wiring techniques include injury at the site of insertion of the wire as well as failure (Timothy *et al.,* 2004).

No specific surgical treatment option exists for the treatment of odontoid fractures (Julien *et al*., 2000; Maak and Grauer, 2006) although several authors reported the use of the posterior fusion or anterior screw fixation via the transoral approach (Ben-Galim and Reitman, *in press*) as shown in **Table 2.7**. Geisler *et al.* (1989), Montesano *et al.* (1991) and Apfelbaum *et al.* (2000) implemented the anterior screw fixation for Type II odontoid fractures **(Table 2.7)**. According to Koivikko *et al.* (2004), Ochoa (2005) and Ben-Galim and Reitman *(in press*) anterior placement of the odontoid screw is a surgical option that is only possible if the facture is non-displaced or is anatomically reduced. According to Etter *et al.* (1991), Asfora *et al.* (1992) and Apostolides *et al.* (1997) the rotation at the C1-2 junction and motion at the C0-C1 is preserved by anterior screw fixation. Morandi *et al*. (1999a) and Perri *et al.* (2007) are in conflict with Kim *et al*. (2008) with respect to the treatment of Type II odontoid fractures. Kim *et al.* (2008) reported that the halo vest is the best choice of treatment while Morandi *et al*. (1999a) and Perri *et al.* (2007) are of the view that odontoid screw fixation is advantageous since it offers immediate stability to acute Type II odontoid fractures and external orthoses is not required and furthermore, C1 and C2 motion is not altered. Geisler *et al.* (1989), Montesano *et al.* (1991) and Apfelbaum *et al.* (2000) are of the view that Type II odontoid fractures with intact transverse ligaments are best treated by anterior screw fixation as it provides the best anatomical and functional results. There is a high fusion rate in addition to it being a cost-effective treatment (Perri *et al.,* 2007) compared to other alternatives such as posterior atlantoaxial fusion and results in earlier return to work and activities of daily living compared to external immobilization and posterior fusion (Finn *et al. in press*).

Clarke and White (1985) on the other hand, reported fusion rates of up to 96% in patients who sustained Type II odontoid fractures who were treated with posterior cervical fusion. The complications related to this technique however, include a decrease in axial rotation and flexion and extension motions of the neck by 50% and 10% respectively (White and Panjabi, 1990). Therefore posterior fusion is used more in chronic instead of acute cases of odontoid fractures (Perri *et al.,* 2007). Wang *et al.* (1984), Hadley *et al.* (1985), Dunn and Seljeskog (1986), Fujii *et al.* (1988), Geisler *et al.* (1989), Etter *et al.* (1991), Apfelbaum (1992), Subach *et al.* (1999) and Kim *et al.* (2000), considered operative treatment of C1-2 posterior fusion as a primary treatment since high failure rate was associated with rigid orthoses such as the halo vest or Minerva jacket.

According to Nagashima *et al.* (2001; **Table 2.7)** the surgical option for isolated odontoid fractures in the elderly is posterior atlantoaxial arthrodesis while for a combination of atlas and an axis fracture, occiputo-atlantoaxial fusion is required. This procedure sacrifices motion of the cervical spine and hampers the activity of the elderly kyphotic patient. In the study of Weller *et al*. (1997) one patient who sustained a Type III odontoid fracture was treated with a Philadelphia collar but did not achieve union after 20 weeks. This patient was then treated by atlantoaxial arthrodeses.

Although posterior atlanto-axial fusion with wiring and cortico-cancellous bone graft was reported by Brooks and Jenkins (1978) and Griswold and Albright (1978) as having high fusion rates the non-union rate reported by Schatzker and Rorabeck (1971) and Sowthwick (1980) was 54%. Henry and Bohly (1999) reported a fusion rate of 92% following anterior screw fixation, while Nielsen and Edal, (2001) reported a lower value of 71%. Posterior fixation by screws or wires was considered as surgical treatment for C1-C2 fractures. This procedure, however, blocked C1-C2 axial rotation (Morandi *et al.,* 1999a). The transoral approach had the risk of the patient contracting an infection (Bohler, 1982; Borne *et al.,* 1988; Malca *et al.,* 1991; Kato and Itoh, 1998).

Kato and Itoh (1998) suggested C1-C2 interlamina spine fusion (Brooks technique) with C1-C2 transarticular screw fusion (Magerl technique) for the treatment of atlantoaxial dislocation. This procedure does not require the use of a halo-vest as a result of the stable fixation of C1 on C2. The treatment of choice for most C1 and C2 fractures in the elderly patient is immobilization with the halo device (Weller *et al.,* 1997). Internal fixation is considered if the elderly patient is unable to tolerate the halo device. Many authors suggest that surgical fusion is not the ideal treatment for the elderly (Pringle, 1974; Gerhart and White, 1982; Pepin *et al.,* 1985) but according to Weller *et al*. (1997), surgery such as posterior cervical fusion may be safely and effectively done on elderly patients.

An axis transpedicular fracture which occurs in conjunction with a C2 – C3 dislocation is treated surgically (Sharma *et al.,* 2001) while a combination of C1 and C2 fractures is treated conservatively (Weller *et al.,* 1997; Vieweg *et al.,* 2000) as well as surgically (Weller *et al.,* 1997; Vieweg *et al.,* 2000 and Nagashima *et al.,* 2001). Instability in the C1–C2 junction is treated surgically using the transarticular screw fixation (Coyne *et al.,* 1996; **Table 2.7**).

Treatment of fractures at the cervicothoracic junction may be done surgically (Rowell, 2006; Lenoir *et al.,* 2006) or conservatively (Brynin and Yomtob, 1999; **Table 2.6**). It is rare to find instability after a compression fracture (Brynin and Yomtob, 1999). If instability does occur, it is due to posterior ligamentous rupture (Stauffer, 1986). Reduction, immobilization and fusion are necessary in unstable fractures (Nykoliation *et al.,* 1986).

Bohlman (1979) reported that closed or open reduction with posterior fusion is the best surgical option for subluxations or dislocations for neurological recovery and stability. According to Pasciak and Doniec (1993) the choice of treatment for unilateral facet dislocations depends largely on the neurological symptoms that the patient presents with. In patients who present without neurological symptoms or nerve root symptoms a conservative approach is undertaken. Surgical option is considered in patients where there is unsuccessful reduction with skull traction, redislocation after the removal of traction or the occurrence of late instability.

According to Goodrich *et al.* (2008) realignment of the cervical spine is a considerable challenge to spinal surgeons with respect to lower cervical spine fractures and dislocation. Cervical tongs and traction are generally utilized to accomplish reduction of bilateral facet dislocations whereas reduction of unilateral facet dislocations may not be as easily accomplished. If reduction is attempted or the neurological deficit is persisting then open reduction and stabilization may be performed using a posterior approach (Goodrich *et al.,* 2008).

## 2.10 POST-SURGICAL ORTHOSES

The use of post-surgical orthoses such as the stiff neck-collar (Vieweg *et al*., 2000), the halo orthosis (Vieweg *et al*., 2000; Laidlaw *et al*., 2004) and the Philadelphia collar (Agrillo and Mastronadi, 2006) is required in some patients. Cervical collars, Philadelphia collars and soft collars are used in patients who undergo atlantoaxial fusion and anterior and/or posterior fusion respectively (Al-Barbarawi and Sekhon*,* 2005; Song and Lee, 2008). Patients with polytrauma especially to the thorax or cranium and associated thoracic and lumbar fractures poorly tolerate external immobilization and these patients are best immobilized in a simple collar-type orthosis (Brodke and Anderson, 1998). However, in some patients even a cervical collar is not necessary after the first post-operative day (Payer and Tessitore, 2007).

## 2.11 POST-SURGICAL COMPLICATIONS OF CERVICAL SPINE FRACTURES

A summary of studies that have reported post-surgical complications following cervical spine surgery is presented in **Table 2.8**.

**Table 2.8 A summary of the studies that have reported post-cervical spine surgical complications**

| Type of procedure/treatment implemented | Reference | Reported complication |
|---|---|---|
| Anterior screw fixation | Fujii *et al.* (1988) | Non-union of odontoid fracture |
| | Etter *et al*. (1991) | Screw pull out, fracture and death |
| | Montesano *et al.* (1991) | Instrument failure (screw pull out and screw cut out) |
| | Jenkins *et al.* (1998), Anderson *et al.* (2000), El Saghir and Anderson (2000), Subach and Haid (2000), Borm *et al.* (2003) | Post-surgical haematoma, malpositioned screw, mechanical failure, dysphagia, post-operative fracture of the anterior body of the axis, post operative tetraparesis, screw failure and death |
| | Fountas *et al*. (2006) | Pulmonary atelectasis, superficial wound infection, screw extrusion |
| Anterior cervical discectomy and fusion | Muzumdar *et al.* (2000) | Bilateral vocal cord paralysis |
| Anterior cervical fusion | Ba *et al.* (2006), Song and Lee (2008) | Pharyngeal diverticulum, distal screw loosening, fusion delay due to graft fractures or pseudoarthrosis, vertebral abscess, metal failure |
| Anterior retropharyngeal approach | Lee and Sung (2006) | Neural and vessel injury, esophageal and pharyngeal perforation, airway obstruction |
| C2 posterior stabilization | Lee and Sung (2006) | Delayed fusion, non-union, unstable non-union, transient dysphagia |
| Atlas lateral mass screw fixation | Lee *et al.* (2006) | Bleeding and greater occipital nerve injury |

Post-surgical complications occur in many patients. Several researchers reported adverse post-surgical complications as shown in **Table 2.8**. Instrument failure was a common complication following anterior screw fixation (Etter *et al*., 1991; Montesano *et al.* 1991; Jenkins *et al.,* 1998; Anderson *et al.,* 2000; El Saghir and Anderson (2000), Subach and Haid (2000); Borm *et al.,* 2003; Fountas *et al*., 2006; Song and Lee, 2008; **Table 2.8**). The 'back-out' of screws was reported as high as 3.4% (Apfelbaum *et al*., 2000). Other serious post-surgical complications following anterior screw fixation included post-operative tetraparesis and death (Etter *et al*., 1991; Jenkins *et al.,* 1998; Anderson *et al.,* 2000; El Saghir and Anderson (2000), Subach and Haid (2000); Borm *et al.,* 2003; **Table 2.8**). Kaya *et al.* (2005) reported that in their study anterior instrumentation with a Synthes type cervical plate (Gassman and Seligson, 1983; Ripa *et al.,* 1991) was performed in 37 patients, posterior stabilization was performed in four patients while six patients had a combined approach. In 14 patients who were operated using the anterior approach, loss of correction of more than three degrees and IVD degeneration adjacent to the fused segment was observed. Other complications reported in this study included two cases of neurological deterioration, two cases of pseudoarthrosis due to infection, one case of oesophageal fistula, six cases of malposition of the anterior cervical plate during application, and two cases of severe neck pain due to degenerating disc spaces. Seven patients in this study died due to cardiovascular and respiratory complications.

Non-union or delayed union (Fujii *et al.,* 1988; Lee and Sung, 2006; Song and Lee, 2008; **Table 2.8**) wound infection (Vieweg *et al*., 2000; Arnold *et al*., 2005; Fountas *et al.,* 2006), esophageal perforation (Sharma *et al*., 2001; Lee and Sung, 2006), spinal cord lesions (Arnold *et al*., 2005; Lenoir *et al*., 2006) and dysphagia (Jenkins *et al.,* 1998; Anderson *et al.,* 2000; El Saghir and Anderson, 2000; Subach and Haid, 2000; Borm *et al.,* 2003; Lee and Sung, 2006; **Table 2.8**) were reported as post-surgical complications. The complications arising as a result of anterior retropharyngeal approaches occurred as a result of direct injury or severe retraction of surrounding structures during the surgical procedure (Lee and Sung, 2006; **Table 2.8**).

Brichall (1993) stated that decubitus ulcers or pressure sores may occur at any part of the body where pressure occurs at a bony prominence resulting in ischaemic injury. Friction, moisture and anaemia predispose a patient to the development of pressure sores (Brown, 1988). Approximately 70% of elderly hospitalized patients are at risk of developing pressure sores (Wai-Han *et al.,* 1997). They are difficult to treat (Wai-Han *et al.,* 1997) and affect one in ten patients (Blaber, 1993). Barrois (1995), Unosson *et al.* (1995) and Lindgren *et al. (*2002), on the other hand report that the prevalence of decubitus ulcers is between 3.75% and 42%. Morbidity and mortality occur as a result of anaemia, cellulitis and systemic infection (Vohra and McCollum, 1994). Mobility, incontinence and nutrition are risk factors for the development of decubitus ulcers (Davies, 1994; Smith *et al.,* 1995) which are determined by scoring systems (Wai-Han *et al.,* 1997). Norton *et al.* (1979) presented a risk assessment scale developed from clinical experience (Lindgren *et al.,* 2002) for the prediction of pressure sore development among elderly patients **(Appendix E)**. The scale included five variables where the maximum score was 20. A score of 14 or below on this scale meant that the patient was at risk of pressure sore development. The scale was then modified and introduced for the first time in other countries such as Sweden in 1987.

Short-term (i.e. within a few weeks) post-surgical complications include decubitus ulceration, sepsis, pneumonia (Weighardt *et al.,* 2000), wound infection (Vieweg *et al*., 2000), tetraparesis (Laidlaw *et al*., 2004) and respiratory distress/difficulties (Laidlaw *et al*. 2004; Agrillo and Mastronadi, 2006). Post anterior cervical spine fusion complications include pharyngeal diverticulum (Ba *et al.,* 2006; **Table 2.8**) which was also reported earlier by Goffart *et al*. (1991) and Sood *et al.* (1998). According to Muzumdar *et al.* (2000; **Table 2.8)** bilateral vocal cord paralysis after anterior cervical discectomy and fusion is rare. The incidence of temporary unilateral vocal cord paralysis after this surgery is 2 - 7% while that of permanent unilateral vocal cord paralysis is 1 - 3.5% (Riley *et al.,* 1969; Heeneman, 1973; Flynn, 1982; Bulger *et al.,* 1985; Crumley, 1994; Netterville *et al.,* 1996; Weisberg *et al.,* 1997). Complications related to lower cervical spine fractures and dislocations include spinal cord injury, pulmonary conditions such as pneumonia, atelectasis and pulmonary emboli, gastrointestinal conditions (e.g. stress ulcers), urological conditions, skin conditions (e.g. decubitus ulcers), DVT, psychological conditions (e.g. depression) and unilateral root injury. Autonomic dysreflexia resulting in distention or fecal impaction was also reported by Goodrich *et al*. (2008).

### 2.11.1 Post-Surgical Infections

Complications of neck infections include arterial rupture, venous thrombosis with or without distant embolism or base of skull involvement (Weber and Siciliano, 2000). Local infection such as osteomyelitis could develop post-surgically. Jellis (1988) reported increased rates of sepsis in patients undergoing internal fixation of fractures. Superficial wound infection and pyrexia of unknown origin were complications that were observed post spinal-surgery (Young *et al.*, 2005).

According to Delgado-Rodriguez *et al*. (2003) alcohol consumption increases community-acquired infections and affects the immune system. They reported that men who consume alcohol heavily (more than 108g/day) and who undergo general surgical procedures are at an increased risk of developing nosocomial infection and surgical-site infection compared to women who drink lightly. Furthermore, patients who consume more than 72g/day of alcohol are at an increased risk of developing lower respiratory tract infections.

Patients with immunocompromised states such as those with human immunodeficiency virus (HIV) and acquired immune deficiency syndrome (AIDS) are more susceptible to the development of infection (Carragee, 1997; King, 2006) as a result of their compromised immune system (Lin *et al*., 2004). The HIV/AIDS strategic plan for South Africa (2000-2005) states that there are currently 4.2 million South Africans infected with HIV. It is estimated that in 1998 over 1,600 people were infected with HIV each day which translates to more than 550,000 people infected each year. In South Africa, Blacks and economically poor populations are severely affected by the HIV epidemic (Harling *et al*., 2008).

Post-surgical cellular immunity depression has been reported by Allendorf *et al.* (1997), Shimaoka *et al.* (1998) and Ogawa *et al*. (2000) and have been attributed to the development of many surgical complications (Shakhar *et al.,* 2003). Severe bleeding post-surgery in haemophiliacs and those with HIV infection was reported by Young *et al*. (2005). The bleeding tended to be aggravated by thrombocytopaenia, protease inhibitors or drugs or infections interfering with bone marrow, liver, clotting factors or platelets. Poor wound healing and post-operative wound breakdown following laparotomy and anorectal procedures were reported in HIV positive patients (Davis *et al*., 1999; Morandi *et al*., 1999b). Infection of an ileo-femoral interposition graft following repair of an HIV-related aneurysm was reported in an isolated case (Nair *et al.,* 2000). This particular patient died of overwhelming systemic sepsis. Tran *et al*. (2000) reported that one patient who had a pre-operative diagnosis of AIDS died of post-operative pneumonia after the incision and drainage of a cervical abscess. HIV/AIDS was also reported as a risk factor for the development of infection of prosthetic materials and implants (Kaplan *et al*., 1996; Eliopoulos and Lyle, 1999; Woolgar and Robbs, 2002). Smoking was also implicated in reducing immunity by inhibiting the production of tumor necrosis alpha (TNF-$\alpha$), interleukin-6 (IL-6), IL-1 and IL-8 which resulted in less effective resistance to invading pathogens (Brown *et al*., 1989; Yamaguchi *et al.,* 1993; Kimberly *et al.,* 1994).

According to Littlewood (2008) highly active antiretroviral therapy (HAART) is administered to HIV positive individuals as it provides more efficient treatment with less toxicity and decreases the likelihood of resistance. An increase in glucose intolerance was however observed in the HAART-treated HIV population but uncertainty exists as to whether this was as a result of the therapy or the disease (Florescu and Kotler, 2007).

Littlewood (2008) emphasised that HIV positive patients may not only present with features of immunosuppression but also treatment associated issues which may be pertinent to the anaesthesiologist. Despite these reports the current literature with respect to clinical outcomes of HIV/AIDS patients who undergo surgical treatment still however remains scarce (Lin *et al.,* 2004).

The world's leading curable cause of infectious disease is tuberculosis (TB) (World Health Organization, 1999). The HIV epidemic in South Africa is one of the fastest growing epidemics in the world. As a result of the rise in the HIV epidemic, TB is common both in the developed (Lademarco and Castro, 2003; Kapoor, 2007; Harling *et al.,* 2008) and under-developed countries of the world (Kapoor, 2007). According to the Department of Health–KwaZulu/Natal Tuberculosis Strategic Plan for South Africa (2007 – 2011) the number of people with TB during the period 1996 to 2006 increased from 109 000 to 341 165.

Extrapulmonary involvement of TB is more common in HIV positive patients (Kapoor, 2007). In sub-Saharan Africa 60 - 90% of patients with extrapulmonary TB are HIV-positive (Kapoor, 2007). Tuberculosis which is isolated to the head and neck regions is commonly seen in patients with HIV infection (Singh *et al.,* 1998). The common post-surgical complications encountered in HIV-infected patients are wound infection, followed by ventilatory support lasting more than two days, opportunistic infection, pneumonia, groin lymphocoele, myocardial infarction, urosepsis and arrhythmia (Lin *et al.,* 2004). Central nervous system involvement is observed in 10% of patients with TB where tuberculous meningitis is the most common clinical manifestation (Skendros *et al.,* 2003). This condition has a high rate of disability and mortality if it is not treated promptly (Hosoglu *et al.,* 2003). Complications of tuberculous meningitis include hydrocephalus, cranial nerve paresis, brain edema, focal ischemia, myelitis and arachnoiditis (Tanriverdi *et al.,* 2003).

## 2.11 POST SURGICAL REHABILITATION OF CERVICAL SPINE FRACTURES

Patients involved in MVAs may present to health care providers (Ferrantelli *et al*., 2005) such as chiropractors (Alcantara *et al.,* 2001; Novicky, 2003; Alpass, 2004; Eriksen,

2005) or they may be referred by orthopaedic surgeons for post-surgical rehabilitation to physiotherapists (Bromley, 2006). It was estimated that 25% of MVA patients develop psychological conditions such as depression and anxiety (Schmand *et al.,* 1998; Radanov *et al.*, 1999) following physical injury (Jaspers, 1998). According to Peebles *et al.* (2001) this is a risk factor for the development of chronic pain syndromes leading to long-term health complaints including headaches, fatigue, sleep disturbance, thoracic pain, low back pain, and general ill health (Berglund *et al.,* 2001).

With respect to the patient who sustains acute spinal cord injury the focus of the treatment is to assist the patient in achieving independence as soon as possible. According Noreau and Shephard (1995) the goal of patients who have sustained spinal cord injury is avoidance of secondary impairments, disabilities and handicaps. The biological benefits of exercise targeting secondary impairments which include loss of cardiorespiratory and muscular function, metabolic alterations and systemic dysfunctions minimized disabilities and appearance of handicaps such as the loss of mobility, physical dependence and poor social integration. A lack of physical fitness in patients who sustain spinal cord injury results in physical deconditioning which decreases the quality of life of these patients rendering them in to state of dependency. Occupational therapy is an essential component of rehabilitation as it helps people carry out everyday tasks ranging from physical exercises, increased strength and dexterity to the use of adaptive equipment such as wheelchairs and orthotics, especially those with spinal cord injuries (Punwar, 2000).

Correct positioning of the patient in bed is imperative in order to maintain correct alignment of a fracture and to prevent decubitus ulcers and contractures. Physiotherapy during the period of bed-rest focuses on respiratory therapy as well as the maintenance of active and passive movements (Bromley, 2006). Post-surgical spinal fusion rehabilitation addresses bed mobility, transfer training, balance and gait training (Bhatnagar *et al*., 1995). The focus of rehabilitation on these patients is on increasing and restoring blood circulation, motion, flexibility, strength and decreasing pain (Reitman and Esses, 1995).

Respiratory therapy is pertinent in order to maintain good ventilation. Passive movements ensure mobility of paralysed structures and encourage good circulation whereas active movements play a role in regaining or maintaining muscle strength (Bromley, 2006). Pre-and-post-surgical chest physiotherapy is also performed in patients where general anaesthetic is used for any surgical procedure (Bromley, 2006). When patients with cervical spine injury have spinal cord damage, the respiratory muscles that are innervated below the level of the lesion become paralysed which interfere with the power and integration of the remaining muscles. This reduces their capability to ensure proper chest wall function (Bromley *et al*., 2006). The effects of posture on respiration are taken into consideration in patients with spinal cord lesions above C5 where the diaphragm is partially or completely paralysed (Bromley *et al*., 2006). Physiotherapy focuses on reducing airway obstruction, promoting sputum mobilization and expectoration and improving ventilation and gas exchange (Bromley *et al*., 2006). Prophylactic treatment includes breathing exercises, positioning and postural drainage, forced expiration as well as assisting the patient in normal coughing (Bromley *et al*., 2006).

In patients with muscle and joint contractures, passive movements, prolonged passive stretching, active exercises, splinting, passive and active exercises in a heated pool, ice therapy and ultrasound are considered but if no improvement is observed after six weeks of intensive therapy surgery is then considered (Bromley, 2006). Gait training and partial body-weight support is used to improve gait (Gardner *et al.,* 1998). Appropriate locomotor training enhances the functional contribution of regenerating pathways in the spinal cord (Muir and Steeves, 1997). Sensorimotor stimulation improves limb action during training which in turn improves locomotor plasticity after spinal cord injury (Muir and Steeves, 1997).

With respect to the treatment of pressure sores, physiotherapy employs passive movements, grease massage, exercise, and chest therapy. The patient is educated in pressure consciousness and transfers in order to check that there is care when moving and lifting the limbs (Bromley, 2006).

## 2.13 THE CHIROPRACTOR AND CERVICAL SPINE FRACTURES

Chiropractors play a role in the management of cervical spine trauma. There have been cases where cervical spine fractures were overlooked by medical physicians and were incidental findings on radiographs which were requested as a result of the history given by the patient to the chiropractor (Brynin and Yomtob, 1999; Eriksen, 2005). The patients were then referred to their primary health-care providers when these were diagnosed (Brynin and Yomtob, 1999; Eriksen, 2005) and chiropractic intervention commenced only after the patient was stable (Brynin and Yomtob, 1999). Brynin and Yomtob (1999) and Eriksen (2005) cautioned that chiropractors be aware of the clinical and radiological features of spinal fractures before commencing any treatment even though a patient may have already been evaluated by a medical physician. Re-evaluation of the patient includes a complete case history and physical examination with emphasis on spinal and neurological examination and the requesting and evaluation of radiographs or other appropriate diagnostic imaging modalities (Shaik, 2008). If there is any doubt about the possibility of a spinal fracture/s, healing fractures, spinal instability, spinal infections or gross osteoporosis then spinal manipulation must be avoided as it is contraindicated in these conditions (Wyatt, 2005).

Patients present to the chiropractor following cervical trauma complaining of neck pain, headache, stiffness or radiculopathy symptoms. The aim of spinal manipulation is to restore mobility to the individual articulations (Gatterman, 2003) which results in improved flexibility and increased joint mobility (Herzog *et al*., 1988; Gal *et al*., 1994; Herzog, 2000; Gatterman *et al*., 2001; Gatterman, 2003). Spinal manual procedures are found to result in hypoalgesic effects in distant areas by activating descending inhibitory mechanisms (Vicenzino *et al.*, 2001; Paungmali *et al.*, 2003; Skyba *et al.*, 2003). Alcantara *et al*. (2001) reported a case of a patient who presented to a chiropractor after he underwent cervical discectomy which was unsuccessful and the patient’s symptoms were unresolved. This patient experienced considerable relief of his symptoms following cervical spine manipulation. Patients suffering from whiplash-associated disorders are found to have greater reduction in their symptoms when receiving a thoracic spine manipulation than patients who do not receive a thoracic spine manipulation (Fernandez-de-las-Penas *et al.,* 2004). In addition to spinal manipulation chiropractors may utilize ROM, strength, proprioception, and exercise training, physiotherapy modalities and traction (Wetherington, 2005).

## 2.14 CONCLUSION

Despite the extensive literature on cervical spine trauma little information exists on the profile of cervical spine trauma at a spinal unit or trauma unit setting. The available epidemiological data, clinical manifestation of cervical spine fractures and conservative and surgical management of the different cervical spine fractures vary considerably while the impact of conditions such as HIV/AIDS and tuberculosis on the development of post-surgical complications have yet to be fully investigated. Knowledge of the profile of cervical spine fractures would contribute to better patient management by spinal health care professionals including surgeons/radiologists/physiotherapists and chiropractors.

# CHAPTER THREE

# MATERIALS AND METHODS

## 3.1 INTRODUCTION

Patients who presented at the King George V Hospital arrived or were referred from surrounding hospitals which included King Edward VIII, KwaDukuza and Prince Msheni hospitals. These patients' conditions were evaluated and a decision was taken as to whether the patient required elective surgery or not. This decision was taken by the registrars in consultation with the Head of the Spinal Unit. If surgery was not required the patient was treated conservatively, sent home and told to return on a given date for re-evaluation. The role of the researcher was to collect data for each of the stages of this research. Ethical clearance and permission to conduct this study had been obtained from the Durban University of Technology Faculty of Health Sciences Research Committee (Ethical Clearance Certificate No. FHSEC 036/07 – **Appendix H)**, the KwaZulu-Natal Provincial Health Department **(Appendix I)** and the King George V Hospital manager **(Appendix F).**

## 3.2 SAMPLE SIZE

The Spinal Unit admits at least six patients with traumatic cervical spine fractures per month (Govender, 2007). Therefore the minimal sample size for this study was set at 20 patients over the three-month period.

## 3.3 BRIEFING SESSION WITH NURSES AND REGISTRARS OF THE SPINAL UNIT

A briefing session was held with the nurses and registrars of the Spinal Unit prior to the commencement of this study. The purpose of this session was to inform them of the nature of the study. The nurses introduced prospective subjects (patients) to the researcher and acted as translators (when the need arose) to explain the research procedure (in isiZulu) and read the subject information sheet **(Appendix B1 (English) or Appendix B2 (isiZulu))** to the prospective subject. The registrars' participation in this study entailed providing the researcher with the relevant medical and surgical data of the subject and also to introduce prospective subjects to the researcher. An information letter was given to the nurses **(Appendix C1)** and the registrars **(Appendix D1**). The researcher answered any queries raised by the nurses or the registrars. Each nurse and registrar had to sign a letter of informed consent **(Appendix C1** (Nurses) **and Appendix D1** (Registrars)**)** if they agreed to participate in this study.

## 3.4 INCLUSION AND EXCLUSION CRITERIA

### 3.4.1 INCLUSION CRITERIA

Patients who were admitted to King George V Hospital's Spinal Clinic with traumatic cervical spine fractures.

### 3.4.2 EXCLUSION CRITERIA

- Patients who did not allow the researcher to collect data from their medical records and who did not sign the informed consent form **(Appendix G1 or G2) (Appendix G1 – English; Appendix G2 – isiZulu)**
- Patients who were unconscious or were in such a state (e.g. drowsy or lethargic) that they were unable to provide informed consent. However, if any of these patients recovered sufficiently to provide informed consent, they were included in this study.
- Any minor patient (i.e. under 18 years of age) who did not present with his/her parent(s) at the Spinal Clinic.
- If a minor did not agree to allow the researcher to inspect his/her medical records, but the parent(s) agreed, then that patient was excluded from this study.
- Any patient who presented with pathological cervical spine fractures (e.g. due to TB or bone tumours, etc.)

## 3.5 RECRUITMENT OF SUBJECTS

Each prospective subject was introduced to the researcher by the nurses or the registrars at the Spinal Unit. The nature of the study was explained in detail to each prospective subject by the researcher. Some of the nursing staff was required as translators during this consultation. Each prospective subject was also given a subject information sheet in English **(Appendix B1**) or isiZulu **(Appendix B2)** to read. The prospective subjects were given an opportunity to ask any questions they may have had and the researcher responded accordingly. All prospective subjects who agreed to participate in this study signed an informed consent form **(Appendix G1 and Appendix G2)**.

If a prospective subject who allowed the researcher to inspect his/her medical records was illiterate or tetraplegic, a right thumb print was taken and an independent person was asked to sign the informed consent **(Appendix G1 or G2)** on behalf of the subject.

## 3.6 PRE-SURGICAL PROCEDURE

### 3.6.1 ON ADMISSION

On admission the nurses on duty took a brief history of the subject **(Appendix E)**. The subject was then examined by the registrars. This examination included a full case history and a physical examination with emphasis on the neurological examination. The radiological findings and other investigations which the patient presented with (these were taken at the primary hospital) were noted. If further investigations were required to confirm or clarify a clinical diagnosis, these were requested by the registrar or Head of the Spinal Unit. The researcher had been granted permission by the Superintendent of the Hospital to be present during the ward rounds and in the operating theatre in order to be able to record the necessary data **(Appendix F)**. If the researcher was unable to be present during the admission of the patient (e.g. subject was admitted late at night or early in the morning) then data were obtained from the patient records after the subject had signed the informed consent form. The following data were recorded by the researcher:

**Appendix A**

- Demographic data
- Examination findings (co-existing medical conditions, HIV status and pressure sore assessment using the Norton Scale (Norton *et al*., 1979))
- Cause of fracture
- Description of fracture (location of the fracture, dislocation, type of fracture/dislocation)
- Associated fracture or injury (head injury, extraspinal fractures)
- Neurological findings (spinal shock, cranial nerve palsy/deficit, pre-surgical Frankel grading (Frankel *et al*., 1962)
- Conservative treatment
- Post-conservative treatment complication (three-weeks)

## 3.7 SURGERY PROCEDURE

The Head of the Spinal Unit took a decision for the type of surgery/procedure required. The decision on the surgical procedure was determined by several factors including type of fracture/dislocation, location of fracture/dislocation, co-existing diseases as well as the individual’s case history.

## 3.8 PROCEDURE IN THE THEATRE

In the theatre all orthopaedic surgeons/registrars, the anaesthetist, the researcher, supervisor as well as the assisting nurses and other observers were swabbed by the theatre nurse in order to reduce the chance of introducing infectious organisms into theatre (this was done as per hospital protocol). All were clad in hygienic and sterile gowns and surgical gloves prior to surgery. The following data were recorded during the surgical procedure by the researcher:

**Appendix A**

- Surgical procedure
- Instrument implanted during surgery
- Complications during surgery

The researcher was present in theatre in order to record all relevant data. If the researcher was unable to be present during the surgical procedure then the data were obtained from the patient records provided that the subject had signed the informed consent form prior to surgery.

## 3.9 POST-SURGICAL PROCEDURE

Radiological investigations such as x-rays were ordered immediately post-surgery by the surgeons and/or registrars. The following data was recorded by the researcher post-surgery:

**Appendix A**

- Post-surgical Frankel grading (Frankel *et al*., 1962) for a period of three weeks or up to the point of discharge from the hospital, whichever came first.
- Post-surgical complications for a period of three weeks or up to the point of discharge from the hospital, whichever came first.
- Post-surgical Norton pressure sore assessment (Norton *et al.,* 1979) for a period of three weeks or up to the point of discharge from the hospital, whichever came first.
- In-hospital post-surgical rehabilitation for a period of three weeks or up to the point of discharge from the hospital, whichever came first.

## 3.10 ETHICAL CONSIDERATIONS

Due to the sensitivity of the information gathered subject confidentiality was maintained at all times. The subject's medical (including HIV status) and surgical records were not divulged to anyone. Only the researcher, supervisor and co-supervisor had access to the data. The names of subjects' were not mentioned in any of the data collecting sheets. No data were collected if the subject refused to provide informed consent.

### 3.11 STATISTICAL ANALYSIS

The sampling strategy was to recruit all eligible and consenting subjects into the study over a three month period. It was assumed that the three months chosen for sampling was representative of the entire year and inference were made from the sample to the larger population in time.

Sample size depended on the number of eligible and consenting subjects over the time period. The majority of the objectives in this study was descriptive in nature and did not require hypothesis testing thus the sample size was not an issue for these objectives. For the objectives which required hypothesis testing statistical tests were applied and *p*-values were reported.

Statistical analysis was achieved using the latest version of SPSS (Statistical Package for the Social Sciences). A *p*-value of $<0.05$ was considered as statistically significant. Appropriate statistical tests were applied to the hypothesis-testing objectives. These involved the Pearson's chi square tests for categorical variables or Fisher's exact tests as appropriate where sample sizes were small. Quantitative data were tested for normality using the skewness statistic and histograms to determine whether parametric or non parametric tests were used. Paired *t*-tests were done to compare pre-and-post-surgical Frankel grading and Norton Pressure Sore Assessment scores.

# CHAPTER FOUR

# RESULTS

## 4.1 DEMOGRAPHIC DATA

During the 12-week period of this study, 20 subjects presented at the King George V Hospital Spinal Unit. The mean (± SD) age of these subjects was 42.9 (± 19.1) years with a range of 21 to 87 years. The majority of the subjects were males (*n* = 17) while three were females as shown in **Figure 4.1**. All the subjects in this study were Black. The occupations of the subjects were varied as shown in **Table 4.1** with the majority being unemployed or pensioners (*n* = 11).

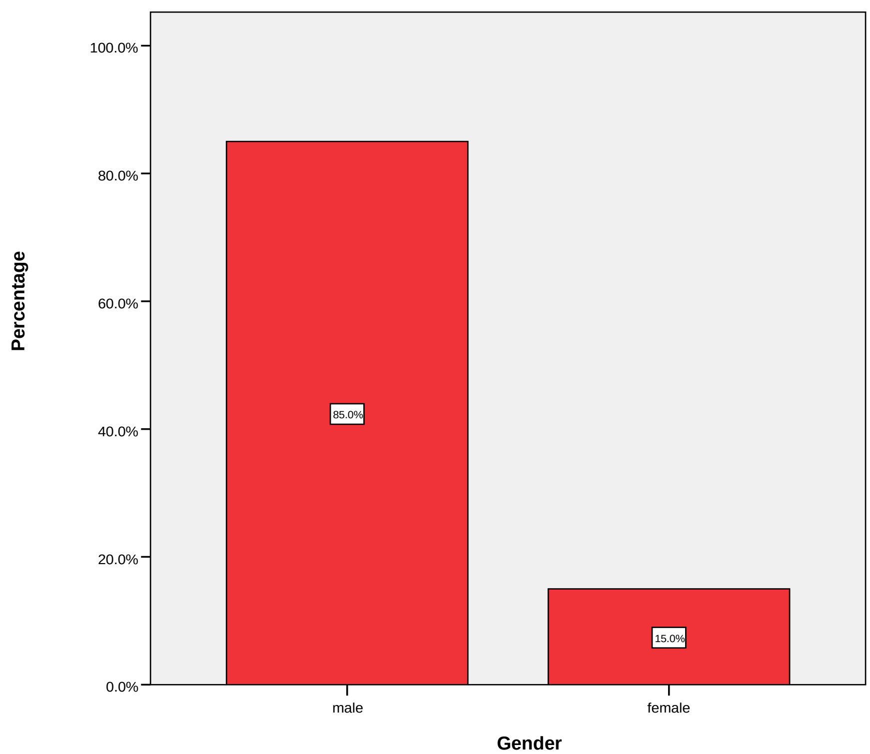


**Figure 4.1 Gender distribution of the subjects (*n* = 20)**

**Table 4.1 Occupation of the subjects (*n* = 20)**

| **Occupation** | ***n*** | **Percent** |
|---|---|---|
| Domestic worker | 1 | 5 |
| Driver | 1 | 5 |
| General worker | 2 | 10 |
| Mortuary service officer | 1 | 5 |
| Pensioner | 3 | 15 |
| Police officer | 1 | 5 |
| Scrap metal collector | 1 | 5 |
| Truck driver | 1 | 5 |
| Unemployed | 8 | 40 |
| Waiter | 1 | 5 |
| **Total** | **20** | **100** |

## 4.2 CO-EXISTING MEDICAL CONDITIONS AND CERVICAL SPINE FRACTURES

The number of subjects presenting with cervical spine fractures who had co-existing medical conditions is illustrated graphically in **Figure 4.2**. Fifteen subjects who presented with cervical spine fractures had associated "other" co-existing medical conditions which are listed in **Table 4.2**. Two individuals presented with hypertension. Neurological co-existing conditions included epilepsy (*n* = 1), hemiparesis (*n* = 1) while infective co-existing conditions included dental caries (*n* = 1) and septic pin sites (*n* = 2). The patients with septic pin sites (*n* = 2) were treated with cones calipers at the primary hospital for their cervical spine fracture prior to being referred to the Spinal Unit. Respiratory (productive cough of indeterminate cause) and cardiac conditions (palpitations) accounted for the least of the co-existing medical conditions. The HIV status of five subjects was not determined as these were not available. One-third of those whose HIV status was known, were positive (*n* = 5).

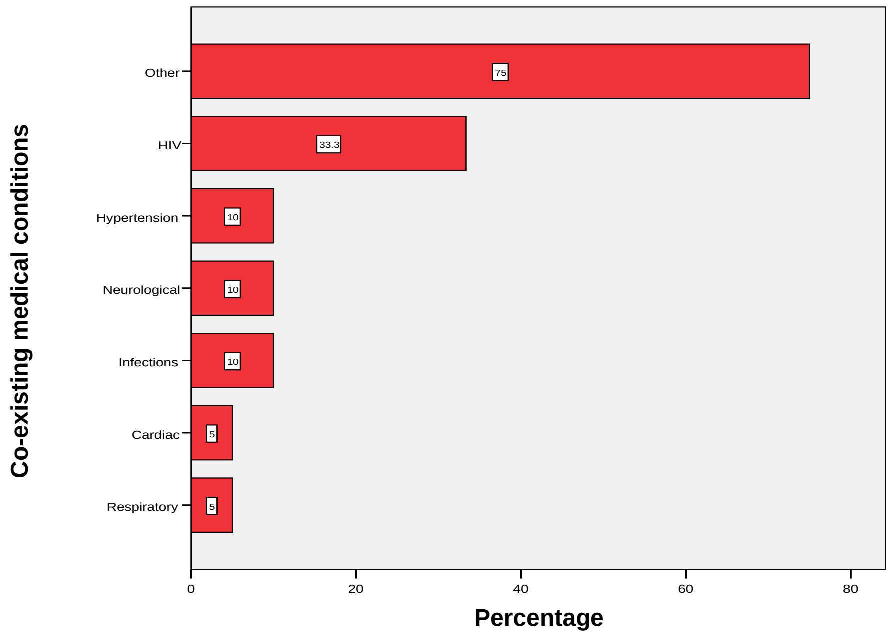


**Figure 4.2 Percentage of subjects with co-existing medical conditions**

**Table 4.2 A description of the "other" co-existing medical conditions**

| **"Other" co-existing medical conditions** | ***n*** |
|---|---|
| Alcohol abuse | 3 |
| Bilateral hip blisters | 1 |
| Craniotomy | 1 |
| Deep vein thrombosis | 1 |
| Depression | 1 |
| Enucleation of right eye | 1 |
| Generalised lymphadenopathy | 1 |
| Obesity | 3 |
| Post-surgical tibial fracture | 1 |
| Pregnant | 1 |
| Smoker | 7 |
| Lacrimation | 1 |
| Lipoma on the neck | 1 |
| Hypopigmentation on the legs | 1 |

## 4.3 CERVICAL SPINE FRACTURES

### 4.3.1 Aetiology

There were three categories of aetiology of cervical spine fractures as shown in **Table 4.3**. Motor vehicle accidents (50%) and falls (45%) were the two primary causes of cervical spine fractures. Relevant medical histories of the subjects who sustained cervical spine fractures as a result of an MVA included depression ($n$ = 1) and alcohol abuse ($n$=1) while that of those who sustained cervical fractures as result of a fall included hypertension ($n$ = 2), alcohol abuse ($n$ = 2), epilepsy ($n$ = 1), palpitations ($n$ = 1) and hemiparesis ($n$ = 1). There was no significant medical history in eight subjects who were involved in an MVA and in two subjects who sustained cervical fractures as a result of a fall. The mean (± SD) age of the subjects who were involved in MVAs was 51.4 (± 19.1) years while the mean (± SD) age of the subjects who sustained cervical spine fractures as a result of a fall was 37.3 (± 16.7) years.

**Table 4.3 The aetiology of cervical spine fractures (*n* = 3)**

| Cause | *n* |
|---|---|
| Fall | 9 |
| Assault | 1 |
| MVA | 10 |
| **Total** | **20** |

MVA = Motor vehicle accident

### 4.3.2 Types of Cervical Spine Fractures and Dislocations

Although there were 20 subjects in this study some had more than one type of fracture. Therefore there were 27 fractures and dislocations in total. The frequency of each type of fracture or dislocation is illustrated in **Figure 4.3**. The percentages added up to more than 100% due to some subjects having more than one fracture. The most common fractures were the odontoid fracture ($n$ = 6) and the Jefferson's fracture ($n$ = 4). The specific types of odontoid fractures are shown in **Table 4.4**. Type II was the most common type of odontoid fracture. The least common type of injuries were the burst fracture, extension tear drop fracture, bilateral facet dislocation and clay shoveler's fractures where there was one case of each. Unilateral facet dislocations were more common (*n* = 6) than bilateral facet dislocations (*n* = 1).

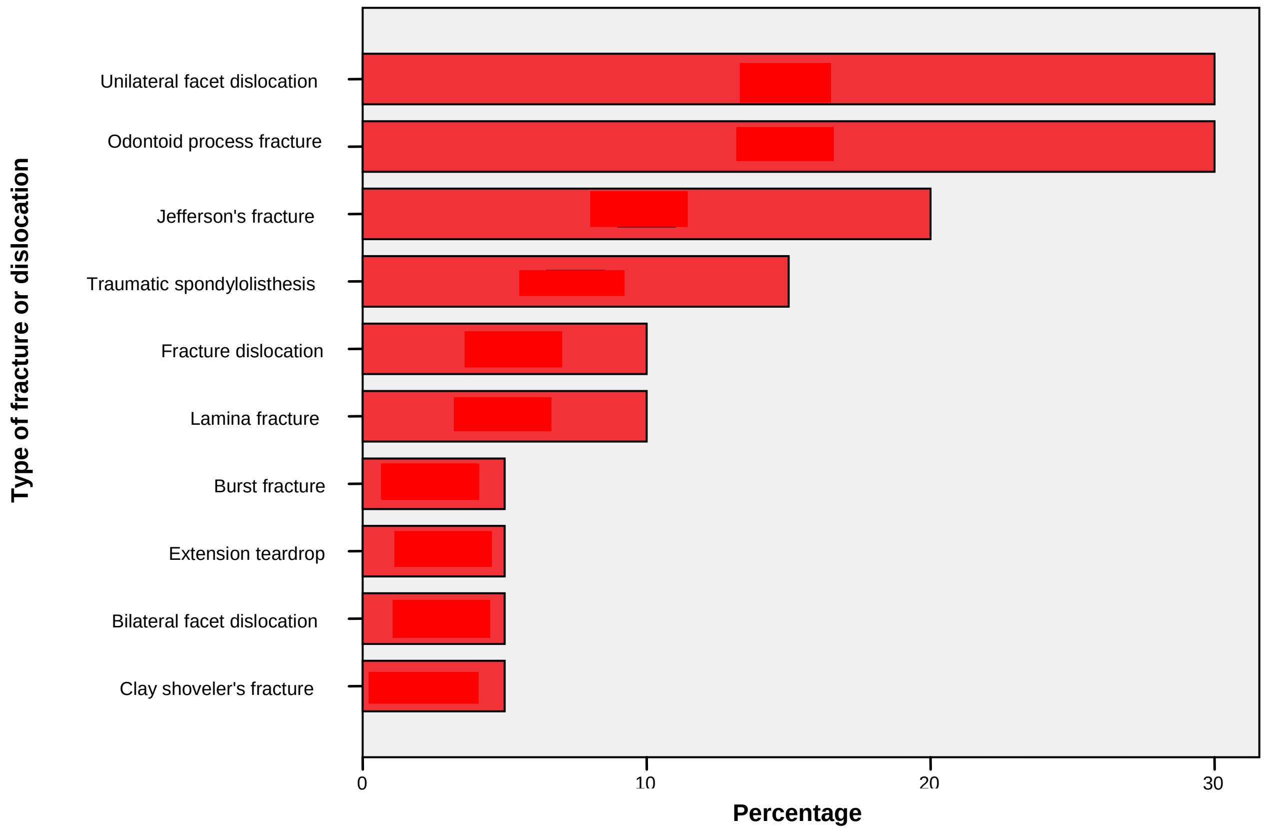


**Figure 4.3 Types of cervical spine fractures and dislocations (*n* = 27)**

**Table 4.4 Specific types of odontoid fracture (*n* = 6)**

| **Odontoid fracture** | ***n*** |
|---|---|
| Type I | 1 |
| Type II | 3 |
| Type III | 1 |
| Unspecified | 1 |
| **Total** | **6** |

### 4.3.3 Location of Cervical Spine Fractures and Dislocations

The three most frequent locations of cervical spine fractures were C2, C1 and the posterior column of C6 as depicted graphically in **Figure 4.4**. There were two anterior column fractures at C4 and C6 respectively but four posterior column fractures in the lower cervical spine ($n$ = 3 at C6 and $n$ = 1 at C7). Middle column fractures were rare with only one case occurring at C4. Dislocations of the zygapophysial joints occurred only in the lower cervical spine at the levels of C5-C6 ($n$ = 5) and C6-C7 ($n$ = 2) as shown in **Figure 4.5**. There were four unilateral facet dislocations at the C5-C6 level and two at the C6-C7 level.

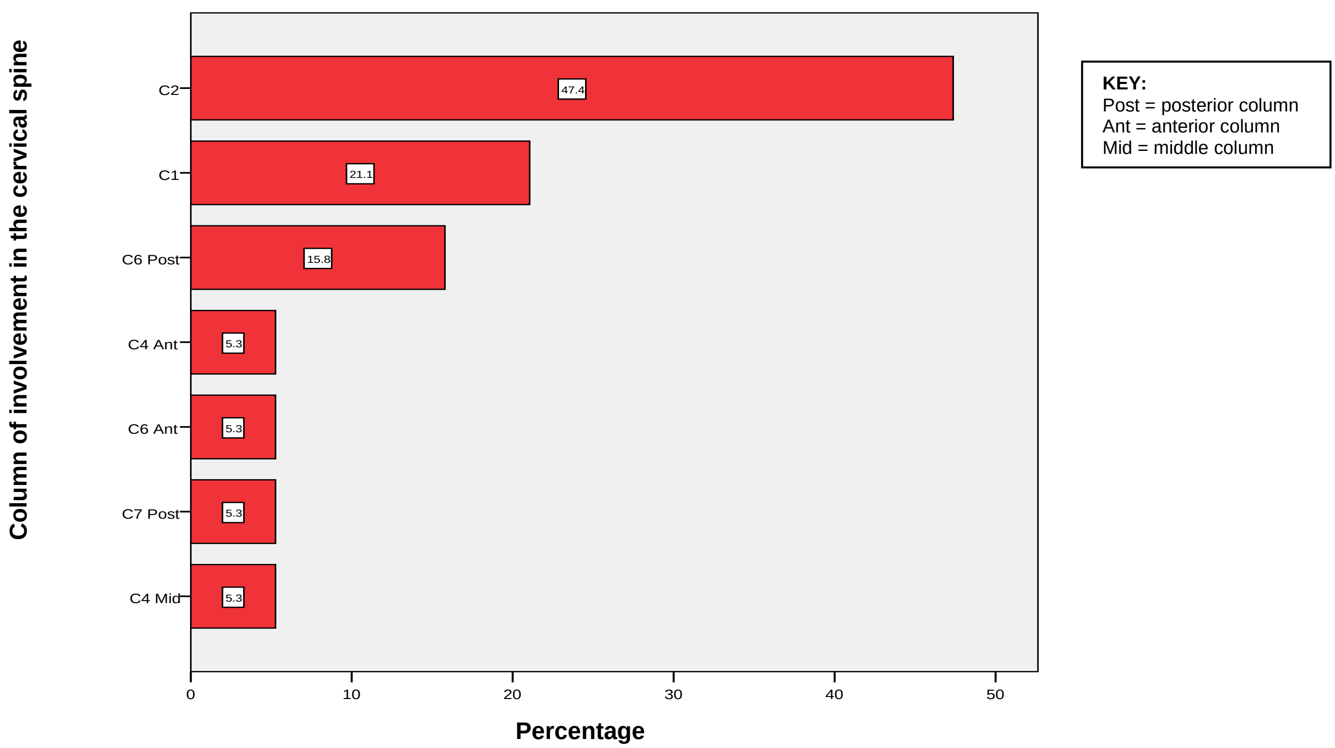


**Figure 4.4 Location of cervical spine fractures**

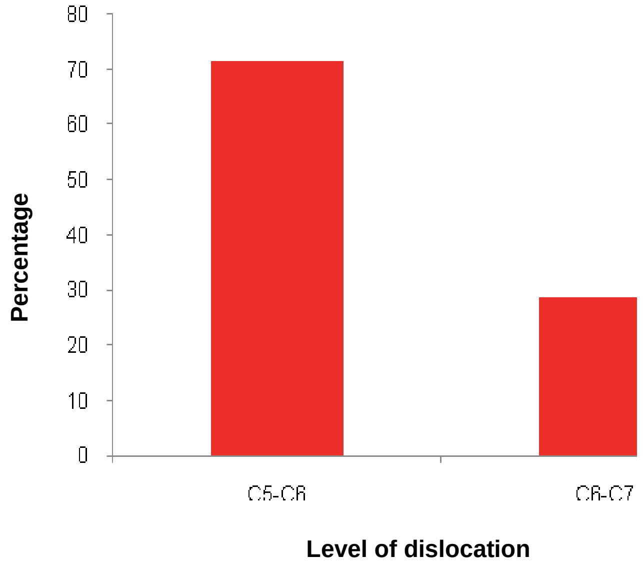


**Figure 4.5 Vertebral levels of cervical spine dislocations**

## 4.4 THE ASSOCIATION BETWEEN GENDER AND AGE AND TYPES OF CERVICAL FRACTURE

There was no significant association ($p > 0.05$; Fisher's exact test) between the type of fracture and gender or age (Table 4.6) with the exception of fracture/dislocation ($p = 0.016$; Fisher's exact test) which was observed in two females as shown in **Table 4.5.**

**Table 4.5 The association between gender and type of cervical spine fracture**

| | | Gender | | | | ***p*-value** |
|---|---|---|---|---|---|---|
| | | Male | | Female | | |
| | | Count | Column *n* % | Count | Column *n* % | |
| Unilateral facet dislocation | No | 12 | 70.6% | 2 | 66.7% | **1.000** |
| | Yes | 5 | 29.4% | 1 | 33.3% | |
| Bilateral facet dislocation | No | 16 | 94.1% | 3 | 100.0% | **1.000** |
| | Yes | 1 | 5.9% | 0 | 0.0% | |
| Traumatic spondylolisthesis | No | 14 | 82.4% | 3 | 100.0% | **1.000** |
| | Yes | 3 | 17.6% | 0 | 0.0% | |
| Jefferson's fracture | No | 15 | 88.2% | 1 | 33.3% | **0.088** |
| | Yes | 2 | 11.8% | 2 | 66.7% | |
| Odontoid fracture | No | 11 | 64.7% | 3 | 100.0% | **0.521** |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Yes | 6 | 35.3% | 0 | 0.0% | |
| Burst fracture | No | 16 | 94.1% | 3 | 100.0% | **1.000** |
| | Yes | 1 | 5.9% | 0 | 0.0% | |
| Clay shoveler's fracture | No | 16 | 94.1% | 3 | 100.0% | **1.000** |
| | Yes | 1 | 5.9% | 0 | 0.0% | |
| Extension teardrop | No | 16 | 94.1% | 3 | 100.0% | **1.000** |
| | Yes | 1 | 5.9% | 0 | 0.0% | |
| Fracture/dislocation | No | 17 | 100.0% | 1 | 33.3% | **0.016*** |
| | Yes | 0 | 0.0% | 2 | 66.7% | |
| Lamina fracture | No | 15 | 88.2% | 3 | 100.0% | **1.000** |
| | Yes | 2 | 11.8% | 0 | 0.0% | |

*** *p* < 0.05; Fisher's Exact Test**

**Table 4.6 The association between age and type of cervical spine fracture**

| | | Age | | ***p*-value** |
|---|---|---|---|---|
| | | Mean | SD | |
| Unilateral facet dislocation | No | 45 | 21 | **0.568** |
| | Yes | 39 | 13 | |
| Bilateral facet dislocation | No | 44 | 19 | **0.439** |
| | Yes | 28 | . | |
| Traumatic spondylolisthesis | No | 45 | 20 | **0.226** |
| | Yes | 30 | 7 | |
| Jefferson's fracture | No | 39 | 17 | **0.069** |
| | Yes | 58 | 23 | |
| Odontoid process fracture | no | 38 | 13 | **0.109** |
| | yes | 53 | 28 | |
| Burst fracture | No | 43 | 20 | **0.911** |
| | Yes | 45 | . | |
| Clay shoveler's fracture | No | 44 | 19 | **0.250** |
| | Yes | 21 | | |
| Extension teardrop fracture | No | 43 | 20 | **0.762** |
| | Yes | 37 | | |
| Fracture/dislocation | No | 42 | 19 | **0.590** |
| | Yes | 50 | 21 | |
| Lamina fracture | No | 45 | 19 | **0.224** |
| | Yes | 27 | 3 | |

## 4.5 THE ASSOCIATION BETWEEN THE CAUSES OF THE CERVICAL FRACTURE OR DISLOCATION AND THE TYPE OF THE FRACTURE

There were no significant associations between the causes of cervical spine fracture and the type of fracture ($p > 0.05$) as shown in **Tables 4.7** to **4.16**.

**Table 4.7 The association between the cause of cervical spine fracture and unilateral facet dislocation**

| | | | **Unilateral facet dislocation** | | **Total** |
|---|---|---|---|---|---|
| | | | No | Yes | |
| Cause | Fall | Count | 6 | 3 | 9 |
| | | % within cause | 66.7% | 33.3% | 100.0% |
| | Assault | Count | 1 | 0 | 1 |
| | | % within cause | 100.0% | 0% | 100.0% |
| | MVA | Count | 7 | 3 | 10 |
| | | % within cause | 70.0% | 30.0% | 100.0% |
| **Total** | | Count | 14 | 6 | 20 |
| | | % within cause | 70.0% | 30.0% | 100.0% |

**Pearson's chi square *p* > 0.05; MVA = Motor vehicle accident**

**Table 4.8 The association between the cause of cervical spine fracture and bilateral facet dislocation**

| | | | **Bilateral facet dislocation** | | **Total** |
|---|---|---|---|---|---|
| | | | No | Yes | |
| Cause | Fall | Count | 8 | 1 | 9 |
| | | % within cause | 88.9% | 11.1% | 100.0% |
| | Assault | Count | 1 | 0 | 1 |
| | | % within cause | 100.0% | 0.0% | 100.0% |
| | MVA | Count | 10 | 0 | 10 |
| | | % within cause | 100.0% | 0.0% | 100.0% |
| **Total** | | Count | 19 | 1 | 20 |
| | | % within cause | 95.0% | 5.0% | 100.0% |

**Pearson's chi square *p* > 0.05; MVA = Motor vehicle accident**

**Table 4.9 The association between the cause of cervical spine fracture and traumatic spondylolisthesis**

| | | | Traumatic spondylolisthesis | | Total |
|---|---|---|---|---|---|
| | | | No | Yes | |
| Cause | Fall | Count | 8 | 1 | 9 |
| | | % within cause | 88.9% | 11.1% | 100.0% |
| | Assault | Count | 1 | 0 | 1 |
| | | % within cause | 100.0% | 0.0% | 100.0% |
| | MVA | Count | 8 | 2 | 10 |
| | | % within cause | 80.0% | 20.0% | 100.0% |
| Total | | Count | 17 | 3 | 20 |
| | | % within cause | 85.0% | 15.0% | 100.0% |

**Pearson's chi square $p > 0.05$; MVA = Motor vehicle accident**

**Table 4.10 The association between the cause of cervical spine fracture and Jefferson's fracture**

| | | | Jefferson's fracture | | Total |
|---|---|---|---|---|---|
| | | | No | Yes | |
| Cause | Fall | Count | 6 | 3 | 9 |
| | | % within cause | 66.7% | 33.3% | 100.0% |
| | Assault | Count | 1 | 0 | 1 |
| | | % within cause | 100.0% | 0.0% | 100.0% |
| | MVA | Count | 9 | 1 | 10 |
| | | % within cause | 90.0% | 10.0% | 100.0% |
| Total | | Count | 16 | 4 | 20 |
| | | % within cause | 80.0% | 20.0% | 100.0% |

**Pearson's chi square $p > 0.05$; MVA = Motor vehicle accident**

**Table 4.11 The association between the cause of cervical spine fracture and odontoid fracture**

| | | | Odontoid fracture | | Total |
|---|---|---|---|---|---|
| | | | No | Yes | |
| Cause | Fall | Count | 6 | 3 | 9 |
| | | % within Cause | 66.7% | 33.3% | 100.0% |
| | Assault | Count | 0 | 1 | 1 |
| | | % within Cause | 0.0% | 100.0% | 100.0% |
| | MVA | Count | 8 | 2 | 10 |
| | | % within Cause | 80.0% | 20.0% | 100.0% |
| Total | | Count | 14 | 6 | 20 |
| | | % within Cause | 70.0% | 30.0% | 100.0% |

**Pearson's chi square $p > 0.05$; MVA = Motor vehicle accident**

**Table 4.12 The association between the cause of cervical spine fracture and burst fracture**

| | | | Burst fracture | | Total |
|---|---|---|---|---|---|
| | | | No | Yes | |
| Cause | Fall | Count | 9 | 0 | 9 |
| | | % within Cause | 100.0% | 0.0% | 100.0% |
| | Assault | Count | 1 | 0 | 1 |
| | | % within Cause | 100.0% | 0.0% | 100.0% |
| | MVA | Count | 9 | 1 | 10 |
| | | % within Cause | 90.0% | 10.0% | 100.0% |
| Total | | Count | 19 | 1 | 20 |
| | | % within Cause | 95.0% | 5.0% | 100.0% |

**Pearson's chi square $p > 0.05$; MVA = Motor vehicle accident**

**Table 4.13 The association between the cause of cervical fracture and fracture/dislocation**

| | | | Fracture dislocation | | Total |
|---|---|---|---|---|---|
| | | | No | Yes | |
| Cause | Fall | Count | 8 | 1 | 9 |
| | | % within Cause | 88.9% | 11.1% | 100.0% |
| | Assault | Count | 1 | 0 | 1 |
| | | % within Cause | 100.0% | 0.0% | 100.0% |
| | MVA | Count | 9 | 1 | 10 |
| | | % within Cause | 90.0% | 10.0% | 100.0% |
| Total | | Count | 18 | 2 | 20 |
| | | % within Cause | 90.0% | 10.0% | 100.0% |

**Pearson's chi square $p > 0.05$; MVA = Motor vehicle accident**

**Table 4.14 The association between the cause of cervical spine fracture and lamina fracture**

| | | | Lamina fracture | | Total |
|---|---|---|---|---|---|
| | | | No | Yes | |
| Cause | Fall | Count | 8 | 1 | 9 |
| | | % within Cause | 88.9% | 11.1% | 100.0% |
| | Assault | Count | 1 | 0 | 1 |
| | | % within Cause | 100.0% | 0.0% | 100.0% |
| | MVA | Count | 9 | 1 | 10 |
| | | % within Cause | 90.0% | 10.0% | 100.0% |
| Total | | Count | 18 | 2 | 20 |
| | | % within Cause | 90.0% | 10.0% | 100.0% |

**Pearson's chi square $p > 0.05$; MVA = Motor vehicle accident**

**Table 4.15 The association between the cause of cervical spine fracture and clay shoveler's fracture**

| | | | Clay shoveler's fracture | | Total |
|---|---|---|---|---|---|
| | | | No | Yes | |
| Cause | Fall | Count | 9 | 0 | 9 |
| | | % within Cause | 100.0% | 0.0% | 100.0% |
| | Assault | Count | 0 | 1 | 1 |
| | | % within Cause | 0.0% | 100.0% | 100.0% |
| | MVA | Count | 10 | 0 | 10 |
| | | % within Cause | 100.0% | 0.0% | 100.0% |
| Total | | Count | 19 | 1 | 20 |
| | | % within Cause | 95.0% | 5.0% | 100.0% |

**Pearson's chi square $p > 0.05$; MVA = Motor vehicle accident**

**Table 4.16 The association between the cause of cervical fracture and extension teardrop fracture**

| | | | Extension teardrop fracture | | Total |
|---|---|---|---|---|---|
| | | | No | Yes | |
| Cause | Fall | Count | 9 | 0 | 9 |
| | | % within Cause | 100.0% | 0.0% | 100.0% |
| | Assault | Count | 1 | 0 | 1 |
| | | % within Cause | 100.0% | 0.0% | 100.0% |
| | MVA | Count | 9 | 1 | 10 |
| | | % within Cause | 90.0% | 10.0% | 100.0% |
| Total | | Count | 19 | 1 | 20 |
| | | % within Cause | 95.0% | 5.0% | 100.0% |

**Pearson's chi square $p > 0.05$; MVA = Motor vehicle accident**

**Table 4.17 The association between the cause of cervical fracture and location of fracture**

| | | Cause | | | | | | ***p*-value** |
|---|---|---|---|---|---|---|---|---|
| | | Fall | | Assault | | MVA | | |
| | | Count | Column % | Count | Column % | Count | Column % | |
| C1 | No | 6 | 66.7% | 1 | 100.0% | 9 | 90.0% | **0.392** |
| | yes | 3 | 33.3% | 0 | 0.0% | 1 | 10.0% | |
| C2 | No | 5 | 55.6% | 0 | 0.0% | 5 | 50.0% | **0.574** |
| | yes | 4 | 44.4% | 1 | 100.0% | 5 | 50.0% | |
| C4 Ant | No | 9 | 100.0% | 1 | 100.0% | 9 | 90.0% | **0.591** |
| | yes | 0 | 0.0% | 0 | 0.0% | 1 | 10.0% | |
| C4 Mid | No | 9 | 100.0% | 1 | 100.0% | 9 | 90.0% | **0.591** |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | yes | 0 | 0.0% | 0 | 0.0% | 1 | 10.0% | |
| C6 Ant | No | 9 | 100.0% | 1 | 100.0% | 9 | 90.0% | **0.591** |
| | yes | 0 | 0.0% | 0 | 0.0% | 1 | 10.0% | |
| C6 Post | No | 8 | 88.9% | 0 | 0.0% | 9 | 90.0% | **0.051** |
| | yes | 1 | 11.1% | 1 | 100.0% | 1 | 10.0% | |
| C7 Post | No | 8 | 88.9% | 1 | 100.0% | 10 | 100.0% | **0.526** |
| | yes | 1 | 11.1% | 0 | 0.0% | 0 | 0.0% | |
| Disl C5-C6 | No | 5 | 55.6% | 1 | 100.0% | 9 | 90.0% | **0.187** |
| | yes | 4 | 44.4% | 0 | 00.0% | 1 | 10.0% | |
| Disl C6-C7 | No | 8 | 88.9% | 1 | 100.0% | 8 | 80.0% | **0.787** |
| | yes | 1 | 11.1% | 0 | 0.0% | 2 | 20.0% | |

**MVA = Motor vehicle accident; Ant = Anterior column; Mid = Middle column; Post = Posterior column; Disl = Dislocation**

## 4.6 ASSOCIATED HEAD INJURY, OTHER SPINAL AND EXTRA-SPINAL FRACTURES

Fifty-five percent of the subjects (*n* = 11) who presented with cervical spine fractures had no associated head injury or extra-spinal fractures. All subjects who sustained head injuries also had associated C1 or C2 fractures. There were no associated thoracic, lumbar, sacral or coccygeal fractures. The extra-spinal fractures were predominantly located in the lower extremity especially in the tibia/fibular and ankle/foot regions as shown in **Table 4.18**

**Table 4.18 Associated head injury and extra-spinal fractures**

| Injury/Fracture | *n* | Percentage |
|---|---|---|
| Head injury | 4 | 20.0% |
| Elbow fracture | 1 | 5.0% |
| Pelvic girdle fracture | 1 | 5.0% |
| Tibial/fibular fracture | 2 | 10.0% |
| Ankle/foot fracture | 1 | 5.0% |

## 4.7 NEUROLOGICAL FINDINGS

### 4.7.1 Pre-Intervention Neurological Findings

The results of the pre-intervention (i.e. conservative or surgical intervention) neurological examination findings of patients with cervical spine fractures are presented in **Table**

**4.19**. The most common neurological aberration was loss of motor function of the upper limb (34.8%). Despite not being able to determine any statistically significant association between cervical spine fractures and the development of neurological complications due to the small sample size, upper limb and lower limb neurological complications were observed more in patients who sustained a Jefferson's fracture, lower cervical fracture/dislocation and unilateral facet dislocations as shown in **Table 4.19**. Overall, serious neurological complications resulted mostly from unilateral facet dislocations in the lower cervical spine especially at the C6-C7 levels **(Table 4.19)**. There were no cases of spinal shock or any cranial nerve palsies.

**Table 4.19 The pre-intervention neurological findings**

| **Neurological examination findings** | ***n*** | **Fracture/s or Dislocations** |
|---|---|---|
| Paraesthesia upper limb | 2 | Jefferson's; fracture/dislocation at C6-C7 |
| Numbness upper limb | 1 | Jefferson's; fracture/dislocation C6/C7; unilateral facet dislocation at C5-C6 |
| Loss of motor function upper limb | 8 | Odontoid; unilateral facet dislocation at C5-C6; Jefferson's; unilateral facet dislocation at C6-C7; traumatic spondylolisthesis |
| Loss of motor function lower limb | 3 | Jefferson's fracture; odontoid; unilateral facet dislocation at C6-C7 |
| Anaesthesia lower limb | 1 | Unilateral facet dislocation C6-C7 |
| Weakness upper limb | 4 | Jefferson's; fracture/dislocation at C6-C7; unilateral facet dislocation at C5-C6; unilateral facet dislocation C6-C7; lamina of C6; traumatic spondylolisthesis |
| Weakness lower limb | 2 | Jefferson's; fracture/dislocation at C6-C7; odontoid |
| Tetraplegia | 1 | Unilateral facet dislocation at C6-C7 |
| Bowel/bladder dysfunction | 1 | Unilateral facet dislocation at C6-C7 |
| **Total** | **23** | |

### 4.7.2 Pre-Post-Surgical Frankel Grading

The majority of the subjects presented with a Frankel grading of E pre-and-post-surgery as shown in **Table 4.20**. One subject who presented with a Type II odontoid fracture and clay shoveler's fracture had a pre-surgical Frankel grading of C which changed to an E during the post-surgical assessment. The nine subjects who did not receive surgical intervention all presented with a pre-surgical Frankel grading of E. Post-surgical Frankel grading was not assessed in these nine subjects as they were treated conservatively and did not undergo surgery.

**Table 4.20 A comparison of the pre-and-post-surgical Frankel grading scores**

| | Pre-surgical | Percent | Post-surgical | Percent |
|---|---|---|---|---|
| B | 1 | 5.0 | 1 | 9.1 |
| C | 1 | 5.0 | | |
| D | 1 | 5.0 | 1 | 9.1 |
| E | 17 | 85.0 | 9 | 81.8 |
| **Total** | **20** | **100.0** | **11** | **100.0** |

## 4.8 THE COMPARISON OF THE PRE-AND-POST-SURGICAL NORTON PRESSURE SORE ASSESSMENT

The mean (± SD) and the standard error of the mean of the NPSA score are presented in **Table 4.21**. There was a statistically significant difference (increase) in the NPSA score post surgery compared to the pre-surgical scores ($p$ = 0.004; paired $t$-test; **Table 4.22**).

**Table 4.21 The mean (± SD) and the standard error of the mean of the pre- and post-surgical Norton Pressure Sore Assessment scores**

| | | ***n*** | **Mean ± SD** | **Std. Error Mean** |
|---|---|---|---|---|
| Pair 1 | Pre-surgical NPSA score | 11 | 16.7 ± 2.8 | 0.832 |
| | Post-surgical NPSA score | 11 | 19.2 ± 2.7 | 0.818 |

**NPSA = Norton Pressure Sore Assessment**

**Table 4.22 Paired *t*-test of the Norton Pressure Sore Assessment scores**

| | | **Paired Differences** | | | | | *t* | df | ***p*-value** |
|---|---|---|---|---|---|---|---|---|---|
| | | Mean | SD | Std. Error Mean | 95% CI of the Difference | | | | |
| Pair 1 | Pre-surgical NPSA score-post-surgical NPSA score | -2.5 | 2.2 | 0.652 | -3.907 | -1.002 | -3.766 | 10 | **0.004 *** |

*** $p$ < 0.05, paired $t$-test**
**NPSA = Norton Pressure Sore Assessment; df = degrees of freedom**

## 4.9 CONSERVATIVE MANAGEMENT OF CERVICAL SPINE FRACTURES

### 4.9.1 Types of Fractures

Nine patients who sustained cervical spine fractures or dislocations were treated using conservative methods. The fracture or dislocation types treated using conservative methods are shown in **Table 4.23**. Fifty percent of the total odontoid fractures (one Type I and two Type II) were treated conservatively. All patients with traumatic spondylolisthesis and extension teardrop fractures were treated using conservative methods. Only ten percent of unilateral facet dislocation cases were treated using a conservative approach. Four patients received physiotherapy as part of their conservative care **(Table 4.23)**. Cones calipers were used in Type I odontoid fractures, traumatic spondylolisthesis, Jefferson's fractures and unilateral facet dislocations **(Table 4.23)**.

**Table 4.23 Types of cervical spine fractures and dislocations which were treated conservatively**

| **Fracture/dislocation** | ***n*** | **Conservative treatment** |
|---|---|---|
| Odontoid | 3 | Type I – Soft collar, cones calipers, physiotherapy; Type II-Minerva jacket (2) |
| Traumatic spondylolisthesis | 3 | Cones calipers (3); Minerva jacket (2); physiotherapy (1); SOMI brace (1); soft collar (1) |
| Jefferson's | 2 | Soft collar (2); cones calipers (1); physiotherapy (1) |
| Unilateral facet dislocation | 1 | Cones calipers; soft collar; physiotherapy |
| Extension teardrop | 1 | Soft collar |
| **Total** | **10** | |

### 4.9.2 The Association between the Type of Cervical Spine Fracture or Dislocation and Conservative Treatment Utilized

There was no statistically significant association ($p > 0.05$) between the type of cervical spine fracture and conservative treatment utilized as shown in **Tables 4.24 - 4.28**.

**Table 4.24 The association between the type of cervical spine fracture and use of cones calipers**

| | | Cones callipers | | | |
|---|---|---|---|---|---|
| | | No | | Yes | |
| | | Count | Column *n* % | Count | Column *n* % |
| Odontoid fracture | No | 2 | 50.0% | 4 | 80.0% |
| | Yes | 2 | 50.0% | 1 | 20.0% |
| Traumatic spondylolisthesis | No | 4 | 100.0% | 2 | 40.0% |
| | Yes | 0 | 0.0% | 3 | 60.0% |
| Jefferson's fracture | No | 3 | 75.0% | 4 | 80.0% |
| | Yes | 1 | 25.0% | 1 | 20.0% |
| Unilateral facet dislocation | No | 4 | 100.0% | 4 | 80.0% |
| | Yes | 0 | 0.0% | 1 | 20.0% |
| Extension teardrop fracture | No | 3 | 75% | 5 | 100% |
| | Yes | 1 | 25% | 0 | 0.0% |

***p* > 0.05; Fisher's exact test**

**Table 4.25 The association between the type of cervical spine fracture and use of the Minerva jacket**

| | | Minerva jacket | | | |
|---|---|---|---|---|---|
| | | No | | Yes | |
| | | Count | Column *n* % | Count | Column *n* % |
| Odontoid fracture | No | 4 | 80.0% | 2 | 50.0% |
| | Yes | 1 | 20.0% | 2 | 50.0% |
| Traumatic spondylolisthesis | No | 4 | 80.0% | 2 | 50.0% |
| | Yes | 1 | 20.0% | 2 | 50.0% |
| Jefferson's fracture | No | 3 | 60.0% | 4 | 100.0% |
| | Yes | 2 | 40.0% | 0 | 0.0% |
| Unilateral facet dislocation | No | 4 | 80.0% | 4 | 100.0% |
| | Yes | 1 | 20.0% | 0 | 0.0% |
| Extension teardrop fracture | No | 4 | 80% | 4 | 100% |
| | Yes | 1 | 20% | 0 | 0.0% |

***p* > 0.05; Fisher's exact test**

**Table 4.26 The association between the type of cervical spine fracture and the use of the soft collar**

| | | Soft collar | | | |
|---|---|---|---|---|---|
| | | No | | Yes | |
| | | Count | Column *n* % | Count | Column *n* % |
| Odontoid fracture | No | 2 | 50.0% | 4 | 80.0% |
| | Yes | 2 | 50.0% | 1 | 20.0% |
| Traumatic spondylolisthesis | No | 3 | 60.0% | 3 | 75.0% |
| | Yes | 2 | 40.0% | 1 | 25.0% |
| Jefferson's fracture | No | 4 | 80.0% | 3 | 75.0% |
| | Yes | 1 | 20.0% | 1 | 25.0% |
| Unilateral facet dislocation | No | 5 | 100.0% | 3 | 75.0% |
| | Yes | 0 | 0.0% | 1 | 25.0% |
| Extension teardrop fracture | No | 4 | 100% | 4 | 80.0% |
| | Yes | 0 | 0.0% | 1 | 20.0% |

**$p > 0.05$; Fisher's exact test**

**Table 4.27 The association between the type of cervical spine fracture and physiotherapy**

| | | Physiotherapy | | | |
|---|---|---|---|---|---|
| | | No | | Yes | |
| | | Count | Column *n* % | Count | Column *n* % |
| Odontoid fracture | No | 3 | 60.0% | 3 | 75.0% |
| | Yes | 2 | 40.0% | 1 | 25.0% |
| Traumatic spondylolisthesis | No | 4 | 80.0% | 2 | 50.0% |
| | Yes | 1 | 20.0% | 2 | 50.0% |
| Jefferson's fracture | No | 5 | 83.3% | 2 | 66.7% |
| | Yes | 1 | 16.7% | 1 | 33.3% |
| Unilateral facet dislocation | No | 6 | 100.0% | 2 | 66.7% |
| | Yes | 0 | 0.0% | 1 | 33.3% |
| Extension teardrop fracture | No | 4 | 80.0% | 4 | 100.0% |
| | Yes | 1 | 20.0% | 0 | 0.0% |

**$p > 0.05$; Fisher's exact test**

**Table 4.28 The association between the type of cervical spine fracture and the use of the SOMI brace**

| | | SOMI brace | | | |
|---|---|---|---|---|---|
| | | No | | Yes | |
| | | Count | Column *n* % | Count | Column *n* % |
| Odontoid fracture | No | 5 | 62.5% | 1 | 100.0% |
| | Yes | 3 | 37.5% | 0 | 0.0% |
| Traumatic spondylolisthesis | No | 6 | 75.0% | 0 | 0.0% |
| | Yes | 2 | 25.0% | 1 | 100.0% |
| Jefferson's fracture | No | 6 | 75.0% | 1 | 100.0% |
| | Yes | 2 | 25.0% | 0 | 0.0% |
| Unilateral facet dislocation | No | 7 | 87.5% | 1 | 100.0% |
| | Yes | 1 | 12.5% | 0 | 0.0% |
| Extension teardrop fracture | No | 7 | 87.5% | 1 | 100% |
| | Yes | 1 | 12.5% | 0 | 0.0% |

***p* > 0.05; Fisher's exact test**

### 4.9.3 Post-conservative treatment complications

There were three reported post-conservative treatment complications as shown in **Table 4.29**. The patient with an occipital pressure sore sustained an odontoid and Jefferson's fracture and was managed conservatively using cone's calipers, soft collar and physiotherapy. The patient who experienced severe discomfort (pain, restricted movement and restlessness) sustained an odontoid fracture where the conservative treatment was a Minerva jacket. Severe neck pain was experienced by a patient who sustained an extension teardrop fracture and was treated using a soft collar.

**Table 4.29 Post-conservative treatment complications**

| **Complication** | ***n*** |
|---|---|
| Occipital pressure sore | 1 |
| Severe discomfort | 1 |
| Severe neck pain | 1 |
| **Total** | **3** |

### 4.9.4 The Association between the Post Conservative-Treatment Complications and the Conservative Treatment Utilized

There was no statistically significant association ($p > 0.05$) between the post-conservative treatment complications and the conservative treatment utilized as shown in **Table 4.30**.

**Table 4.30 The association between the post conservative-treatment complications and the conservative treatment utilized**

| | | Post-conservative treatment complications | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | None | | Occipital pressure sore | | Severe discomfort | | Severe neck pain | |
| | | Count | Row *n* % | Count | Row *n* % | Count | Row *n* % | Count | Row *n* % |
| Cones calipers | No | 2 | 50.0% | 0 | 0.0% | 1 | 25.0% | 1 | 25.0% |
| | Yes | 4 | 80.0% | 1 | 20.0% | 0 | 0.0% | 0 | 0.0% |
| Minerva jacket | No | 3 | 60.0% | 1 | 20.0% | 0 | 0.0% | 1 | 20.0% |
| | Yes | 3 | 75.0% | 0 | 0.0% | 1 | 25.0% | 0 | 0.0% |
| Soft collar | No | 3 | 60.0% | 1 | 20.0% | 1 | 20.0% | 0 | 0.0% |
| | Yes | 3 | 60.0% | 1 | 20.0% | 0 | 0.0% | 1 | 20.0% |
| Physiotherapy | No | 4 | 66.7% | 0 | 0.0% | 1 | 16.7% | 1 | 16.7% |
| | Yes | 2 | 66.7% | 1 | 33.3% | 0 | 0.0% | 0 | 0.0% |
| SOMI brace | No | 5 | 62.5% | 1 | 12.5% | 1 | 12.5% | 1 | 12.5% |
| | Yes | 1 | 100.0% | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% |

**$p > 0.05$; Fisher's exact test**

## 4.10 CERVICAL SPINE SURGERY

### 4.10.1 Types of Surgical Procedures

The five most common surgical procedures that were implemented were anterior decompression, anterior fusion, allograft strut, discectomy and anterior cervical plating while the least implemented surgical procedures were corpectomy and posterior reduction as shown in **Table 4.31**. More than one surgical procedure was performed for several types of cervical fractures or dislocations. In the cases where Jefferson's fractures occurred in combination with either a C6-C7 fracture/dislocation or an odontoid fracture, only the fracture/dislocation or the odontoid fracture was surgically addressed. However, pre-surgically the patient with a Jefferson's fracture and C6-C7 fracture/dislocation was treated with a Philadelphia collar while the patient with the Jefferson's and odontoid fractures was treated with cones calipers.

When there was a combination of an odontoid and a clay shoveler's fracture, surgical intervention addressed only the odontoid fracture. The subject was however treated pre-surgically with a Philadelphia collar. When unilateral facet dislocations (C5-C6; C6-C7) occurred in combination with fracture/dislocations (*n* = 1; C6-C7) and lamina fractures (*n* = 2; C5 and C6) respectively the surgical procedures were performed at the involved levels i.e either at C5-C6 or C6-C7. A malunited odontoid fracture was observed in one subject for whom the transoral approach was used. In this subject, no surgical instrumentation was used.

**Table 4.31 Types of surgical procedures (*n* = 9)**

| Surgical procedure | *n* | Types of fractures |
|---|---|---|
| Anterior decompression | 8 | Bilateral facet dislocation; fracture/dislocation at C6-C7*; unilateral facet dislocation; unilateral facet dislocation and lamina fracture; burst fracture; unilateral facet dislocation; unilateral facet dislocation and fracture/dislocation; unilateral facet dislocation and lamina fracture |
| Anterior fusion | 8 | Bilateral facet dislocation; fracture/dislocation at C6-C7*; unilateral facet dislocation; unilateral facet dislocation and lamina fracture; burst fracture; unilateral facet dislocation; unilateral facet dislocation and fracture/dislocation; unilateral facet dislocation and lamina fracture |
| Allograft strut | 8 | Bilateral facet dislocation; fracture/dislocation at C6-C7*; unilateral facet dislocation; unilateral facet dislocation and lamina fracture; burst fracture; unilateral facet dislocation; unilateral facet dislocation and fracture/dislocation; unilateral facet dislocation and lamina fracture |
| Corpectomy | 1 | Burst fracture |
| Discectomy | 8 | Bilateral facet dislocation; fracture/dislocation at C6-C7*; unilateral facet dislocation; unilateral facet dislocation and lamina fracture; burst fracture; unilateral facet dislocation; unilateral facet dislocation and fracture/dislocation; unilateral facet dislocation and lamina fracture |
| Anterior cervical plating | 8 | Bilateral facet dislocation; fracture/dislocation at C6-C7*; unilateral facet dislocation; unilateral facet dislocation and lamina fracture; burst fracture; unilateral facet dislocation; unilateral facet dislocation and fracture/dislocation; unilateral facet dislocation and lamina fracture |
| Anterior screw fixation | 2 | Odontoid fracture#% |
| Transoral approach | 1 | Odontoid fracture≈ |
| Posterior reduction | 1 | Unilateral facet dislocation and lamina fracture |

*** = Patient had a C6-C7 fracture/dislocation and a Jefferson's fracture, but only the fracture/dislocation was addressed surgically**
**# = One patient had an odontoid fracture and a Jefferson's fracture, but only the odontoid fracture was addressed surgically**
**% = One patient had an odontoid fracture and a clay shoveler's fracture, but only the odontoid fracture was addressed surgically**
**≈ = No surgical instrumentation utilized**

### 4.10.2 Instrumentation Used During Surgery

The surgical instruments used during cervical spine surgery are shown in **Figure 4.6**. Bone grafts and plate fixation were the instruments most commonly used during surgery (*n* = 8 respectively). No wiring techniques were utilised in this study. No surgical instruments were used in one patient who received cervical spine surgery.

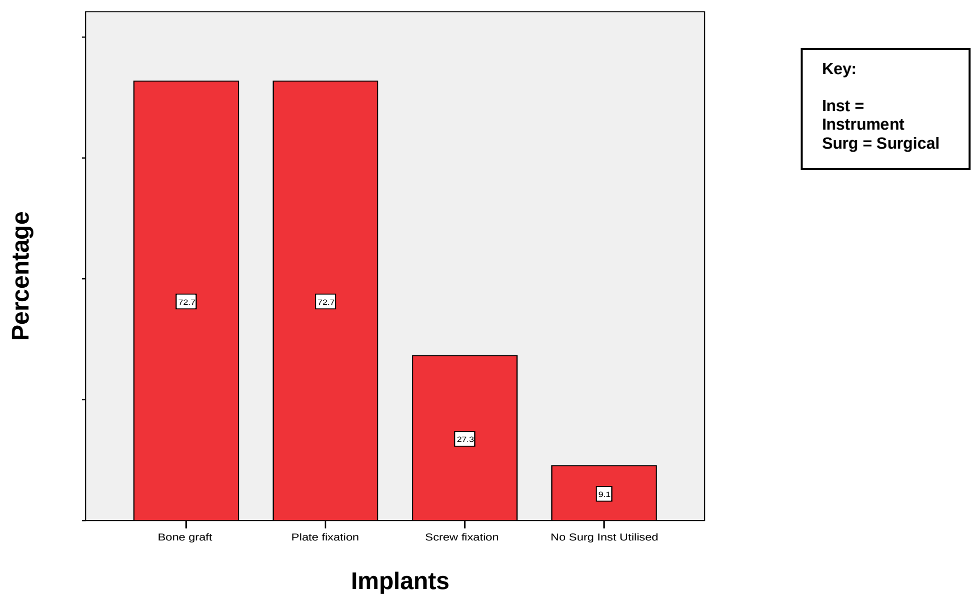


**Figure 4.6 Instruments used during cervical spine surgery**

### 4.10.3 Complications during Cervical Spine Surgery

There were no complications during any of the 11 cervical spine surgeries.

### 4.11 The Association between the Surgical Procedures/Approaches used and the Specific Type of Cervical Spine Fracture

The association with the types of surgical procedures/approaches implemented and the different fracture types are shown in **Tables 4.32** to **4.40**. Only odontoid peg fracture was negatively associated with anterior decompression (*p* = 0.006; Fisher's exact test), anterior fusion (*p* = 0.006; Fisher's exact test), allograft strut (*p* = 0.006; Fisher's exact test), discectomy (*p* = 0.006; Fisher's exact test) and anterior cervical plating (*p* = 0.006; Fisher's exact test).

**Table 4.32 The association between the anterior decompression procedure and the type of fracture**

| | | Anterior decompression | | | | *p*-value |
|---|---|---|---|---|---|---|
| | | No | | Yes | | |
| | | Count | Column *n* % | Count | Column *n* % | |
| Unilateral facet dislocation | No | 3 | 100.0% | 3 | 37.5% | **0.182** |
| | Yes | 0 | 0.0% | 5 | 62.5% | |
| Bilateral facet dislocation | No | 3 | 100.0% | 7 | 87.5% | **1.000** |
| | Yes | 0 | 0.0% | 1 | 12.5% | |
| Jefferson's fracture | No | 2 | 66.7% | 7 | 87.5% | **0.491** |
| | Yes | 1 | 33.3% | 1 | 12.5% | |
| Odontoid process fracture | No | 0 | 0.0% | 8 | 100.0% | **0.006*** |
| | Yes | 3 | 100.0% | 0 | 0.0% | |
| Burst fracture | No | 3 | 100.0% | 7 | 87.5% | **1.000** |
| | Yes | 0 | 0.0% | 1 | 12.5% | |
| Clay shoveler's fracture | No | 2 | 66.7% | 8 | 100.0% | **0.273** |
| | Yes | 1 | 33.3% | 0 | 0.0% | |
| Extension teardrop fracture | No | 3 | 100.0% | 8 | 100.0% | **-** |
| | Yes | 0 | 0.0% | 0 | 0.0% | |
| Fracture/dislocation | No | 3 | 100.0% | 6 | 75.0% | **1.000** |
| | Yes | 0 | 0.0% | 2 | 25.0% | |
| Lamina fracture | No | 3 | 100.0% | 6 | 75.0% | **1.000** |
| | Yes | 0 | 0.0% | 2 | 25.0% | |

*** $p < 0.05$; Fisher's exact test**

**Table 4.33 The association between the anterior fusion procedure and the type of fracture**

| | | Anterior fusion | | | | *p*-value |
|---|---|---|---|---|---|---|
| | | No | | Yes | | |
| | | Count | Column *n* % | Count | Column *n* % | |
| Unilateral facet dislocation | No | 3 | 100.0% | 3 | 37.5% | **0.182** |
| | Yes | 0 | 0.0% | 5 | 62.5% | |
| Bilateral facet dislocation | No | 3 | 100.0% | 7 | 87.5% | **1.000** |
| | Yes | 0 | 0.0% | 1 | 12.5% | |
| Jefferson's fracture | No | 2 | 66.7% | 7 | 87.5% | **0.491** |
| | Yes | 1 | 33.3% | 1 | 12.5% | |
| Odontoid process fracture | No | 0 | 0.0% | 8 | 100.0% | **0.006*** |
| | Yes | 3 | 100.0% | 0 | 0.0% | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Burst fracture | No | 3 | 100.0% | 7 | 87.5% | **1.000** |
| | Yes | 0 | 0.0% | 1 | 12.5% | |
| Clay shoveler's fracture | No | 2 | 66.7% | 8 | 100.0% | **0.273** |
| | Yes | 1 | 33.3% | 0 | 0.0% | |
| Extension teardrop fracture | No | 3 | 100.0% | 8 | 100.0% | **-** |
| | Yes | 0 | 0.0% | 0 | 0.0% | |
| Fracture/dislocation | No | 3 | 100.0% | 6 | 75.0% | **1.000** |
| | Yes | 0 | 0.0% | 2 | 25.0% | |
| Lamina fracture | No | 3 | 100.0% | 6 | 75.0% | **1.000** |
| | Yes | 0 | 0.0% | 2 | 25.0% | |

*** $p < 0.05$; Fisher's exact test**

**Table 4.34 The association between the allograft strut procedure and the type of fracture**

| | | Allograft strut | | | | ***p*-value** |
|---|---|---|---|---|---|---|
| | | No | | Yes | | |
| | | Count | Column *n* % | Count | Column *n* % | |
| Unilateral facet dislocation | No | 3 | 100.0% | 3 | 37.5% | **0.182** |
| | Yes | 0 | 0.0% | 5 | 62.5% | |
| Bilateral facet dislocation | No | 3 | 100.0% | 7 | 87.5% | **1.000** |
| | Yes | 0 | 0.0% | 1 | 12.5% | |
| Jefferson's fracture | No | 2 | 66.7% | 7 | 87.5% | **0.491** |
| | Yes | 1 | 33.3% | 1 | 12.5% | |
| Odontoid process fracture | No | 0 | 0.0% | 8 | 100.0% | **0.006*** |
| | Yes | 3 | 100.0% | 0 | 0.0% | |
| Burst fracture | No | 3 | 100.0% | 7 | 87.5% | **1.000** |
| | Yes | 0 | 0.0% | 1 | 12.5% | |
| Clay shoveler's fracture | No | 2 | 66.7% | 8 | 100.0% | **0.273** |
| | Yes | 1 | 33.3% | 0 | 0.0% | |
| Extension teardrop fracture | No | 3 | 100.0% | 8 | 100.0% | **-** |
| | Yes | 0 | 0.0% | 0 | 0.0% | |
| Fracture/dislocation | No | 3 | 100.0% | 6 | 75.0% | **1.000** |
| | Yes | 0 | 0.0% | 2 | 25.0% | |
| Lamina fracture | No | 3 | 100.0% | 6 | 75.0% | **1.000** |
| | Yes | 0 | 0.0% | 2 | 25.0% | |

*** $p < 0.05$; Fisher's exact test**

**Table 4.35 The association between the corpectomy procedure and the type of fracture**

| | | Corpectomy | | | | *p*-value |
|---|---|---|---|---|---|---|
| | | No | | Yes | | |
| | | Count | Column *n* % | Count | Column *n* % | |
| Unilateral facet dislocation | No | 5 | 50.0% | 1 | 100.0% | **1.000** |
| | Yes | 5 | 50.0% | 0 | 0.0% | |
| Bilateral facet dislocation | No | 9 | 90.0% | 1 | 100.0% | **1.000** |
| | Yes | 1 | 10.0% | 0 | 0.0% | |
| Jefferson's fracture | No | 8 | 80.0% | 1 | 100.0% | **1.000** |
| | Yes | 2 | 20.0% | 0 | 0.0% | |
| Odontoid process fracture | No | 7 | 70.0% | 1 | 100.0% | **1.000** |
| | Yes | 3 | 30.0% | 0 | 0.0% | |
| Burst fracture | No | 10 | 100.0% | 0 | 0.0% | **0.091** |
| | Yes | 0 | 0.0% | 1 | 100.0% | |
| Clay shoveler's fracture | No | 9 | 90.0% | 1 | 100.0% | **1.000** |
| | Yes | 1 | 10.0% | 0 | 0.0% | |
| Extension teardrop fracture | No | 10 | 100.0% | 1 | 100.0% | **-** |
| | Yes | 0 | 0.0% | 0 | 0.0% | |
| Fracture/dislocation | No | 8 | 80.0% | 1 | 100.0% | **1.000** |
| | Yes | 2 | 20.0% | 0 | 0.0% | |
| Laminar fracture | No | 8 | 80.0% | 1 | 100.0% | **1.000** |
| | Yes | 2 | 20.0% | 0 | 0.0% | |

**Table 4.36 The association between the discectomy procedure and the type of fracture**

| | | Discectomy | | | | *p*-value |
|---|---|---|---|---|---|---|
| | | No | | Yes | | |
| | | Count | Column *n* % | Count | Column *n* % | |
| Unilateral facet dislocation | No | 3 | 100.0% | 3 | 37.5% | **0.182** |
| | Yes | 0 | 0.0% | 5 | 62.5% | |
| Bilateral facet dislocation | No | 3 | 100.0% | 7 | 87.5% | **1.000** |
| | Yes | 0 | 0.0% | 1 | 12.5% | |
| Jefferson's fracture | No | 2 | 66.7% | 7 | 87.5% | **0.491** |
| | Yes | 1 | 33.3% | 1 | 12.5% | |
| Odontoid process fracture | No | 0 | 0.0% | 8 | 100.0% | **0.006*** |
| | Yes | 3 | 100.0% | 0 | 0.0% | |
| Burst fracture | No | 3 | 100.0% | 7 | 87.5% | **1.000** |
| | Yes | 0 | 0.0% | 1 | 12.5% | |
| Clay shoveler's fracture | No | 2 | 66.7% | 8 | 100.0% | **0.273** |
| | Yes | 1 | 33.3% | 0 | 0.0% | |
| Extension teardrop fracture | No | 3 | 100.0% | 8 | 100.0% | **-** |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Yes | 0 | 0.0% | 0 | 0.0% | |
| Fracture/dislocation | No | 3 | 100.0% | 6 | 75.0% | **1.000** |
| | Yes | 0 | 0.0% | 2 | 25.0% | |
| Lamina fracture | No | 3 | 100.0% | 6 | 75.0% | **1.000** |
| | Yes | 0 | 0.0% | 2 | 25.0% | |

**Table 4.37 The association between the anterior cervical plating procedure and the type of fracture**

| | | **Anterior cervical plating** | | | | ***p*-value** |
|---|---|---|---|---|---|---|
| | | No | | Yes | | |
| | | Count | Column *n* % | Count | Column *n* % | |
| Unilateral facet dislocation | No | 3 | 100.0% | 3 | 37.5% | **0.182** |
| | Yes | 0 | 0.0% | 5 | 62.5% | |
| Bilateral facet dislocation | No | 3 | 100.0% | 7 | 87.5% | **1.000** |
| | Yes | 0 | 0.0% | 1 | 12.5% | |
| Jefferson's fracture | No | 2 | 66.7% | 7 | 87.5% | **0.491** |
| | Yes | 1 | 33.3% | 1 | 12.5% | |
| Odontoid process fracture | No | 0 | 0.0% | 8 | 100.0% | **0.006*** |
| | Yes | 3 | 100.0% | 0 | 0.0% | |
| Burst fracture | No | 3 | 100.0% | 7 | 87.5% | **1.000** |
| | Yes | 0 | 0.0% | 1 | 12.5% | |
| Clay shoveler's fracture | No | 2 | 66.7% | 8 | 100.0% | **0.273** |
| | Yes | 1 | 33.3% | 0 | 0.0% | |
| Extension teardrop fracture | No | 3 | 100.0% | 8 | 100.0% | **-** |
| | Yes | 0 | 0.0% | 0 | 0.0% | |
| Fracture/dislocation | No | 3 | 100.0% | 6 | 75.0% | **1.000** |
| | Yes | 0 | 0.0% | 2 | 25.0% | |
| Lamina fracture | No | 3 | 100.0% | 6 | 75.0% | **1.000** |
| | Yes | 0 | 0.0% | 2 | 25.0% | |

*** $p < 0.05$; Fisher's exact test**

**Table 4.38 The association between the anterior screw fixation procedure and the type of fracture**

| | | **Anterior screw fixation** | | | | ***p*-value** |
|---|---|---|---|---|---|---|
| | | No | | Yes | | |
| | | Count | Column *n* % | Count | Column *n* % | |
| Unilateral facet dislocation | No | 4 | 44.4% | 2 | 100.0% | **0.455** |
| | Yes | 5 | 55.6% | 0 | 0.0% | |
| Bilateral facet dislocation | No | 8 | 88.9% | 2 | 100.0% | **1.000** |
| | Yes | 1 | 11.1% | 0 | 0.0% | |
| Jefferson's fracture | No | 8 | 88.9% | 1 | 50.0% | **0.345** |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Yes | 1 | 11.1% | 1 | 50.0% | |
| Odontoid process fracture | No | 8 | 88.9% | 0 | 0.0% | **0.055** |
| | Yes | 1 | 11.1% | 2 | 100.0% | |
| Burst fracture | No | 8 | 88.9% | 2 | 100.0% | **1.000** |
| | Yes | 1 | 11.1% | 0 | 0.0% | |
| Clay shoveler's fracture | No | 9 | 100.0% | 1 | 50.0% | **0.182** |
| | Yes | 0 | 0.0% | 1 | 50.0% | |
| Extension teardrop fracture | No | 9 | 100.0% | 2 | 100.0% | **-** |
| | Yes | 0 | 0.0% | 0 | 0.0% | |
| Fracture/dislocation | No | 7 | 77.8% | 2 | 100.0% | **1.000** |
| | Yes | 2 | 22.2% | 0 | 0.0% | |
| Lamina fracture | No | 7 | 77.8% | 2 | 100.0% | **1.000** |
| | Yes | 2 | 22.2% | 0 | 0.0% | |

**Table 4.39 The association between the transoral approach procedure and the type of fracture**

| | | **Transoral approach** | | | | ***p*-value** |
|---|---|---|---|---|---|---|
| | | No | | Yes | | |
| | | Count | Column *n* % | Count | Column *n* % | |
| Unilateral facet dislocation | No | 5 | 50.0% | 1 | 100.0% | **1.000** |
| | Yes | 5 | 50.0% | 0 | 0.0% | |
| Bilateral facet dislocation | No | 9 | 90.0% | 1 | 100.0% | **1.000** |
| | Yes | 1 | 10.0% | 0 | 0.0% | |
| Jefferson's fracture | No | 8 | 80.0% | 1 | 100.0% | **1.000** |
| | Yes | 2 | 20.0% | 0 | 0.0% | |
| Odontoid process fracture | No | 8 | 80.0% | 0 | 0.0% | **0.273** |
| | Yes | 2 | 20.0% | 1 | 100.0% | |
| Burst fracture | No | 9 | 90.0% | 1 | 100.0% | **1.000** |
| | Yes | 1 | 10.0% | 0 | 0.0% | |
| Clay shoveler's fracture | No | 9 | 90.0% | 1 | 100.0% | **1.000** |
| | Yes | 1 | 10.0% | 0 | 0.0% | |
| Extension teardrop fracture | No | 10 | 100.0% | 1 | 100.0% | **-** |
| | Yes | 0 | 0.0% | 0 | 0.0% | |
| Fracture/ dislocation | No | 8 | 80.0% | 1 | 100.0% | **1.000** |
| | Yes | 2 | 20.0% | 0 | 0.0% | |
| Lamina fracture | No | 8 | 80.0% | 1 | 100.0% | **1.000** |
| | Yes | 2 | 20.0% | 0 | 0.0% | |

**Table 4.40 The association between the posterior reduction procedure and the type of fracture**

| | | Posterior reduction | | | | *p*-value |
|---|---|---|---|---|---|---|
| | | No | | Yes | | |
| | | Count | Column *n* % | Count | Column *n* % | |
| Unilateral facet dislocation | No | 6 | 60.0% | 0 | 0.0% | **0.455** |
| | Yes | 4 | 40.0% | 1 | 100.0% | |
| Bilateral facet dislocation | No | 9 | 90.0% | 1 | 100.0% | **1.000** |
| | Yes | 1 | 10.0% | 0 | 0.0% | |
| Jefferson's fracture | No | 8 | 80.0% | 1 | 100.0% | **1.000** |
| | Yes | 2 | 20.0% | 0 | 0.0% | |
| Odontoid process fracture | No | 7 | 70.0% | 1 | 100.0% | **1.000** |
| | Yes | 3 | 30.0% | 0 | 0.0% | |
| Burst fracture | No | 9 | 90.0% | 1 | 100.0% | **1.000** |
| | Yes | 1 | 10.0% | 0 | 0.0% | |
| Clay shoveler's fracture | No | 9 | 90.0% | 1 | 100.0% | **1.000** |
| | Yes | 1 | 10.0% | 0 | 0.0% | |
| Extension teardrop fracture | No | 10 | 100.0% | 1 | 100.0% | **-** |
| | Yes | 0 | 0.0% | 0 | 0.0% | |
| Fracture/dislocation | No | 8 | 80.0% | 1 | 100.0% | **1.000** |
| | Yes | 2 | 20.0% | 0 | 0.0% | |
| Lamina fracture | No | 9 | 90.0% | 0 | 0.0% | **0.182** |
| | Yes | 1 | 10.0% | 1 | 100.0% | |

## 4.12 The Type of Post-Surgical Instruments Used For the Specific Types of Cervical Spine Fractures

The types of post-surgical instruments used for the specific types of cervical spine fractures are tabulated in **Table 4.41**. In three subjects a soft collar was used in conjunction with cervical traction, a Minerva jacket and a Philadelphia collar respectively. Cervical tongs, halo vests and hard collars were not used on any of the subjects.

**Table 4.41 Types of post-surgical instrumentation utilized**

| Post-surgical instruments | *n* | Type of fracture/dislocation |
|---|---|---|
| Soft collar | 4 | Odontoid; burst; unilateral facet dislocation and fracture/dislocation; unilateral facet dislocation and lamina fracture |
| Cervical traction | 1 | Odontoid |
| Philadelphia collar | 8 | Bilateral facet dislocation; Jefferson's fracture and fracture/dislocation; Jefferson's facture and odontoid fracture; Unilateral facet dislocation (2); |

| | | |
|---|---|---|
| | | Unilateral facet dislocation and lamina fracture; odontoid fracture and Clay shoveler's fracture |
| Minerva jacket | 1 | Burst fracture |

## 4.13 The Association between the Type of Post-Surgical Instruments Used and the Specific Type of Cervical Spine Fracture

The types of post surgical instruments used for each type of fracture are shown in **Tables 4.42** to **4.45**. There were no statistically significant associations ($p > 0.05$) between the type of post-surgical instrumentation used and a specific type of cervical spine fracture.

**Table 4.42 The association between the use of a soft collar and the type of fracture**

| | | Soft collar | | | | ***p*-value** |
|---|---|---|---|---|---|---|
| | | No | | Yes | | |
| | | Count | Column *n* % | Count | Column *n* % | |
| Unilateral facet dislocation | No | 4 | 57.1% | 2 | 50.0% | **1.000** |
| | Yes | 3 | 42.9% | 2 | 50.0% | |
| Bilateral facet dislocation | No | 6 | 85.7% | 4 | 100.0% | **1.000** |
| | Yes | 1 | 14.3% | 0 | 0.0% | |
| Jefferson's fracture | No | 5 | 71.4% | 4 | 100.0% | **0.491** |
| | Yes | 2 | 28.6% | 0 | 0.0% | |
| Odontoid process fracture | No | 5 | 71.4% | 3 | 75.0% | **1.000** |
| | Yes | 2 | 28.6% | 1 | 25.0% | |
| Burst fracture | No | 7 | 100.0% | 3 | 75.0% | **0.364** |
| | Yes | 0 | 0.0% | 1 | 25.0% | |
| Clay shoveler's fracture | No | 6 | 85.7% | 4 | 100.0% | **1.000** |
| | Yes | 1 | 14.3% | 0 | 0.0% | |
| Extension teardrop fracture | No | 7 | 100.0% | 4 | 100.0% | **-** |
| | Yes | 0 | 0.0% | 0 | 0.0% | |
| Fracture/dislocation | No | 6 | 85.7% | 3 | 75.0% | **1.000** |
| | Yes | 1 | 14.3% | 1 | 25.0% | |
| Lamina fracture | No | 6 | 85.7% | 3 | 75.0% | **1.000** |
| | Yes | 1 | 14.3% | 1 | 25.0% | |

**Table 4.43 The association between the use of traction and the type of fracture**

| | | Traction | | | | *p*-value |
|---|---|---|---|---|---|---|
| | | No | | Yes | | |
| | | Count | Column *n* % | Count | Column *n* % | |
| Unilateral facet dislocation | No | 5 | 50.0% | 1 | 100.0% | **1.000** |
| | Yes | 5 | 50.0% | 0 | 0.0% | |
| Bilateral facet dislocation | No | 9 | 90.0% | 1 | 100.0% | **1.000** |
| | Yes | 1 | 10.0% | 0 | 0.0% | |
| Jefferson's fracture | No | 8 | 80.0% | 1 | 100.0% | **1.000** |
| | Yes | 2 | 20.0% | 0 | 0.0% | |
| Odontoid process fracture | No | 8 | 80.0% | 0 | 0.0% | **0.273** |
| | Yes | 2 | 20.0% | 1 | 100.0% | |
| Burst fracture | No | 9 | 90.0% | 1 | 100.0% | **1.000** |
| | Yes | 1 | 10.0% | 0 | 00.0% | |
| Clay shoveler's fracture | No | 9 | 90.0% | 1 | 100.0% | **1.000** |
| | Yes | 1 | 10.0% | 0 | 0.0% | |
| Extension teardrop fracture | No | 10 | 100.0% | 1 | 100.0% | **-** |
| | Yes | 0 | 0.0% | 0 | 0.0% | |
| Fracture/dislocation | No | 8 | 80.0% | 1 | 100.0% | **1.000** |
| | Yes | 2 | 20.0% | 0 | 0.0% | |
| Lamina fracture | No | 8 | 80.0% | 1 | 100.0% | **1.000** |
| | Yes | 2 | 20.0% | 0 | .0% | |

**Table 4.44 The association between the Philadelphia collar and the type of fracture**

| | | Philadelphia collar | | | | *p*-value |
|---|---|---|---|---|---|---|
| | | No | | Yes | | |
| | | Count | Column *n* % | Count | Column *n* % | |
| Unilateral facet dislocation | No | 2 | 66.7% | 4 | 50.0% | **1.000** |
| | Yes | 1 | 33.3% | 4 | 50.0% | |
| Bilateral facet dislocation | No | 3 | 100.0% | 7 | 87.5% | **1.000** |
| | Yes | 0 | 0.0% | 1 | 12.5% | |
| Jefferson's fracture | No | 3 | 100.0% | 6 | 75.0% | **1.000** |
| | Yes | 0 | 0.0% | 2 | 25.0% | |
| Odontoid process fracture | No | 2 | 66.7% | 6 | 75.0% | **1.000** |
| | Yes | 1 | 33.3% | 2 | 25.0% | |
| Burst fracture | No | 2 | 66.7% | 8 | 100.0% | **0.273** |
| | Yes | 1 | 33.3% | 0 | 0.0% | |
| Clay shoveler's fracture | No | 3 | 100.0% | 7 | 87.5% | **1.000** |
| | Yes | 0 | 0.0% | 1 | 12.5% | |
| Extension teardrop fracture | No | 3 | 100.0% | 8 | 100.0% | **-** |
| | Yes | 0 | 0.0% | 0 | 0.0% | |
| Fracture/dislocation | No | 2 | 66.7% | 7 | 87.5% | **0.491** |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Yes | 1 | 33.3% | 1 | 12.5% | |
| Lamina fracture | No | 3 | 100.0% | 6 | 75.0% | **1.000** |
| | Yes | 0 | 0.0% | 2 | 25.0% | |

**Table 4.45 The association between the minerva jacket and the type of fracture**

| | | Minerva Jacket | | | | *p*-value |
|---|---|---|---|---|---|---|
| | | No | | Yes | | |
| | | Count | Column *n* % | Count | Column *n* % | |
| Unilateral facet dislocation | No | 5 | 50.0% | 1 | 100.0% | **1.000** |
| | Yes | 5 | 50.0% | 0 | 0.0% | |
| Bilateral facet dislocation | No | 9 | 90.0% | 1 | 100.0% | **1.000** |
| | Yes | 1 | 10.0% | 0 | 0.0% | |
| Jefferson's fracture | No | 8 | 80.0% | 1 | 100.0% | **1.000** |
| | Yes | 2 | 20.0% | 0 | 0.0% | |
| Odontoid process fracture | No | 7 | 70.0% | 1 | 100.0% | **1.000** |
| | Yes | 3 | 30.0% | 0 | 0.0% | |
| Burst fracture | No | 10 | 100.0% | 0 | 0.0% | **0.091** |
| | Yes | 0 | 0.0% | 1 | 100.0% | |
| Clay shoveler's fracture | No | 9 | 90.0% | 1 | 100.0% | **1.000** |
| | Yes | 1 | 10.0% | 0 | 0.0% | |
| Extension teardrop fracture | No | 10 | 100.0% | 1 | 100.0% | **-** |
| | Yes | 0 | 0.0% | 0 | 0.0% | |
| Fracture/dislocation | No | 8 | 80.0% | 1 | 100.0% | **1.000** |
| | Yes | 2 | 20.0% | 0 | 0.0% | |
| Lamina fracture | No | 8 | 80.0% | 1 | 100.0% | **1.000** |
| | Yes | 2 | 20.0% | 0 | 0.0% | |

## 4.14 POST-CERVICAL SPINE SURGERY

### 4.14.1 The Short-Term Post-Surgical Complications and the Association between the Co-Existing Medical Conditions and the Development of Post-Surgical Complications

The short-term post-surgical complications are depicted graphically in **Figure 4.7**. The results of the 11 individuals who underwent cervical surgery were analysed to determine the association between the co-existing medical conditions and the development of post-surgical complications. The short-term post-surgical complications observed in this study are shown in **Table 4.46**. Severe neck pain, hoarseness and odynophagia were pooled together as “other post-surgical complications” and examined in conjunction with the presence or absence of various co-existing medical conditions **(Table 4.47)**. Of the six subjects with post-surgical complications, three were HIV negative; two were HIV positive while the status of one patient was unknown. There were no statistically significant associations with any co-existing medical condition ($p > 0.05$) since the numbers were very small.

**Table 4.46 Short-term post-surgical complications**

| Post-surgical complication | Type of fracture/dislocation |
|---|---|
| Infection (oral thrush) | Unilateral facet dislocation |
| Pneumonia | Odontoid fracture; Clay shoveler's fracture |
| Odynophagia | Bilateral facet dislocation |
| Severe neck pain (2) | Unilateral facet dislocation (2); lamina fracture |
| Hoarseness | Unilateral facet dislocation; lamina fracture |

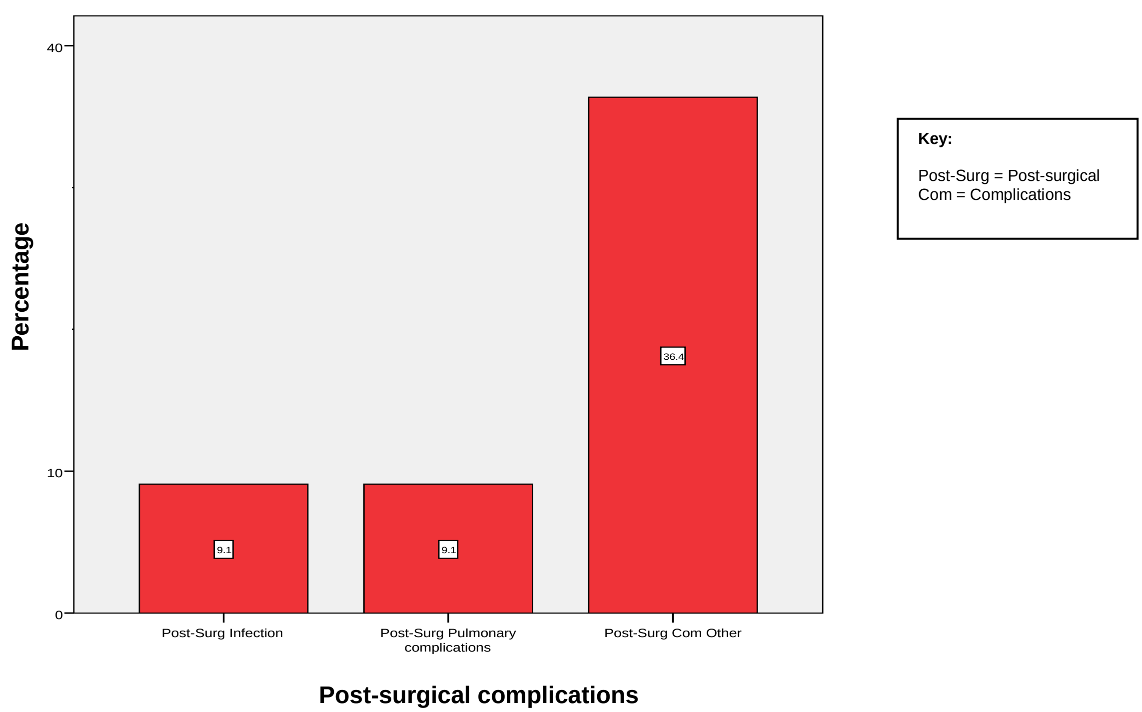


**Figure 4.7 Percentage of the types of post-surgical complications**

**Table 4.47 The association between the co-existing medical conditions and the development of post-surgical complications**

| | **Post-surgical complications** | | | | ***p*-value** |
|---|---|---|---|---|---|
| | No | | Yes | | |
| | Count | Row % | Count | Row % | |
| No cardiac | 4 | 40.0% | 6 | 60.0% | **0.455** |
| Cardiac | 1 | 100.0% | 0 | 0.0% | |
| No infections | 4 | 40.0% | 6 | 60.0% | **0.455** |
| Infections | 1 | 100.0% | 0 | 0.0% | |
| No hypertension | 4 | 40.0% | 6 | 60.0% | **0.455** |
| Hypertension | 1 | 100.0% | 0 | 0.0% | |
| No neurological | 4 | 44.4% | 5 | 55.6% | **1.000** |
| Neurological | 1 | 50.0% | 1 | 50.0% | |
| No other | 1 | 33.3% | 2 | 66.7% | **1.000** |
| Other | 4 | 50.0% | 4 | 50.0% | |
| HIV negative | 4 | 57.1% | 3 | 42.9% | **1.000** |
| HIV positive | 1 | 33.3% | 2 | 66.7% | |

### 4.14.3 Short-Term In-Hospital Post-Surgical Rehabilitation

Of the 11 subjects who received cervical spine surgery, one received occupational therapy while ten subjects received physiotherapy (90.9%) during the three-week post-surgical observation period as shown in **Figure 4.8**. The post-surgical rehabilitation for the types of fractures and dislocations is shown in **Table 4.51**.

**Table 4.48 Post-surgical rehabilitation**

| **Post surgical rehabilitation** | **Type of fracture/dislocation** |
|---|---|
| Physiotherapy | Bilateral facet dislocation; unilateral facet dislocation (4); Jefferson's fracture (2); fracture/dislocation (2); odontoid fracture (3); lamina fracture (2); burst fracture; clay shoveler's fracture |
| Occupational therapy | Unilateral facet dislocation; fracture/dislocation |

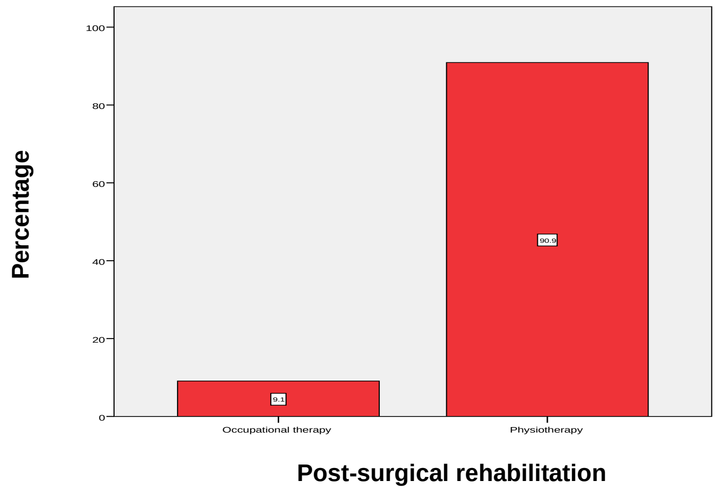


**Figure 4.8   The types of short-term post-surgical rehabilitation**

# CHAPTER FIVE

# DISCUSSION

## 5.1 DEMOGRAPHIC DATA

The mean age of the subjects in this study was greater than that reported by Walter *et al.* (1984) and Vieweg *et al*. (2000), but less than that reported by Ryan and Henderson (1992), Grauer *et al*. (2005) and Lenoir *et al*. (2006). This observation suggests that the age of patients with cervical spine fractures varies considerably in different settings including university hospitals (Vieweg *et al*., 2000; Lenoir *et al*., 2006). A surprising finding was that no paediatric patients presented with cervical spine fractures at the Spinal Unit which was disparate with the reports of Brown *et al*. (2001) and Hackl *et al*. (2001). This finding suggests that adults are more likely to sustain cervical spine fractures than children although no significant association was found between age and any specific type of cervical spine fracture **(Table 4.8)**.

The findings of this study are in agreement with those of Vieweg *et al*. (2000), Grauer *et al*. (2005), Daffner *et al*. (2006), Lenoir *et al.* (2006) and Malik *et al*. (2008) who reported that males are more likely to experience cervical spine injuries or fractures although no specific fracture type was significantly associated with gender ($p < 0.05$) with the exception of fracture/dislocation **(Table 4.7)**. The participation of Black only subjects in this study could be due to them being the predominant population group in KwaZulu Natal (http://www.statssa.gov.za/publications/P0302/P03022007.pdf). Furthermore all the subjects were referred to the Spinal Unit from the surrounding state hospitals where the majority of patients are Black (Zwarenstein *et al*., 1991). The occupation of the subjects **(Table 4.1)** including the high number of those who were unemployed reflected the socioeconomic circumstances of the majority of Blacks in KwaZulu-Natal (http://www.info.gov.za/aboutsa/landpeople.htm#KZN). These subjects may not have been able to afford private health-care and were therefore treated for free at King George V Hospital.

## 5.2 CERVICAL SPINE FRACTURES

### 5.2.1 Aetiology

The primary aetiology of the cervical spine fractures in this study was trauma which was in agreement with the reports of Maiman and Cusick (1982), Walter *et al*. (1984), Hadley *et al*. (1989), Kirshenbaum *et al*. (1990), Oller *et al*. (1992), Greene *et al*. (1997), Merritt and Williams (1997), Young *et al*. (1999), Preutu, (1999), Inamasu *et al*. (2001), Lenoir *et al*. (2006) and Verettas *et al.* (2008). With respect to the specific aetiology of the cervical spine fractures, the results of this study corroborated with those of Allen *et al*. (1982), Later *et al*. (2005), Song *et al.* (2007), and Malik *et al.* (2008) with regards to MVAs, and with those of Grauer *et al.* (2005), Lakshmanan *et al.* (2005), and Later *et al.* (2005) with regards to falls. Of the three subjects who were alcoholics, two sustained cervical spine fractures during a fall while one sustained a cervical spine fracture in an MVA. Jurkovich *et al.* (1992) reported that 40% of patients involved in MVAs and falls were intoxicated at the time of injury. The percentage of cervical spine fractures **(4.3.1)** due to falls and MVAs were higher than that reported by Later *et al*. (2005) for geriatric patients. This shows that younger individuals are more likely to sustain cervical spine fractures due to falls and MVAs. A cervical spine fracture was also observed in an epileptic patient who suffered a fall. In 1999 Vestergaard *et al*. reported that epileptic individuals were at risk of sustaining spinal fractures during attacks. Cervical spine fractures due to assaults had been reported by Merritt and Williams (1997), Inamasu *et al*. (2001) and Lenoir *et al*. (2006). The results of this study however, did not show any significant association between any type of trauma and a specific type **(Tables 4.12 - 4.21)** or location **(Table 4.22)** of cervical spine fracture.

### 5.2.2 Description and Vertebral Level and Associated Fractures

The results of this study supported the observation of Timothy *et al.* (2004) that cervical spine injuries are the most common of all spinal injuries as there were no fractures or injuries to the rest of the vertebral column. The most common locations of cervical spine fractures was at the atlanto-axial region and the lower cervical spine (C6-C7) **(Figure 4.3)** but no fractures or dislocations were observed at the C3 level. This shows that the two ends of the kinematic chain pertaining to the cervical spine are more susceptible to injury than its mid-region. The results shown in **Figure 4.3** indicate that fractures of the lower cervical spine (C6-C7) (caudal end of the kinematic chain) are more likely to involve the posterior column **(Figure 4.3)** resulting in highly unstable injuries (Eismont and Kitchel, 1994).

The percentage of subjects with cervical spine fractures and other associated injuries are similar to the observation of Saboe *et al.* (1991). The observation of head injury being the most common extra-spinal injury is in agreement with the findings of Saboe *et al.* (1991). Head injuries were also reported by Kirshenbaum *et al*. (1990), Oller *et al*. (1992), Merritt and Williams (1997), Morandi *et al.* (1999a), Holly *et al.* (2002), Meyer *et al*. (2005) and Aslam *et al.* (2008). All subjects in this study who had head injuries also had associated fractures in the C1 or C2 regions of the cervical spine. This observation shows that head injuries are likely to occur in conjunction with injuries to the cephalad end of the cervical kinematic chain (C1-C2) (Moskovich, 2001). The observation of extremity injuries in this study are in agreement with the reports of Saboe *et al.* (1991), Verettas *et al.* (2008), and Song and Lee (2008) who reported long bone injuries, bimaleolar ankle fractures and multiple extremity fractures respectively **(Table 4.4)**. In contrast to the reports of Saboe *et al.* (1991), Song *et al*. (2007), and Song and Lee (2008) there were no chest injuries, thoracolumbar fractures, clavicle fractures, pulmonary contusions and haemothorax. This observation suggests that associated injuries with cervical spine fractures may vary due to differences in the types of trauma, force of trauma, mechanism of injury and patient profile.

The most common type of cervical spine fracture reported in this study **(Figure 4.2)** is in agreement with the reports of Pepin *et al*. (1985), Hadley *et al.* (1985), Hadley *et al.* (1989), Harrop *et al*. (2001), Kirkpatrick *et al.* (2004), and Grauer *et al.* (2005). The prevalence of odontoid fractures reported in this study **(Figure 4.2)** is higher than that reported by Maiman *et al*. (1983), Lee *et al.* (1984), Amling *et al.* (1995), Subach *et al.* (1999), Vaccaro *et al.* (2000) and Perri *et al*. (2007) but close to the range reported by Pepin *et al*. (1985), Hadley *et al.* (1985), Hadley *et al.* (1989) and Kirkpatrick *et al.* (2004). The only atlas fracture observed in this study was the Jefferson's fracture **(Figure 4.2).** This observation is in conflict with Young *et al*. (1999) who reported that posterior arch fractures are the most common atlas fractures. Due to the paucity of literature on the epidemiology of many of the cervical spine fractures, it was not possible to compare the prevalence of traumatic spondylolisthesis, fracture/dislocation, lamina fracture, burst fracture, extension teardrop fracture and clay shoveler's fracture to previous studies although Lin *et al*. (2003) had previously reported a C6-C7 fracture/dislocation and five clay shoveler's fractures on their evaluation of 68 cervical spine fractures over a four-year period.

With respect to facet dislocations, the findings of this study are in conflict with those of Pasciak and Doniec (1993), and Kim and Yoon (1997) who reported that bilateral facet dislocations are more common than unilateral facet dislocations. This discrepancy is most likely explained by the fact that unilateral facet dislocations are often misdiagnosed as instability or subluxation (Braakman and Vinken, 1967; Braakman and Vinken, 1968; Rorabeck *et al.,* 1987) in previous studies. The vertebral levels of the facet dislocations found in this study are in agreement with those of Sonntag (1981), Maiman *et al*. (1986), Wolf *et al*. (1991), Lu *et al*. (1998) and Razack *et al*. (2000), Goldberg *et al.* (2001), and Daffner and Daffner (2002) although the percentage involvement at C5-C6 and C6-C7 levels are considerably higher **(Figure 4.5)** than that reported by Goldberg *et al.* (2001). Furthermore there were no dislocations observed at other vertebral levels unlike those reported by Goldberg *et al*. (2001). The likelihood of C5-C6 being the most common location for facet dislocations could be explained by the fact that this is the most mobile region of the subaxial spine with posterolateral-facing superior articular facets (Daffner and Daffner, 2002).

### 5.2.3 Pre-Surgical Neurological Findings

With respect to the neurological complications as a result of unilateral facet dislocations, the results of this study **(Table 4.5)** are in conflict with the reports of Pasciak and Doniec (1993), and Davenport *et al.* (2008) who observed that unilateral facet dislocations are associated with a decreased chance of neurological complications. With respect to neurological complications as a result of a Jefferson's fracture the results of this study are in agreement with the observations of Timothy *et al*. (2004) and Davenport *et al.* (2008) who reported that neurological impairments are often associated with this type of fracture. The results of this study are in agreement with the reports of Inamasu *et al.* (2001) with respect to selective paralysis of the limbs, Agrillo and Mastronadi (2006) with respect to motor weakness in the limbs, and loss of motor function as reported by Licina and Nowitzke (2005). Furthermore, paresthesia (Hadley *et al*., 1985), specific motor weakness (Hadley *et al*., 1985), monoparesis (Przybylski *et al*., 2002), and tetraplegia (Pasciak and Doniec, 1993; Przybylski *et al.,* 2002) were also observed in previous reports. The tetraplegia observed in this study **(Table 4.19)** was most likely due to cord compression following a unilateral facet dislocation (Pasciak and Doniec, 1993). Paresthesia, motor weakness or monoparesis could have been due to cervical myelopathy (Przybylski *et al*., 2002), brachial plexus injury (Webb *et al*., 2002), spinal stenosis (Daentzer *et al*., 2003), nerve root entrapment or cord compression (Pasciak and Doniec, 1993) following cervical spine fractures. Upper limb impairment was more than twice that of lower limb impairment. These findings together with a lack of sensory deficits in the sacral area are indicative of a central cord syndrome (Meyer *et al.,* 1976; Morse, 1982; Cooper, 1986; Timothy *et al*., 2004) which was described as the most common spinal cord syndrome (Timothy *et al*., 2004). The bowel and bladder dysfunction observed in this study was most likely due to autonomic dysfunction following spinal cord injury (Glickman and Kamm, 1996; Davenport *et al*., 2008).

There were no vertebrobasilar artery injuries observed in this study even though dislocations of the zygapophysial joints were reported as predictive of vertebral artery injury (Giacobetti *et al.,* 1997; Veras *et al.,* 2000; Parbhoo *et al.*, 2001) and odontoid and Jefferson's fractures were reported to be associated with vertebral artery injury (Willis *et al.,* 1994; Giacobetti *et al.,* 1997; Weller *et al.,* 1999; Veras *et al.,* 2000; Parbhoo *et al.,* 2001). Despite the results of this study indicating no vertebrobasilar artery injuries, the patient needs to be monitored for several weeks for the development of clinical features related to the development of vertebrobasilar artery injuries following cervical spine trauma as onset of symptoms may vary from one hour post-injury to several weeks post-injury (Perry *et al*., 1980; Davis *et al*., 1990; Cogbill *et al.,* 1994; Biffl *et al*., 2002).

## 5.3 Conservative Treatment

The conservative treatment for Type I odontoid fracture (Weller *et al*., 1997; Forster *et al.,* 2002), Type II odontoid fracture (Weller *et al*., 1997; Richman, 1998; Vieweg *et al.* 2000; Forster *et al*., 2002; Malik *et al.,* 2008), traumatic spondylolisthesis (Timothy *et al.,* 2004; Buchowski and Riley, 2005), Jefferson's fracture (Weller *et al.,* 1997; Vieweg *et al*., 2000; Haus and Harris, 2008) and unilateral facet dislocations (Pasciak and Doniec, 1993) have been described in the literature **(Table 2.8)**. In this study the three key reasons for the choice of the conservative treatment for the fractures in **Table 4.25** are: first, the fractures were stable; second, there were no neurological complications and third, the patient opted for conservative treatment.

Conservative treatment of Type I and Type II odontoid fractures observed in this study **(Table 4.25)** differed from those of Weller *et al*. (1997), Richman (1998), Vieweg *et al.* (2000), Forster *et al.* (2002), and Malik *et al.* (2008) **(Table 2.8)**. There were also differences in the conservative treatment of traumatic spondylolisthesis, Jefferson's fracture and unilateral facet dislocation in this study **(Table 4.25)** compared to Pasciak and Doniec (1993), Weller *et al*. (1997), Vieweg *et al*. (2000), Timothy *et al*. (2004), Buchowski and Riley (2005) and Haus and Harris (2008) **(Table 2.8)**. The Philadelphia collar and the halo orthosis were not utilized for any of the fractures that were treated conservatively. The similarities of the conservative treatment utilized in this study compared to previous studies are the use of a cervical collar for Jefferson's fracture (Haus and Harris, 2008; **Table 2.8)** and cones calipers (skull traction) for unilateral facet dislocation (Pasciak and Doniec, 1993; **Table 2.8)**. The use of the soft collar to treat an extension teardrop fracture **(Table 4.25)** is in agreement with the views of Wheeless (2008). Soft collars were used as they limited flexion and extension movements, but permitted axial rotation and lateral flexion (Perri *et al*., 2007), as well as reduced residual symptoms such as pain (Ersmark and Kalen, 1987). The SOMI brace was considered more supportive than the collar (Timothy *et al*., 2004) while the Minerva jacket limited cervical spine flexion-extension and axial rotation, but not lateral flexion (Perri *et al.,* 2007).

The lack of a significant association between the type of cervical spine fracture and any conservative treatment ($p > 0.05$; **Tables 4.26 - 4.30**) showed that no specific type of conservative treatment was utilized more than another for any specific cervical spine fracture. This finding was most likely due to the small sample size in this study.

### 5.3.1 Post-Conservative Treatment Complications

The observation of an occipital pressure sore following the use of the cones calipers is in agreement with the report of the Department of Orthopaedic Surgery, University of Stellenbosch (2008) on complications of cervical spine traction. Severe discomfort following the use of the Minerva jacket was most likely due to a lack of head/neck and trunkal movement for a prolonged period of time. Severe neck pain following an extension teardrop fracture was most likely due to damage to osseoligamentous and muscular complexes following hyperextension of the cervical spine (Timothy *et al*., 2004).

## 5.4 Cervical Spine Surgery

Surgical treatment of the cervical spine was considered when the spine was unstable in order to reduce deformity and improve any neurological deficit. Furthermore, decompression of the spinal canal was done when the canal was found to be compromised (Timothy *et al*., 2004; Licina and Nowitzke, 2005) in order to make the patient mobile sooner (Timothy *et al*., 2004; Goodrich *et al*., 2008). The surgical procedure and the implants utilized at the Spinal Unit were evidence-based i.e. they depended on the type/s and complexity/ies of the cervical spine fracture/s, the availability of the implements and associated pathological and clinical findings (Naidoo, 2007). All subjects underwent cervical spine surgery only once any co-existing condition (e.g. hypertension) was treated or when the subject was stabilized (e.g. after an epileptic attack). Careful pre-surgical treatment of co-existing conditions was crucial in order to prevent the development of life-threatening conditions during surgery (Goodrich *et al*., 2008). The timing of the surgery depended on the seriousness of the fracture and clinical presentation of the patient.

Besides the fractures and dislocations shown in **Table 4.25**, and the Jefferson's fractures which were in combination with a C6-C7 fracture/dislocation and odontoid fracture and the clay shoveler's fracture, all cervical fractures were treated surgically **(Table 4.33)**. The Smith-Robinson approach (Kaya *et al*., 2005; Goodrich *et al*., 2008) was the preferred anterior approach for cervical spine surgery at the Spinal Unit. This procedure permitted anterior decompression after which allograft struts, anterior fusion and anterior cervical plating were done. The Synthes Anterior Cervical Locking Plate was used at the Spinal Unit as the screws maintained rigid alignment of the bone grafts (Timothy *et al*., 2004). The anterior approach was implemented more than the posterior approach as it was less painful to the patient due to the relative lack of muscle dissection (Timothy *et al*., 2004). The posterior approach (reduction) was implemented on the subject who presented with a unilateral facet dislocation and a lamina fracture **(Table 4.33)** as the anterior approach was unsuccessful in reducing the dislocation. Goodrich *et al*. (2008) had reported that reduction using a posterior approach should be used if previous attempts at reduction had failed.

The surgical interventions for odontoid fractures in this study were in agreement with those of Gallie (1939), Brooks and Jenkins (1978), Geisler *et al.* (1989), Montesano *et al.* (1991), Jeanneret and Magerl (1992), Shaha (1993), Coyne *et al.* (1995), Apfelbaum *et al.* (2000), Vieweg *et al*. (2000), Harms and Melcher (2001), Koivikko *et al.* (2004), Ochoa (2005), Min *et al*. (2006), Song *et al.* (2007), and Ben-Galim and Reitman (*in press*) **(Table 2.7)**. For the combination of an odontoid and Jefferson's fracture the Philadelphia collar was utilized **(Table 4.44)** after the anterior screw fixation procedure instead of the stiff neck collar which was utilized by Vieweg *et al*. (2000) **(Table 2.7)**. The anterior screw fixation was possible when the fracture was non-displaced or had been anatomically reduced (Koivikko *et al.,* 2004, Ochoa, 2005; Ben-Galim and Reitman, *in press*). The anterior screw fixation also offered immediate stability to the Type II odontoid fractures (Morandi *et al*., 1999a; Perri *et al*., 2007) and preserved motion at the C0-C1 and C1-C2 levels (Etter *et al.,* 1991; Asfora *et al.,* 1992; Apostolides *et al.,* 1997). The lack of an IVD between C1 and C2 explained the significant negative association between odontoid fractures and anterior decompression, anterior fusion, allograft strut, discectomy and anterior cervical plating **(Tables 4.32 - 4.34, 4.36** and **4.37)**. The disruption of two or more columns in the burst fracture **(Table 4.33)** necessitated a corpectomy (Timothy *et al*., 2004). Surgical intervention was selected for the five subjects with unilateral facet dislocations as they presented with neurological complications **(Table 4.5)**. This was in agreement with the approach favoured by Pasciak and Doniec (1993).

The use of the soft collar and Philadelphia collar post-surgically **(Table 4.44)** was mentioned by Vieweg *et al*. (2000), Agrillo and Mastronadi (2006), Al-Barbarawi and Sekhon (2005) and Song and Lee (2008). The purpose of the post-surgical instrumentation **(Table 4.44)** was to provide additional support and to prevent injury by restricting unnecessary movement.

There were no reported complications during any of the cervical spine surgical procedures. This showed that the surgical team at the Spinal Unit was well-trained in a highly specialized surgical field and technical errors during surgery which could have been fatal (Rogers, 1957) were avoided.

The results of the pre-post surgical Frankel grading shown in **Table 4.6** are indicative of the neurological stability of the majority of the subjects who underwent cervical spine surgery.

### 5.4.1 Post-Surgical Complications

There were not many post-surgical complications observed in this study **(Table 4.49; Figure 4.7)**. There were no significant associations between any of the co-existing medical conditions **(Table 4.50)** including HIV and alcohol and the development of post-surgical complications although this observation should be treated with caution as the numbers were small. Nevertheless, the development of oral thrush, a common fungal infection in HIV positive/AIDS patients, in an HIV positive subject who was also a smoker, was likely due to this individual being more susceptible to infection (Brown *et al*., 1989; Yamaguchi *et al.,* 1993; Kimberly *et al.,* 1994; Carragee, 1997; Tran *et al*., 2000; Young *et al*., 2005; King, 2006) as a result of a compromised immune system (Lin *et al*., 2004). Post-surgical cellular immunity depression (Allendorf *et al*., 1997; Shimaoka *et al*., 1998; Ogawa *et al*., 2000) and the use of a surgical instrument in this patient (Woolgar and Robbs, 2002) most likely hastened the development of the fungal infection. The observation of one case of pneumonia was in agreement with the reports of Weighardt *et al*. (2000) and Goodrich *et al*. (2008). There were no statistically significant associations with any medical condition since the numbers were very small. The only condition which appeared to show a trend of an association with post-surgical complications was HIV where more of those subjects with HIV had post-surgical complications but the numbers were too small for statistical significance.

Rupture of the interspinous ligaments and facet capsule on the affected side (Kricun, 1988; Pathria, 1995; Daffner, 1996), degeneration of the IVDs (Kaya *et al*., 2005) dissection of the anterior cervical muscles and damage to the recurrent laryngeal nerve, unilateral vocal cord paralysis (Muzumdar *et al*., 2000) during the anterior approach for the unilateral facet dislocation and lamina fracture (Timothy *et al*., 2004) were probably responsible for the severe post-surgical neck pain and hoarseness **(Table 4.49)**. The symptom of odynophagia was reported by the patient who sustained a C5-C6 bilateral facet and was most likely due to damage to the oesophagus (Lee and Sung, 2006; **Table 2.8**) which begins posterior to the cricoid cartilage at the level of C6 (Moore and Dalley, 1999).

There were no post-surgical cases of decubitus ulcers observed in the three-week post-surgery observation period. This was corroborated by the significant increase ($p$ = 0.004) of the NPSA scores post-surgically **(Tables 4.10 and 4.11)** which showed that the subjects' risk of developing post-surgical decubitus ulcers was reduced. This was probably due to the excellent care of the patients by the nursing and physiotherapy staff at the hospital.

### 5.4.2 Post-Surgical Rehabilitation

The overwhelming majority of the subjects were referred to the in-hospital physiotherapists for post-surgical rehabilitation **(Figure 4.8)** which was in agreement with the report of Bromley (2006). The tetraplegic patient was sent for occupational therapy as she required therapy relating to the use of adaptive equipment, orthotics and aids in self-care (e.g. eating and dressing herself) in addition to physical exercises (Punwar, 2000). Physiotherapy rehabilitation was instituted within 24 hours in nearly all cases of cervical spine fractures which were treated surgically **(Table 4.51)** but only 40% of patients with cervical spine fractures who were managed conservatively also received physiotherapy. These were patients who were treated using the cones calipers **(Table 4.25)**. Irrespective of the interventions, the goals of the physiotherapy rehabilitation were to correctly position the patient in bed in order to maintain correct alignment of the fracture(s), to prevent decubitus ulcers and contractures, and to address bed mobility, transfer training, balance and gait training (Bhatnagar *et al*., 1995). The focus of rehabilitation for these patients was on increasing and restoring blood circulation, motion, flexibility, strength and decreasing pain as described by Reitman and Esses (1995). Although passive movements were utilized since they ensured mobility of paralysed structures and encouraged good circulation, patients were also encouraged to display active movements of their limbs as this played a role in regaining or maintaining muscle strength and preventing the development of joint and muscle contractures (Bromley, 2006).

Post-surgical chest physiotherapy was also performed in these patients as general anaesthetic was used in their surgical procedures (Bromley, 2006). Chest physiotherapy focused on reducing airway obstruction, promoting sputum mobilization and expectoration and improving ventilation and gas exchange. Treatment included breathing exercises, positioning and postural drainage, forced expiration as well as assisting in normal coughing. To reduce the development of decubitus ulcers, passive movements, grease massage, exercise, and chest therapy were employed. All these physiotherapy rehabilitation protocols were in agreement with those of Bromley (2006).

# CHAPTER SIX

# CONCLUSIONS AND RECOMMENDATIONS

## 6.1 CONCLUSIONS

The primary aim of this study was to:
determine the profile of cervical spine fractures with respect to the epidemiology, clinical presentation, types of fractures, conservative and surgical intervention, short-term post-intervention (i.e. post-conservative and post-surgical) complications and short-term post-surgical rehabilitation of patients presenting at the Spinal Unit of King George V Hospital over a 12-week period.

This was the first epidemiological study concerning cervical spine fractures to be conducted in a South African public hospital setting. Due to the small sample size in this study, it was not possible to determine many statistically significant associations. Despite the small sample size, the results observed were reflective of the literature surrounding cervical spine fractures.

## 6.2 RECOMMENDATIONS

Recommendations for future studies include the following:

- A similar epidemiological study to be performed over a longer period of time at a public health care spinal unit in South Africa in order to confirm or refute the results of this study. This will allow a better overview of the spectrum and diversity of the presentation of cervical spine fractures in this setting.

# REFERENCES


1. Abbed, K.M. and Coumans, J.V. 2007. Cervical radiculopathy: pathophysiology, presentation, and clinical evaluation. *Journal of Neurosurgery,* 60(1): S1 28-34.

2. Abel, M. 1962. Roentgenographic aspects of post-traumatic arthritis, instability and disc degeneration following occult fractures of the cervical spine. *Clinical Orthopedics,* 24: 49–60.

3. Agrillo, U. and Mastronardi, L. 2006. Acute combination fracture of atlas and axis: triple anterior screw fixation in a 92 year-old man. *Journal of Surgical Neurology,* 65(1):58-62.

4. Alcantara, J., Plaugher, G., Thornton, R.E. and Salem, C. 2001. Chiropractic Care of a Patient with Vertebral Subluxations and Unsuccessful Surgery of the Cervical Spine. *Journal of Manipulative and Physiological Therapeutics,* 24(7): 477-482.

5. Allen, B.L. Jr., Ferguson, R.L., Lehmann, T.R. and O'Brien, R.P.1982. A mechanistic classification of closed, indirect fractures and dislocations of the lower cervical spine. *The Spine Journal,* 7:1–27.

6. Allendorf, D., Bessler, M., Whelan, R.L., Trokel, W., Laird, D.A., Terry, M.B. and Treat, M.R.1997. Postoperative immune function varies inversely with the degree of surgical trauma in a murine model. *Surgical Endoscopy,* 11: 427–430.

7. Al-Barbarawi, M. and Sekhon, L.H.S. 2005. Protection of the C1 posterior arch in atlantal lateral mass fixation: technical case report. *Journal of Clinical Neuroscience,* 12(1): 59-61.

8. Alpass, L. 2004. Chiropractic management of 'intractable' chronic whiplash syndrome'. *Journal of Clinical Chiropractic*, 7: 16-23.

9. American Spinal Injury Association. 1984. *Standards for neurological classification of spinal injury patients*. Chicago: American Spinal Injury Association.

10. American Spine Injury Association (ASIA). 2002. International Standards for Neurological Classification of SCI, revised. *American Spine Injury Association booklet*. ASIA.

11. Amirjamshidi, A., Abbassioun, K., Khazenifar, M. and Esmailijah, A. 2008. Traumatic rotary posterior dislocation of the atlas on the axis without fracture. Report of a case and review of literature. *Journal of Surgical Neurology*, *Article in press.*

12. Amling, M., Pösl, M., Wening, V.J., Ritzel, H., Hahn, M. and Delling, G. 1995. Structural heterogeneity within the axis: The main cause in the etiology of dens fractures. A histomorphometric analysis of 37 normal and osteoporotic autopsy cases. *Journal of Neurosurgery,* 83: 330–335.

13. Anderson, L.D. and D'Alonzo, R.T. 1974. Fractures of the odontoid process of the axis. *Journal of Bone and Joint Surgery – American volume*, 56: 1663–1674.

14. Anderson, P.A. and Montesano, P.X. 1988. Morphology and treatment of occipital condyle fractures. *The Spine Journal*, 13: 731–736.

15. Anderson, S., Rodrigues, M. and Olerud, C. 2000. Odontoid fractures: high complication rate associated with anterior screw fixation in the elderly. *European Spine Journal,* 9: 56–60.

16. Apfelbaum, R.I. 1992. Anterior screw fixation for odontoid fractures. In: S.S. Rengachary and R.H. Wilkins (eds.) *Neurosurgical operative atlas.* American Association of Neurological Surgeons, Park Ridge (Ill). pp. 89–199.

17. Apfelbaum, R.I., Lonser, R.R., Veres, R. and Casey, A. 2000. Direct anterior screw fixation for recent and remote odontoid fractures. *Journal of Neurosurgery,* 93 (2): 227–236.

18. Apostolides, P.J., Theodore, N., Karahalios, D.G. and Sonntag, V.K.H. 1997. Triple anterior screw fixation of an acute combination atlas–axis fracture: Case report. *Journal of Neurosurgery,* 87: 96–99.

19. Arnold, P. M., Bryniarski, M. and McMahon, J. K. 2005. Posterior stabilization of subaxial cervical spine trauma. *Injury*, 36: S-B36-S-B43.

20. Asfora, W.T., Free, T.W. and Johnson, J.H. 1992. Odontoid fracture in the elderly: A case report of the screw fixation technique. *S. D. J. Medical Journals*, 45: 175–177.

21. Aslam, N., Sadiq, S. and Ellahi, M. 2008. Cervical injury in association with craniomaxillofacial fractures. *Injury Extra,* 39(5): 184.

22. Ba, A.M., LoTempio, M.M. and Wang, M.B. 2006. Pharyngeal diverticulum as a sequela of anterior cervical fusion. *American Journal of Otolaryngology*, 27(4): 295-297.

23. Bachs, A., Barraquer-Bordas, L., Barraquer-Ferré, L., Canadell, J.M. and Modolell, A. 1955. Delayed myelopathy following atlanto-axial dislocation by separated odontoid process. *Brain,* 78: 537–553.

24. Baisden, J., Voo, L.M., Cusick, J.F., Pintar, F.A. and Yoganandan, N. 1999. Evaluation of cervical laminectomy and laminoplasty: a longitudinal study in the goat model. *The Spine Journal*, 24(13):1283–1289.

25. Balanger, E. and Levi, A. 2000. Acute and Chronic Management of Spinal Cord Injury. *Journal of American College of Surgeons,* 190: 603-618.

26. Barrois, B. 1995. A survey of pressure sore prevalence in hospitals in the greater Paris region. *Journal of Wound Care,* 5: 234–236.

27. Batson, O.V.1940.The function of the vertebral veins and their role in the spread of metastases. *Annals of Surgery,* 112:138.

28. Batzdorf, U. and Batzdorff, A. 1988. Analysis of cervical spine curvature in patients with cervical spondylosis. *Journal of Neurosurgery,* 22 (5): 827–836.

29. Benarroch, E.E*.,* Westmoreland, B.F., Daube, J.R., Reagan, T.J. and Sandok, B.A. 1999. *Medical Neurosciences: An approach to anatomy, pathology, and physiology by systems and* levels. Minnesota: Mayo foundation.

30. Ben-Galim, P. and Reitman, C.A. *Article in press*. Direct transoral manipulation to reduce a displaced odontoid fracture: a technical note. *The Spine journal.*

31. Benzel, E.C. and Larson, S.J. 1987. Functional recovery after decompressive spine operation for cervical spine fractures. *Neurosurgery*, 20(5): 742-6.

32. Berglund, A., Alfredsson, L., Jensen, I., Cassidy, J. and Nygren, X. 2001. The association between exposure to a rear-end collision and future health complaints. *Journal of Clinical Epidemiology,* 54(8): 851—856.

33. Bhatnagar, M.K., Kostuik, J.P., Tooke, S.M.T. and Huckell C. 1995. Spinal fusion and Rehabilitation aftercare. In Young M.A. and Lavin R.A (ed.) *Spine: State of the art reviews.* Philadelphia: Hanley & Belfus. pp. 621-624.

34. Bhattacharjee, S. and Poonnoose, P. 2003. Management of Paraplegia in Palliative Care. *Indian Journal of Palliative Care,* 9(1): 14-18.

35. Bickley, L.S. and Szilagyi, P.G. 2003. *Bates' guide to physical examination and history taking.* USA: Lippincott Williams & Wilkins.

36. Biffl, W.L., Ray, C.E. Jr., Moore, E.E., Franciose, R.J., Aly, S.B.S., Heyrosa, M.G. Johnson, J, L. and Burch, J.M. 2002. Treatment-related outcomes from blunt cerebrovascular injuries: importance of routine follow-up arteriography. *Annals Surgery*, 235(5): 699-706.

37. Blaber, C. 1993. Centred on excellence. *Nursing Times,* 89(49), 61-66.

38. Blackmore, C.C., Emerson, S.S., Mann, F.A. and Koepsell, T.D. 1999. Cervical spine imaging in patients with trauma: determination of fracture risk to optimize use. *Journal of Emergency Radiology*, 211: 759-765.

39. Bland, J. H. 1994. *Disorders of the cervical spine: diagnosis and medical management*. 2$^{nd}$ ed. Pennsylvania: W. B. Saunders Company.

40. Bogduk, N. 1997*. Clinical anatomy of the lumbar spine and sacrum*. 3$^{rd}$ ed. Edinburgh: Churchill Livingstone.

41. Bogduk, N and Mercer, S. 2002. Biomechanics of the cervical spine I: Normal kinematics. *Clinical Biomechanics*, 15(9): 633-648.

42. Bohler, J. 1982. Anterior stabilization for acute fractures and non-unions of the dens. *Journal of Bone and Joint Surgery,* 64A:18–27.

43. Bohlman, H.H. 1979. Acute fractures and dislocations of the cervical spine: An analysis of three hundred hospitalized patients and review of the literature. *Journal of Bone and Joint Surgery – American volume*, 61: 1119-1142.

44. Borm, W., Kast, E., Richter, H. and Mohr, K. 2003. Anterior screw fixation in type II odontoid fractures: is there a difference in outcome between age groups? *Journal of Neurosurgery*, 52: 1089–1094.

45. Borne, G.M., Bedou, G.L., Pinaudeau, M., Cristino, G. and Hussein, A. 1988. Odontoid process fracture osteosynthesis with a direct screw fixation technique in nine consecutive cases. *Journal of Neurosurgery*, 68:223– 6.

46. Braakman, R. and Vinken, P.J. 1967. Unilateral facet interlocking in the lower cervical spine. *Journal of Bone and Joint Surgery – British volume,* 49: 249-257.

47. Braakman, R. and Vinken, P.J. 1968. Old luxations of the lower cervical spine. *Journal of Bone and Joint Surgery – British volume,* 50: 52-60.

48. Bresler, M. and Rich, G. 1982. Occult cervical spine fracture in an ambulatory patient. *Annals of Emergency Medicine,* 11:79–81.

49. Brinckmann, P., Frobin, W., Hierholzer, E., and Horst, M. 1983. Deformation of the vertebral endplate under axial loading of the spine. *The Spine Journal,* 8: 851-856.S.

50. Brodke, D.S. and Anderson, P.A .1998. Anterior surgery for cervical spine fractures. In Devlin, V.J. (ed.) Spine: State of the art reviews. Philadelphia: Hanley & Belfus Inc. pp.571-587.

51. Breig, A. 1978. *Adverse mechanical tension in the central nervous system: analysis of cause and effect—relief by functional neurosurgery*, New York: John Wiley and Sons.

52. Brichall, L. 1993. Pressure sore prediction calculators. *Nursing Times,* 89(18): 34-37.

53. Brickley-Parsons, D. and Glimcher, M.J. 1983. Is the chemistry of collagen in intervertebral discs an expression of Wolff's law? A study of the human lumbar spine. *The Spine Journal*, 9: 148–163.

54. Bromley, I. 2006. *Tetraplegia and paraplegia: A guide for physiotherapists.* 6th ed. Philadelphia: Churchill Livingstone Elsevier.

55. Bromley, I., Brownlee, S. and Rose, L. 2006. In Bromley, I. (ed.) *Tetraplegia and paraplegia: A guide for physiotherapists.* Philadelphia: Churchill Livingstone Elsevier.

56. Brooks, A.L. and Jenkins, E.B. 1978. Atlano-axial arthrodesis by the wedge compression method. *Journal of Bone and Joint Surgery,* 60A**:** 279–284.

57. Brown, G.P., Iwamoto, G.K., Monick, M.M. and Hunninghake, G.W. 1989. Cigarette smoking decreases interleukin-1 release by human alveolar macrophages. *American Journal of Physiology*, 256: C260-264.

58. Brown, P. 1988. *Health Care and Aged: A Nursing Perspective.* London: Williams & Wilkins and Associates.

59. Brown R. L., Brunn M. A. and Garcia, V. F. 2001. Cervical spine injuries in children: A review of 103 patients treated conservatively at a level 1 pediatric trauma center. *Journal of Pediatric Surgery*, 36(8):1107-1114.

60. Brynin, R. and Yomtob, C. 1999. Missed cervical spine fracture: Chiropractic implications. *Journal of Manipulative and Physiological Therapeutics*, 22(9): 610-614.

61. Buchowski, J.M. and Riley, L.H. 2005. Epidural haematoma after immobilization of a “hangman’s” fracture: a case report and review of the literature. *The Spine Journal,* 5(3): 332-335.

62. Bulger, R.F., Rejowski, J.E. and Beatty, R.A. 1985. Vocal cord paralysis associated with anterior cervical fusion: consideration for prevention and treatment. *Journal of Neurosurgery,* 62: 657–661.

63. Butler, J.C. and Whitecloud, T.D. 1992. Postlaminectomy kyphosis. *Orthopedic Clinics of North America,* 23: 505–511.

64. Cadoux, C.G. 1987. High-yield roentgenographic criteria for cervical spine injuries. *Annals of Emergency Medicine,* 16: 738–742.

65. Cadoux, C.G. and White, D.J. 1986. High-yield radiographic considerations for cervical spine injuries. *Annals of Emergency Medicine,* 15:236–240.

66. Camille, R.R., Saillant, G., Berteaux, D. and Serge, M-A. 1979. Early management of spinal injuries. In: McKibbin, B. (ed.) *Recent advances in orthopaedics*. Churchill Livingstone: Edinburg. pp. 57–87.

67. Carragee E. J. 1997. Pyogenic vertebral osteomyelitis. *Journal of Bone and Joint Surgery*, 79-A (6):874.

68. Cassinelli, E.H., Hall, R.A. and Kang, J.D. 2001. Biochemistry of intervertebral disc degeneration and the potential for gene therapy applications. *The Spine Journal,* 1(3): 205-14.

69. Choi, J.U., Hoffman, H.J., Hendrick, E.B., Humphreys, R.P. and Keith, W.S. 1986. Traumatic infarction of the spinal cord in children. *Journal of Neurosurgery*, 65(5):608–10.

70. Clark, C.R. and White, A.A. III. 1985. Fractures of the dens A multicenter study. *Journal of Bone and Joint Surgery,* 67:1340–1348.

71. Cloward, R.B. 1959. Vertebral body fusion for ruptured cervical discs: description of instruments and operative technique. *American Journal of Surgery,* 98: 722.

72. Cogbill, T.H., Moore, E.E., Meisner, M. Fischer, R.P., Hoyt, D.B., Morris, J.A., Shackford, S.R., Wallace, J.R., Ross, S.E., Ochsner, M.G., Sugerman, H.J., Lambert, P.J., Moore, F.A., Jurkovich, G.J., Cocanour, C.S., Potenza, B., Chang, M.C., Trevasani, G.T., Aprahamian, C. and Frankel, H.L. 1994. The spectrum of blunt injury to the carotid artery: a multicenter perspective. *Journal of Trauma*, 37(3): 473-9.

73. Cohen, A., Hirsch, M., Katz, M. and Sofer, S. 1991. Traumatic atlanto-occipital dislocation in children: review and report of five cases. *Pediatriatic Emergency Care*, 7: 24–27.

74. Cokluk, C., Takayasu, M. and Yoshida, J. 2005. Case report: Pedicle fracture of the axis: report of two cases and a review of literature. *Clinical Neurology and Neurosurgery*, 107: 136-139.

75. Cooper, P.R. 1986. Initial evaluation and management. In Berczeller, P.H., Bezkor, M.H. (eds.) Medical Complications of Quadriplegia. Chicago, Year Book Medical Publishers. Pp 1-10.

76. Cothren, C.C., Moore, E.E., Biffl, W.L., Ciesla, D.J., Ray, C.E.Jr., Johnson, J.L., Moore, J.B. and Burch, J.M. 2003.Cervical spine fracture patterns predictive of blunt vertebral artery injury. *Journal of Trauma*, 55(5): 811-3.

77. Coyne, T.J., Fehlings, M.G. and Martin, R.J. 1996. Clinical study: C1–C2 transarticular screw fixation for treatment of C1–C2 instability. *Journal of Clinical Neuroscience*, 3(3): 243-246.

78. Coyne, T.J., Fehlings, M.G., Wallace, M.C., Bernstein, M. and Tator, C.H. 1995. C1-C2 posterior cervical fusion: long-term evaluation of results and efficacy, *Neurosurgery* 37: 688–693.

79. Craig, J.B. and Hodgson, B.F. 1991.Superior facet fractures of the axis vertebra. *The Spine Journal,* 16:875–7.

80. Crissey, M.M. and Bernstein, E.F. 1974. Delayed presentation of carotid intimal tear following blunt craniocervical trauma. *Journal of Surgery*, 75(4): 543-9.

81. Croft, A. C. 1995. Biomechanics. In Foreman, S.M. and Croft, A.C. (eds.) *Whiplash injuries – The acceleration/deceleration syndrome*. USA: Williams & Wilkins.

82. Crowther, E.R. 1995.Missed cervical spine fractures: the importance of reviewing radiographs in chiropractic practice. *Journal of Manipulative and Physiological Therapeutics,* 18: 29–33.

83. Crumley, R.L. 1994. Unilateral recurrent laryngeal nerve paralysis. *Journal of Voice,* 8: 74–83.

84. Daentzer, D., Deinsberger, W. and Bo¨ker, D-K. 2003. Vertebral artery complications in anterior approaches to the cervical spine: report of two cases and review of literature. *Journal of Surgical Neurology*, 59: 300-9.

85. Daffner, R.H. 1996. Imaging of Vertebral Trauma. 2nd ed. Philadelphia: Lippincott-Raven. Pp. 143–98.

86. Daffner, R. H., Sciulli, R. L., Rodriguez, A. and Protetch, J. 2006. Imaging for evaluation of suspected cervical spine trauma: A 2-year analysis. *Injury Journal,* 37(7):652-658.

87. Daffner, S.D. and Daffner, R.H. 2002. Computed tomography diagnosis of facet dislocations: the “hamburger bun” and “reverse hamburger bun” signs. *The Journal of Emergency Medicine*, 23(4): 387–394.

88. Dankmeijer, J. and Rethmeier, B.J. 1943. The lateral movement in the atlanto-axial joints and its clinical significance. *Acta Radiologica,* 24: 55–66.

89. Darby, S.A. 2005. General anatomy of the spinal cord. In: Cramer, G.D. and Darby, S.A.(eds.) *Basic and clinical anatomy of the spine, spinal cord, and ANS*. USA: Elsevier Mosby.

90. Davenport, M., Mueller, J.B., Belaval, E. and Roy, S.P. 2008. Fracture, cervical spine. [online] Available from: http://www.emedicine.com/emerg/emergTRAUMA_AND_ORTHOPEDICS.htm [Accessed 08 September 2008].

91. Davis, J.W., Holbrook, T.L., Hoyt, D.B. Mackersie, R.C., Field, T.O. Jr. and Shackford, S.R. 1990. Blunt carotid artery dissection: incidence, associated injuries, screening, and treatment. *Journal of Trauma*, 30(12): 1514-7.

92. Davies, K. 1994. Pressure sores: aetiology, risk factors and assessment scales. *British Journal of Nursing,* 3: 256–262.

93. Davis, P.A., Corless, D.J., Gazzard, B.G. and Wastell, C. 1999. Increased risk of wound complications and poor healing following laparotomy in HIV-seropositive and AIDS patients. *Digestive Surgery* 16: 60-67.

94. Dean, N.A. and Mitchell, B.S. 2002. Anatomic relation between the nuchal ligament (ligamentum nuchae) and the spinal dura mater in the craniocervical region. *Clinical Anatomy*, 15: 182-185.

95. Deburge, A., Guigui, P., Ouahes, M. and Barre, E. 1996. Cervical pseudoarthrosis in ankylosing spondylitis. *Spine,* 21(23): 2801–2805.

96. Delgado-Rodriguez, M., Mariscal-Ortiz, M., Gomez-Ortega, M., Martinez-Gallego,G., Palma-Perez, S., Sillero-Arenas, M. and Medina-Cuadros, M. 2003. Alcohol consumption and the risk of nosocomial infection in general surgery. *British Journal of Surgery*, 90(10): 1287-1293.

97. Denis, F. 1983. The three column spine and its significance in the classification of acute thoracolumbar spinal injuries*. The Spine Journal,* 8: 817–831.

98. DePalma, A.F. and Rothman, R.H. 1970. *The Intervertebral Disc*. WB Saunders Company, Philadelphia.

99. Ditunno, J.F., Little, J.W., Tessler, A. and Burns, A.S. 2004. Spinal shock revisited: a four-phase model. *Spinal Cord*, 42(7): 383-395.

100. Dorland, W.A.N. 2007. Dorland's illustrated medical dictionary. 31st ed. Philadelphia: Saunders.

101. Djindjian, M., Ribeiro, A., Ortega, E., Gaston, A. and Poirier, J.1988. The normal vascularization of the intradural filum terminale in man. *Surgical and Radioogical Anatomy*, 10*:* 201-209.

102. Dunn, M.E. and Seljeskog, E.L. 1986. Experience in the management of odontoid process injuries: an analysis of 128 cases. *Journal of Neurosurgery,* 18**:** 306–310.

103. Dvorak, J., Froehlich, D., Penning, l., Baumgartner, H. and Panjabi, M.M. 1988. Functional radiographic diagnosis of the cervical spine: Flexion /extension. *The Spine Journal.* 13(7):748-755.

104. Dvorak, J. and Panjabi, M.M., 1987. Functional anatomy of the alar ligaments. *The Spine Journal,* 12: 183-189.

105. Edmondston, S.J., Henne, S-E, Loh, W. and Ostvold, E. 2005. Influence of cranio-cervical posture on three-dimensional motion of the cervical spine. *Journal of Manual Therapy,* 10(1): 44-51.

106. Effendi, B., Roy, D., Cornish, B., Dussault, R.G. and Laurin, C.A. 1981. Fractures of the ring of the axis: a classification based on analysis or 131 cases. *Journal of Bone and Joint Surgery – British volume,* 63B: 319–327.

107. Eismont, F. and Kitchel, S.H. 1994. Thoracolumbar spine. In Delee, J.C. and Drez, D. (ed.) *Orthopaedic sports medicine: principles and practice.* Philadelphia: W B Saunders Company.

108. Eliopoulos, D.A. and Lyle, G. 1999. Mycobacterium avium infection in a patient with the acquired immunodeficiency syndrome and silicone breast implants. *Southern Medical Journal*, 92: 80-83.

109. El Saghir, H. and Anderson, B.H. 2000.Type II fracture of the odontoid process: results of anterior screw fixation. *Journal of Spine Disorders,* 13: 527–530.

110. Enoka, R. 1988. *Neuromechanical basis of kinesiology*. Champaign IL: Human Kinetics Books.

111. Eriksen K. 2005. Long-standing axis odontoid fracture in patient presenting with acute low back pain. *Journal of Clinical Chiropractic*, 8(2):81-92.

112. Errico, T.J. 1993. Spinal fracture-dislocation. In Levenz, M.A. (ed.) *Spine: State of the art reviews.* Philadelphia: Hanley & Belfus, Inc.

113. Ersmark, H. and Kalen, R. 1987. Injuries of the atlas and axis. A follow-up study of 85 axis and 10 atlas fractures. *Journal of Clinical Orthopaedics and Related Research*, 217: 257-60.

114. Etter, C., Coscia, M., Jaberg, H. and Aebi, M. 1991. Direct anterior screw fixation of dens fractures with a cannulated screw system. *The Spine Journal,* 16 (Suppl 3): S25–S32.

115. Feipel, V., Rondelet, B., Le Pallec J-P. and Rooze, M. 1999. Normal global motion of the cervical spine an electrogoniometric study*. Journal of Clinical Biomechanics* 14: 462–470.

116. Ferrantelli, J.R., Harrison, D.E., Harrison, D.D. and Stewart, D. 2005. Conservative treatment of a patient with previously unresponsive whiplash-associated disorders using clinical biomechanics of posture rehabilitation methods. *Journal of Manipulative and Physiological Therapeutics*, 28(3): e1-e8.

117. Fernández-de-las-Peñas, C., Fernández-Carnero, J., Plaza-Fernández, A., Lomas-Vega, R. and Miangolarra-Page, J.C. 2004. Dorsal manipulation in whiplash injury treatment: a randomized controlled trial. *Journal of Whiplash Related Disorders,* 3: 55–72.

118. Fielding, J.W., Cochran, G.V.B. and Lawsing, J.F. III. 1974. Tears of the transverse ligament of the atlas: A clinical and biomechanical study. *Journal of Bone and Joint Surgery*. 56A. 1683-1691.

119. Fielding, J.W. and Hawkins, R.J., 1976. Roentenographic diagnosis of the injured neck. In American Academy of Orthopedic Surgeons Instructional Course Lectures.St.Louis, CV Mosby.

120. Finn, M., Fasset, D., Apfelbaum, R. Odontoid Screw Fixation. In Vaccaro, A.R., Baron, E.M. (eds.) *Operative Techniques: Spine Surgery*. Philadelphia: Elsevier. *(In press).*

121. FitzGerald, M.J.T., Gruener, G. and Mtui, E. 2007. 5th ed. *Clinical neuroanatomy and neuroscience.* Philadelphia: Saunders Elsevier.

122. Florescu, D. and Kotler, D.P. 2007. Insulin resistance, glucose intolerance and diabetes mellitus in HIV-infected patients. *Antiviral therapy*, 12(2): 149-162.

123. Flynn, T.B. 1982. Neurologic complications of anterior cervical interbody fusion. *The Spine Journal*, 7: 536–539.

124. Frankel, H.L., Hancock, D.O., Hyslop, G., Melzak, J., Michaelis, L.S., Ungar G.H., Vernon, J.D. and Walsh, J.J. 1962. The value of postural reduction in the initial management of closed injuries of the spine with paraplegia and tetraplegia. *Paraplegia,* 7(3): 179–192.

125. Friedman, D., Flanders, A., Thomas, C. and Millar, W. 1995. Vertebral artery injury after acute cervical spine trauma: rate of occurrence as detected by MR angiography and assessment of clinical consequences. *American Journal Roentgenology*, 164:443–7.

126. Forster, M.C., Saldanha, K., Rajan, R., Wilkinson, J.M. 2002. Case report: Segmental fracture of the dens. *Injury, International Journal of. Care of the Injured*, 33: 633-634.

127. Fountas, K., Kapsalaki, E., Nikolakakos, L., Machinis, T., Grigorian, A., Johnston, K., Robinson, J. Jr. and Smisson, H. III. 2006. P82. Long-term Outcome of Anterior Screw Stabilization for Surgical Management of Type II and Rostral Type III Acute Odontoid Fractures. *The Spine Journal*, 6(5) Supplement 1: 122S.

128. Fujii, E., Kobayashi, K. and Hirabayashi, K. 1988. Treatment in fractures of the odontoid process. *The Spine Journal*, 13:604–9.

129. Fukuyama, S., Nakamura, Ikeda, T. and Takagi, K.1995. The effect of mechanical stress on hypertrophy of the lumbar ligamentum flavum. *Journal of Spinal Disorders,* 8: 126–130.

130. Gal, J.M., Herzog, W., Kawchuk, G.N., Conway, P.J. and Zhang, Y. 1994. Biomechanical studies of spinal manipulative therapy (SMT): quantifying the movements of vertebral bodies during SMT. *Journal of the Canadian Chiropractic Association;* 38: 11-24.

131. Gallie, W.E. 1939. Fractures and dislocations of the upper cervical spine. *The American Journal of Surgery,* 46: 495–499.

132. Gardner, M.B., Holden, M.K., Leikauskas, J.M. and Richard, R.L. 1998. Partial body weight support with treadmill locomotion to improve gait after incomplete spinal cord injury: a single-subject experimental design. *Journal of Physical Therapy,* 78:361–374.

133. Gassman, J. and Seligson, D. 1983. The anterior cervical plate. *The Spine Journal*, 8: 700-707.

134. Gatterman, M.I. 2003. *Chiropractic Management of Spine Related Disorders.* Baltimore: Lippincott Williams & Wilkins.

135. Gatterman, M.I., Cooperstein, R., Lantz, C., Perle, S.M. and Schneider, M.J. 2001. Rating specific chiropractic technique procedures for common low back conditions. *Journal of Manipulative and Physiological Therapeutics;* 24(7): 449-456.

136. Gehweiler, J.A.Jr., Osborne, R.L. and Becker, R.F. 1980. Fractures of the atlas. In: *The radiology of vertebral trauma.* Philadelphia: WB Saunders Company. Pp. 147-158

137. Geisler, F.H., Cheng, C., Pokra, A. and Brumback, R.J. 1989. Anterior screw fixation of posteriorly displaced type II odontoid fractures. *Journal of Neurosurgery,* 25: 30–38.

138. Gerhart, T.N. and White, A.A. III. 1982. An impacted dens fracture in an elderly woman. *Journal of Clinical Orthopaedics*, 167:173-5.

139. Giacobetti, F.B., Vaccaro, A.R., Bos-Giacobetti, M.A., Deeley, D.M., Albert, T.J., Farmer, J.C. and Cotler, J.M. 1997. Vertebral artery occlusion associated with cervical spine trauma. A prospective analysis. *The Spine Journal*, 22(2):188–192.

140. Glickman, S. and Kamm, M.A. 1996. Bowel dysfunction in spinal cord injury patients. *The Lancet,* 347(9016): 1651-1653.

141. Goffart, Y., Lenelle, J., Moreau, P. and Boverie, J. 1991. Traction diverticulum of the hypopharynx following anterior cervical spine surgery. *Annals of Otology, Rhinology and Laryngology,* 100(10):852–855.

142. Goldberg, W., Mueller, C., Panacek, E., Tigges, S., Hoffman, J.R. and Mover, W.R. 2001.NEXUS Group. Distribution and patterns of blunt traumatic cervical spine injury. *Annals of Emergency Medicine*, 38(1):17—21.

143. Goodrich, J. A., Riddle, T. and Hu, S. 2008. Lower cervical spine fractures and dislocations. (online) Available from: http://www.emedicine.com/orthoped/spine.htm (Accessed August 2008).

144. Gore, D., Sepic, S. and Gardner, G. 1986. Roentgenographic findings of the cervical spine in asymptomatic people. *The Spine Journal*, 11:521–524.

145. Govender, S. 2007. Interviewed by N.Singh. University of KwaZulu Natal-Nelson Mandela School of Medicine, Durban, October 15.00.

146. Govender, S. and Grootboom, M. 1988. Fractures of the dens: The results of non-rigid immobilization. *Injury Journal*, 19:165–167.

147. Gowitzke, B. and Milner, M. 1988. *Scientific bases of human movement*, 3rd ed. Baltimore: Williams & Wilkins.

148. Graber, M. A. and Kathol, M. 1999. Cervical spine radiographs in the trauma patient. American Family Physician [online], 59(2). Available from: http://www.aafp.org/online/en/home/publications.html [Accessed August 2008].

149. Grauer, J.N., Shafi, B., Hilibrand, A.S., Harrop, J.S., Kwon, B.K., Beiner, J.M., Albert, T.J., Fehlings, M.G. and Vaccaro, A.R. 2005. Proposal of a modified, treatment-oriented classification of odontoid fractures. *The Spine Journal*, 5(2): 123-129.

150. Greene, K.A., Dickman, C.A., Marciano, F.F., Drabier, J.B., Hadley, M.N. and Sonntag, V.K. 1997. Acute axis fractures Analysis of management and outcome in 340 consecutive cases. *The Spine Journal*, 22**:** 1843–1852.

151. Greenstein, G. 1994. Functional anatomy and biomechanics of the cervical spine. In Curl, D. D. (ed.) *Chiropractic approach to head pain*. USA: Williams & Wilkins.

152. Griswold, D.M. and Albright, J.A. 1978. Atlanto-axial fusion for instability. *Journal of Bone and Joint Surgery,* 60-A: 285–92.

153. Guigui, P., Benoist, M. and Deburge, A. 1998. Spinal deformity and instability after multilevel cervical laminectomy for spondylotic myelopathy. *The Spine Journal,* 23(4): 440–447.

154. Hackl W., Hausberger K., Sailer R., Ulmer H. and Gassner R. 2001. Prevalence of cervical spine injuries in patients with facial trauma. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontics*, 92(4): 370-376.

155. Hadida, C. and Lemire, J.J. 1997. Missed upper cervical spine fracture: clinical and radiological considerations. *Journal of the Canadian Chiropractic Association,* 41: 77–85.

156. Hadley, M.N., Browner, C. and Sonntag, V.K. 1985. Axis fractures: a comprehensive review of management and treatment in 107 cases. *Journal of Neurosurgery,* 17: 281–290.

157. Hadley, M.N., Dickman, C.A., Browner, C.M. and Sonntag, V.K. 1989. Acute axis fractures: a review of 229 cases. *Journal of Neurosurgery,* 71: 642–647.

158. Haines, J.D. 1986. Occult cervical spine fractures: illustrative cases and x-ray guidelines. *Journal of Postgraduate Medicine,* 80:73–77.

159. Haku, T., Okuda, S., Kanematsu, F., Oda, T., Miyauchi, A., Yamamoto, T. and Iwasaki, M. 2008. Repair of cervical esophageal perforation using longus colli muscle flap: a case report of a patient with cervical spinal cord injury. *The Spine Journal*, *article in press.*

160. Hall, S.J. 1999. *Basic mechanics*. 3rd ed. Boston: McGraw-Hill.

161. Hanigan, W.C., Powell, F.C., Elwood, P.W. and Henderson, J.P.1993. Odontoid fractures in elderly patients. *Journal of Neurosurgery*, 78:32-35.

162. Harling, G., Ehrlich, R. and Myer, L. 2008. The social epidemiology of tuberculosis in South Africa: A multilevel analysis. *Social science & medicine*, 66(2): 492-505.

163. Harms, J. and Melcher, R.P. 2001. Posterior C1-2 fusion with polyaxial screw and rod fixation. *The Spine Journal*, 22: 2467–2471.

164. Harrison, D.E., Cailliet, R., Harrison, D.D. and Troyanovich, S.J. 1999. A review of biomechanics of the central nervous system—part II: spinal cord strains from postural loads. *Journal of Manipulative and Physiological Therapeutics,* 22:322–332.

165. Harrop, J.S., Vaccaro, A. and Przybylski, G.J. 2001. Acute respiratory compromise associated with flexed cervical traction after C2 fractures. *The Spine Journal,* 26: E50–E54.

166. Haus, B.M. and Harris, M.B. 2008. Case Report: Nonoperative Treatment of an Unstable Jefferson Fracture Using a Cervical Collar. *Journal of Clinical Orthopaedics and Related Research, Epub ahead of print.*

167. Haynes, M.J. and Edmondston, S. 2002. Accuracy and reliability of a new, protractor-based neck goniometer. *Journal of Manipulative and Physiological Therapeutics,* 25:579–86.

168. Heeneman, H. 1973. Vocal cord paralysis following approaches to the anterior cervical spine. *Laryngoscope,* 83: 17–21.

169. Henry, A.D. and Bohly, J. 1999. Fixation of odontoid fractures by an anterior screw. *Journal of Bone and Joint Surgery,* 81-B:472–7.

170. Herzog, W. 2000. The mechanical, neuromuscular and physiologic effects produced by the spinal manipulation. In Herzog, W. (ed.) *Clinical Biomechanics of Spinal Manipulation*. New York: Churchill Livingstone.

171. Herzog, W., Nigg, B.M. and Read, L.J. 1988. Quantifying the effects of spinal manipulations on gait using patients with low back pain. *Journal of Manipulative and Physiological Therapeutics;* 11(3):151-157.

172. Hirsch, C. and Nachemson, A. 1954. A new observation on the mechanical behavior of lumbar discs. *Acta Orthopaedica Scandinavica*, 23:254-83.

173. HIV/AIDS/STD Strategic Plan for South Africa [online]. 2000–2005. Available from: http://www.info.gov.za/otherdocs/2000/aidsplan2000.pdf [Accessed September 2008].

174. Hladky, J.P., Lejeune, J.P., Leclercq, F., Dhellemmes, P. and Christiaens, J.L. 1991. La dislocation occipito-atloidienne traumatique. *Journal de la Société de Neurochirurgie de Langue Française et de la Société Française de Neurochirurgie,* 37: 312–317.

175. Hole, D.E., Cook, J.M., and Bolton, J.E. 1995. Reliability and concurrent validity of two instruments for measuring cervical range of motion effects of age and gender. *Manual Therapy,* 1: 36–42.

176. Hollinshead, W. and Rosse, C. 1985. *Textbook of anatomy*, 4$^{th}$ edition. Philadelphia: Harper & Row.

177. Holly, L.T., Kelly, D.F., Counelis, G.J., Blinman, T., McAuthur, P.L., Cryer, H.G. 2002. Cervical spine trauma with moderate and severe head injury: incidence, risk factors, and injury characteristics. *Journal of Neurosurgery.* 96 (3Suppl): 285–91.

178. Holmes, A., Han, Z., Dang, G., Chen, Z., Wang, Z. and Fang, J. 1996. Changes in cervical canal spinal volume during in vitro flexion-extension. *The Spine Journal*, 21:1313–1319A.

179. Hong Cho, Ki., Yong Sam, S., Soo Han, Y., Se Hyuk, K., Young Hwan, A. and Kyung, G-C. 2005. Poor surgical technique in cervical plating leading to vertebral artery injury and brainstem infarction-case report. *Journal of Surgical Neurology,* 64(3): 221-225.

180. Hosoglu, S., Geyik, M.F., Balik, I., Aygen, B., Erol, S., Aygencel, S.G., Mert, A., Saltoglu, N., Dokmetas, I., Felek, S., Sunbul, M., Irmak, H., Aydin, K., Ayaz, C., Kokoglu, O.F., Ucmak, H., Satilmis, S. and Sumbul, M. 2003.Tuberculous meningitis in adults in Turkey: epidemiology, diagnosis, clinic and laboratory. *European Journal of Epidemiology,* 18: 337–343.

181. Houle, P., McDonnell, D.E. and Vender, J. 2001. Traumatic atlanto-occipital dislocation in children. *Journal of Pediatriatic Neurosurgery*, 34: 193–197.

182. Hsieh, C-T., Chiang, Y-H., Chiu, T-F., Sun, J-M. and Chang, C-F. A pitfall in neck pain: Occult odontoid fracture. *Journal of Emergency Medicine, article in press.*

183. Ianuzzi, A., Zambrano, I., Tataria, J., Ameerally, A., Agulnick.M., Goodwin, J.S.L., Stephen, M. and Khalsa, P.S. 2006. Biomechanical evaluation of surgical constructs for stabilization of cervical teardrop fractures. *The Spine Journal*, 6: 514-523.

184. Inamasu J., Hori S., Ohsuga F. and Aikawa N. 2001. Selective paralysis of the upper extremity after odontoid fracture: acute central cord syndrome of cruciate paralysis? *Clinical Neurology and Neurosurgery*, 103(4): 238-241.

185. Jaspers J. 1998. Whiplash and post-traumatic stress disorder. *Journal of Disability and Rehabilitation,* 20(11):397—404.

186. Jeanneret, B. and Mageral, F. 1992. Primary posterior fusion C1/2 in odontoid fractures: indications, technique, and results of transarticular screw fixation. *Journal of Spinal Disorders,* 5:464–475.

187. Jellis, J.E. 1988. Taking orthopaedics to the people. In: Watters, D.A.K. (ed.) Surgery in the Tropics. London: Bailli_ere Tindall. Bailli_ere's *Clinical Tropical Medicine and Communicable Diseases*, 3: 257-274.

188. Jenkins, J., Coric, D. and Branch, C. 1998. A clinical comparison of one and two screw odontoid fixation. *Journal of Neurosurgery,* 89: 366–370.

189. Johnson, R.M., Hart, D.L., Simmons, E.F., Ramsby, G.R. and Southwick, W.O. 1977. Cervical orthoses. A study comparing their effectiveness in restricting cervical motion in normal subjects. *Journal of Bone and Joint Surgery – American volume,* 59: 332-339.

190. Johnson, R.M., Owen, J.R., Hart, D.L. and Callahan, R.A. 1981. Cervical orthoses. A guide to their selection and use. *Journal of Clinical Orthopaedics*, 154: 34-45.

191. Johnston, J.J.E. and McGovern, S.J. 2004. Alcohol-related falls: an interesting pattern of injuries. *Emergency Medicine Journal*, 21: 185-188.

192. Jones, M., Pais, M. and Omiya, B. 1988. Bony overgrowths and abnormal calcifications about the spine. *Radiology Clinicals North America,* 26:1213–1234.

193. Julien, T.D., Frankel, B., Traynelis, V.C. and Ryken, T.C. 2000. Evidence-based analysis of odontoid fracture management. *Journal of Neurosurgical Focus*, 8:e1.

194. Jurkovich, G.J., Rivara, F.P., Gurney, J.G., Seguin, D., Fligner, C.L. and Copass, M. 1992. Effects of alcohol intoxication on the initial assessment of trauma patients. *Annals of Emergency Medicine,* 21:704—8.

195. Kaminski, A., Gstrein, A., Muhr, G. and Muller, E.J. 2008. Transarticular C1-C2 screw fixation: results of unstable odontoid fractures and pseudoarthrosis in the elderly. *Der Unfallchirurg*, *ahead of print.*

196. Kaplan, A., Orsetti, K.E. and Kuzon, W.M. Jr. 1996. Mycobacterium avium infection in a patient with acquired immunodeficiency syndrome and a solid silicone buttock implant. *Annals of Plastic Surgery,* 37: 411±414.

197. Kapoor, V.K. 2007. Abdominal tuberculosis. *Medicine*, 35(5): 257-260.

198. Kato, Y. and Itoh, T. 1998. Atlantoaxial dislocation. *Current Orthopaedics*, 12:20-27.

199. Kaya, R.A., Kilinc, B.M., Musluman, M., Turkmenoglu, O., Cavusoglu, H. and Aydin, Y. 2005. Selection of the surgical approach for stabilization of subaxial cervical spine injuries. *Turkish Neurosurgery,* 15(2): 76-86.

200. Kenter, K., Worley, G., Griffin, T. and Fitch, R.D. 2001. Pediatric traumatic atlanto-occipital dislocation: five cases and a review. *Journal of Pediatriatic Orthopaedics*, 21: 585–589.

201. Kessinger, R.C. and Boneva, D.V. 2000. Case study acceleration/deceleration injury with angular kyphosis. *Journal of Manipulative Physiological Therapeutics, 23*(4): 279–287.

202. Kim, D.H., Vaccaro, A.R., Affonso, J., Jenis, L., Hilibrand, A.S. and Albert, T.J. 2008. Early predictive value of supine and upright X-ray films of odontoid fractures treated with halo-vest immobilization. *Spine*, 8(4): 612-618.

203. Kim, M.J., Hwang, J.H., Sung, J.K., Hwang, S.K., Hamm, I.S., Park, Y.M. and Kim, S.L. 2000. Anterior screw fixation of type II odontoid fracture. *Journal of Korean Neurosurgery Society,* 29:1461–1468.

204. Kim, Y-S. and Yoon, D-H. 1997. Locked facet syndrome of the cervical spine. *Spine-spinal injury*, S170.

205. Kimberly, A., McCrea, K.A. and Ensor, J.E. 1994. Altered cytokine regulation in the lungs of cigarette smokers. *American Journal of Respiratory and Critical Care Medicine*, 150: 696-703.

206. King George V Hospital [online]. 2008. Available from: http://www.kznhealth.gov.za/kgv/history.htm [Accessed 20 September 2008].

207. King R. W. 2006. Osteomyelitis. [online] Available from: http://www.emedicine.com/emerg/INFECTIOUS_DISEASES.HTM [Accessed 23 August 2007].

208. Kirkpatrick, J.S., Sheils, T. and Theiss, S.M. 2004. Type-III dens fracture with distraction: an unstable injury A report of three cases. *Journal of Bone and Joint Surgery – American volume***,** 86-A: 2514–2518.

209. Kirshenbaum, K.J., Nadimpalli, S.R., Fantus, R. and Cavallino, R. P. 1990. Unsuspected upper cervical spine fractures associated with significant head trauma: Role of CT*. Journal of Emergency Medicine*, 8(2):183-198.

210. Koch, R.A. and Nickel, V.L. 1978. The halo vest: an evaluation of motion and forces across the neck. *The Spine Journal,* 3: 103-107.

211. Koivikko, M.P., Kiuru, M.J., Koskinen, S.K., Myllynen, P., Santavirta, S. and Kivisaari, L. 2004. Factors associated with nonunion in conservatively-treated type-II fractures of the odontoid process. *Journal of Bone and Joint Surgery - British volume,* 86 (8):1146–1151.

212.Kreipke, D.L., Gillespie, K., McCarthy, M.C., Mail, J.T., Lappas, J.C. and Boradie, T.A. 1989. Reliability of indications for cervical spine films in trauma. *Journal of Trauma,* 29:1438–1439.

213.Kricun, M.E. 1988. Conventional radiography. In: Kricun, M.E. (ed.) Imaging Modalities in Spinal Disorders. Philadelphia: WB Saunders Company.

214.Kumaresan, S., Yoganandan, N., Pintar F.A. and Maiman, D.J. 1999. Finite element modeling of the lower cervical spine: role of intervertebral disc under axial and eccentric loads. *Medical Engineering and Physics Journal,* 21:689–700.

215.Labbe, J.L., Leclair, O. and Duparc, B. 2001. Traumatic atlanto-occipital dislocation with survival in children. *Journal of Pediatric Orthopaedics,* Part B. 10: 319–327.

216.Lademarco, M.F. and Castro, K.G. 2003. Epidemiology of tuberculosis. *Seminar in Respiratory Infections Journal,* 18: 225–240.

217.Laidlaw, J. D., Kavar, B. and Siu, K.H. 2004. Acute atlanto-axial post-operative subluxation following posterior C1/C2 fusion. *Journal of Clinical Neuroscience,* 11(2):172-178.

218.Lakshmanan, P., Jones, A., Howes, J. and Lyons, K. 2005. CT evaluation of the pattern of odontoid fractures in the elderly-relationship to upper cervical spine osteoarthritis. *European Spine Journal* 14: 78–83.

219.Landells, C.D. and Peteghem, P.K.V. 1988. Fractures of the atlas: classification, treatment and morbidity. *The Spine Journal,* 13:450.

220.Later, P.R., Geer, B.M. and Pollack, M.L. 2005. Cervical Spine Fractures in the Elderly. *Annals of Emergency Medicine,* 46(3): S66.

221.Lazorthes, G., Gouaze, A., Zadeh, J.O., Santini, J.J., Lazorthes, Y. and Burdin, P. 1971. Arterial vascularization of the spinal cord. *Journal of Neurosurgery*, 35: 253-262.

222.Leclerc, X., Lucas, C., Godefroy, O., Nicol, L., Moretti, A., Leys, D. and Pruvo, J.P. 1999. Preliminary experience using contrast-enhanced MR angiography to assess vertebral artery structure for the follow-up of suspected dissection. *American Journal of Neuroradiology,* 20:1482–90.

223.Lee, M., Cassinelli, E. and Riew, K.D. 2006. The feasibility of inserting atlas lateral mass screws via the posterior arch. *The Spine Journal,* 6(5): 69S.

224.Lee, P.C., Chun, S.Y. and Leong, J.C.Y. 1984. Experience of posterior surgery in atlanto-axial instability. *The Spine Journal,* 9: 230–231.

225.Lee, S-H. and Sung, J-K. 2006. Anterior odontoid fixation using a 4.5-mm Herbert screw: the first report of 20 consecutive cases with odontoid fracture. *Surgical Neurology*, 66(4): 361-366.

226.Lehmkuhl, L.D. and Smith, L. 1983. *Brunnstrom's Clinical Kinesiology*. 4th ed. Philadelphia: Davis.

227.Lenoir, T., Hoffmann, E., Therenin-Lemoine, C., Lavelle, G., Rillardon, L. and Guigui P. 2006. Neurological and functional outcome after unstable cervicothoracic junction injury treated by posterior reduction and synthesis. *The Spine Journal*, 6(5): 507-513.

228.Levine, A.M. and Edwards, C.C., 1986. Treatment of injuries in the C1–C2 complex. *Orthopedic Clinic of North America,* 17: 31–44.

229.Licina, P. and Nowitzke, A.M. 2005. Approach and considerations regarding the patient with spinal injury. *Injury, Int.J.Care Injured* 36: S-B2-S-B12.

230.Lin, J.T., Lee, J.L. and Lee, S.T. 2003. Evaluation of occult cervical spine fractures on radiographs and CT. *Emergency Radiology*, 10: 128-134.

231.Lin, P.H., Bush, R.L., Yao, Q., Lam, R., Paladugu, R., Zhou, W., Chen, C. and Lumsden, A.B. 2004. Abdominal aortic surgery in patients with human immunodeficiency virus infection. *The American Journal of Surgery*, 188(6): 690-697.

232.Lind, B., Bake, B., Lundqvist, C. and Nordwall, A. 1987. Influence of halo vest treatment on vital capacity. *The Spine Journal,* 12:449-451.

233. Lindgren, M., Unosson, M. and Ek, A.C. 2002. Pressure sore prevalence within a public health services area. *International Journal of Nursing Practice,* 6: 333–337.

234. Littlewood, K.E. 2008. The immunocompromised adult patient and surgery. *Best Practice & Research Clinical Anaesthesiology,* 22(3): 585-609.

235. Liu, Y.K. and Dai, Q.G. 1989. The second stiffest axis of beam-column implications for cervical spine trauma. *Journal of Biomechanical Engineering,* 111:122–127.

236. Loembe, P.M., Bouger, D. and Dukuly, L. 1988. Traumatismes du rachis cervical: revue de 70 cas traites sur une periode de cinq ans a la Fondation Jeanne Ebori, Libreville, Gabon (Afrique Centrale). Journal *de la Société de Neurochirurgie de Langue Française et de la Société Française de Neurochirurgie*, 34:258-61.

237. Lomoschitz, F.M., Blackmore, C.C., Mirza, S.K. and Mann, F.A. 2002. Cervical Spine Injuries in Patients 65 Years Old and Older: Epidemiologic Analysis Regarding the Effects of Age and Injury Mechanism on Distribution, Type, and Stability of Injuries. *American Journal of Roentgenology,* 178: 573-577.

238. Lu, K., Lee, T.C. and Chen, H.J. 1998. Closed reduction of bilateral locked facets of the cervical spine under general anaesthesia. *Acta neurochirurgie (Wien)*, 140: 1055-61.

239. Lysell. 1969. Motion in the cervical spine: an experimental study on autopsy specimens. *Acta Orthopaedica Scandanavica, Suppl* 123: 41–61.

240. Maak, T.G. and Grauer, J.N. 2006. The contemporary treatment of odontoid injuries. *The Spine Journal,* 31(11 suppl):S53–60; discussion S61.

241. Mace, S.E. 1985. Emergency evaluation of cervical spine injuries: CT versus plain radiographs. *Annals of Emergency Medicine,* 14**:** 973–975.

242. Macnab, I. 1975. Cervical spondylosis. *Clinical Orthopaedics* 109:69-77.

243. Maiman, D.J. 1997. Management of hangman’s fracture. *Surgical Neurology*, 47: 326-7.

244. Maiman, D.J., Barolat, G. and Larson, S.J. 1986. Management of bilateral locked facets of the cervical spine. *Journal of Neurosurgery*, 18: 542-7.

245. Maiman, D. J. and Cusick, J. F. 1982. Traumatic atlantoaxial dislocation. *Surgical Neurology*, 18(5):388-392.

246. Maiman, D.J., Sances, A., Myklebust, J.B., Larson, S.J., Houterman, C., Chilbert, M. and Ghatit, E.I. 1983. Compression injuries of the cervical spine: A biomechanical analysis. *Journal of Neurosurgery* 13: 254–260.

247. Maiman, D.J., Yoganandan, N. and Printar, F.A. 2002. Preinjury cervical alignment affecting spinal trauma. *Journal of Neurosurgery*, 97: 57–62.

248. Malca, S., Valenzuela, S., Pellet, W. and Combalbert, A. 1991. Le vissage de l'odontoı¨de: une intervention fonctionnelle. *Journal de la Société de Neurochirurgie de Langue Française et de la Société Française de Neurochirurgie*, 37:273–7.

249. Maldonado, V.C. 1997. Management of hangman's fracture. *Surgical neurology*, 47: 326-7.

250. Malik, S.A., Murphy, M., Connolly, P. and O'Byrne, J. 2008. Evaluation of morbidity, mortality and outcome following cervical spine injuries in elderly patients. *European Spine Journal*, *epub ahead of print.*

251. Mascalchi, M., Bianchi, M.C., Mangiagico, S., Ferrito, G., Puglioli, M., Marin, E., Mugnai, S., Canapicchi, R., Quilici, N. and Inzitari, D. 1997. MRI and MR angiography of vertebral artery dissection. *Journal of Neuroradiology*, 39(5):329–40.

252. Mattson, R.H. and Gidal, B.E. 2004. Fractures, epilepsy, and antiepileptic drugs. *Epilepsy and Behavior,* 5(2): S36-S40.

253. McGraw, R.W. and Rusch, R.M. 1973. Atlanto-axial arthrodesis. *Journal of Bone and Joint Surgery,* 55-B: 482–8.

254. Mendel, T., Wink, C.S. and Zimny, M. L. 1992. Neural elements in human cervical intervertebral discs. *The Spine Journal*, 17(2): 132-135.

255. Merritt, R. M. and Williams, M. F. 1997. Cervical spine injury complicating facial trauma: Incidence and management. *American Journal of Otolaryngology*, 18(4):235-238.

256. Meyer, P.A. Jr., Rosen, J.S., Hamilton, B.B. and Hall, W.J. 1976. Fracture-dislocation of the cervical spine: Trnsportation, assessment, and immediate management. In *American Academy of Orthopaedic Surgeons Instructional Course Lectures*. St Louis, CV Mosby.

257. Meyer, P-G., Meyer, F., Orliaguet, G., Blanot, S., Renier, D. and Carli, P. 2005. Combined high cervical spine and brain stem injuries: a complex and devastating injury in children. *Journal of Pediatric Surgery*, 40(10): 1637-1642.

258. Middleditch, A. and Oliver, J. 2005. *Functional anatomy of the spine*. 2nd ed. USA: Elsevier Butterworth Heinemann.

259. Mikawa, Y., Shikata, J. and Yamamuro, T. 1987. Spinal deformity and instability after multilevel cervical laminectomy. *The Spine Journal*, 12: 6–11.

260. Milne, N. 1993. Composite motion in the cervical disc segments. *Journal of Clinical Biomechanics,* 8:193–202.

261. Mimura, M., Moriya, H., Watanabe, T., Takahashi, K., Yamagata, M., Tamaki, T. 1989. Three-dimensional motion analysis of the cervical spine with special reference to the axial rotation. *The Spine Journal,* 14: 1135-1139.

262. Min, W-K., Sung, J-K., Jeon, I-H., Oh, C-W., Kim, S-Y. and Park, B-C. 2006. Anterior Screw Fixation in Type II Odontoid Fractures: Is it a Reliable Method in the Elderly? *The Spine Journal*, 6: 1S-161S.

263. Mirza, S.K., Krengel, W.F. III., Chapman, J.R., Anderson, P.A., Bailey, J.C., Grady, M.S and Yuan, H.A.. 1999. Early versus delayed surgery for acute cervical spinal cord injury. *Journal of Clinical Orthopaedics,* 104-114.

264. Montesano, P.X., Anderson, P.A. and Schlehr, F., Thalgott, J.S., Lowrey, G. 1991. Odontoid fractures treated by odontoid anterior screw fixation. *The Spine Journal,* 16: 33–37.

265. Moore, K. L. and Dalley, A. F. 1999. *Clinically Oriented Anatomy*. USA: Lippincott Williams & Wilkins.

266. Morandi, E., Merlini, D., Salvaggio, A., Foschi, D. and Trabucchi, E. 1999b. Prospective study of healing time after hemorrhoidectomy: influence of HIV infection, acquired

immunodeficiency syndrome, and anal wound infection. *Diseases of the Colon and Rectum*, 42:1140-1144.

267. Morandi, X., Hanna, A., Hamlat, A. and Brassier, G. 1999a. Anterior Screw Fixation of Odontoid Fractures. *Surgical Neurology*, 51: 236-40.

268. Moroney, S.P., Schultz, A.B., Miller, J.A. and Andersson, G.B. 1988. Load-displacement properties of lower cervical spine motion segments. *Journal of Biomechanics,* 21 (9): 769–779.

269. Morse, S.D. 1982. Acute central cervical spine cord syndrome. *Annals of Emergency Medicine*, 11:436-439.

270. Moskovich, R. 2001. Biomechanics of the cervical spine. In Nordin, M. and Frankel, V.H. (eds.) *Basic biomechanics of the musculoskeletal system*. USA: Lippincott Williams & Wilkins.

271. Mow, V.C. and Hayes, W.C. 1991. *Basic orthopaedic biomechanics*. New York: Raven Press.

272. Muir, G.D. and Steeves, J.D. 1997. Sensorimotor stimulation to improve locomotor recovery after spinal cord injury. *Trends in Neurosciences*, 20(2): 72-77.

273. Munro, D.S. 1990. Missed C1 posterior arch fracture: a case report. *Journal of the Canadian Chiropractic Association,* 34: 27–29.

274. Muzumdar, D.P., Deopujari, C.E. and Bhojraj, S.Y. 2000. Bilateral vocal cord paralysis after anterior cervical discoidectomy and fusion in a case of whiplash cervical spine injury: a case report. *Surgical Neurology*, 53(6): 586-588.

275. Myklebust, J.B., Pintar, F.A., Yoganandan, N., Cusick, J.F., Maiman, D.J., Myers, T. and Sances, A. Jr. 1988. Tensile strength of spinal ligaments. *The Spine Journal.* 13:526–31.

276. Nachemson, A. and Evans, J. 1968. Some mechanical properties of the third lumbar inter-laminar ligament and ligamentum flavum. *Journal of Biomechanics,* 1: 211–217.

277. Nagashima, H., Morio, Y., Hasegawa, K. and Teshima, R. 2001. Case report: Odontoid fractures complicated by fractures of the posterior arch of the atlas in the elderly over 85 years with severe thoracic kyphosis secondary to osteoporosis. *Injury Journal,* 32(6): 501-504.

278. Naidoo, N.D. 2007. Interviewed by N.Singh. King George V Hospital, Durban, August 2007.

279. Nair, R., Robbs, J.V., Naidoo, N.G. and Woolgar, J. 2000. Clinical profile of HIV-related aneurysms. *European Journal of Vascular and Endovascular Surgery*, 20: 235-240.

280. Netterville, J.L., Koriwchak, M.J., Winkle, M., Courey, M.S. and Ossoff, R.H. 1996. Vocal cord paralysis following the anterior approach to the cervical spine. *Annals of Otology, Rhinology and Laryngology,* 105 (2): 85–91.

281. Nickel, V.L., Perry, J., Garrett, A. and Heppenstall, M. 1968. The halo: A spinal skeletal traction fixation device. *Journal of Bone and Joint Surgery – American volume,* 50: 1400-1409.

282. Nielsen, O.J. and Edal, A.L. 2001. Anterior screw fixation of fractures of the dens axis. *Ugeskr Laeger,* 163:2140–3.

283. Noreau, L. and Shephard, R.J. 1995. Spinal cord injury, exercise and quality of life. *Journal of Sports Medicine,* 20(4): 226-50.

284. Norton, D., McLaren, R. and Exton-Smith, A.N. 1979. *An Investigation of Geriatric Problems in Hospital.* 3rd ed. Churchill Livingstone: London.

285. Novicky, S.D. 2003. Chiropractic/rehabilitative management of chronic headaches: A retrospective case report. *Journal of Chiropractic Medicine*, 2(3): 96-101.

286. Noyes, F.R., DeLucas, J.L. and Torvik, P.J. 1974. Biomechanics of the anterior cruciate ligament failure: an analysis of strain-rate sensitivity and mechanisms of failure in primates. *Journal of Bone and Joint Surgery.* 56A: 236.

287. Nykoliation, J.W., Cassidy, J.D., Dupuis, P., Yoing-Hing, K. and Crnec, M. 1986. Missed cervical spine fracture-dislocations prior to manipulation: a review of three cases. *Journal of the Canadian Chiropractic Association,* 30: 69–75.

288. Ochoa G. 2005. Surgical management of odontoid fractures*. Injury Journal*, 36(2):S54-S64.

289. Ogawa, K., Hirai, M., Katsube, T., Murayama, M., Hamaguchi, K., Shimakawa, T., Maritake, Y., Hosokawa, T. and Kajiwara, T. 2000. Suppression of cellular immunity by surgical stress. *Surgery*, 127: 329–336.

290. Oller, D.W., Meredith, J.W., Rutledge, R., Thomason, M., Clancy, T., Moylan, J. and Foil, B. 1992. The relationship between face or skull fractures and cervical spine and spinal cord injuries: A review of 13. 834 patients. *Accident Analysis and Prevention*, 24(2):187-192.

291. Pack, A.M. and Morrell, M.J. 2001. Adverse effects of antiepileptic drugs on bone structure: epidemiology, mechanisms, and therapeutic implications. *CNS Drugs,* 15: 633–642.

292. Palastanga, N., Field, D. and Soames, R. 2000. *Anatomy and Human Movement Structure and Function.* 3rd ed. Oxford: Butterworth Heinemann.

293. Panjabi, M.M., Kraig, M.H., and Goel, V.K. 1981. A technique for measurement and description of three-dimensional six degree-of-freedom motion of a body joint with and application to the human spine. *Journal of Biomechanics*, 14. 447-460.

294. Panjabi, M.M. and White, A.A. 1978. Physical properties and functional biomechanics of the spine. In White, A.A. and Panjabi, M.M. (eds.) *Clinical Biomechanics of the Spine*. Philadelphia: JB Lippincottt.

295. Papadopoulos, S.M., Selden, N.R., Quint, D.J., Patel, N., Gillespie, B. and Gruber, S. 2002. Immediate spinal cord decompression for cervical spinal cord injury: feasibility and outcome. *Journal of Trauma,* 52(2): 323-332.

296. Parbhoo, A.H., Govender, S. and Corr, P. 2001. Vertebral artery injury in cervical spine trauma*. Injury Journal,* 32:565–8.

297. Parke, W.W. and Sherk, H.H. 1989. In: Sherk, H.H. (ed.) *The cervical spine: The Cervical Spine Research Society Editorial Committee.* Philadelphia: J B Lippincott Company.

298. Pasciak, M. and Doniec, J.1993. Results of conservative treatment of unilateral cervical spine dislocations. *Archives of Orthopaedic and Trauma Surgery*, 112: 226-227.

299. Patel, C.K., Truumees, E., Fischgrund, J.S. and Herkowitz, H.N. 2002. Evaluation and Treatment of Thoracolumbar Junction Trauma. *University of Pennsylvania Orthopaedic Journal*, 15: 7-12.

300. Pathria, M. 1995. Physical injury: spine. In: Resnick, D. (ed.) *Diagnosis of Bone and Joint Disorders.* 3rd ed. Philadelphia: WB Saunders Company.

301. Patton, M.S. and Renshaw, P.R. 2006. Solitary isolated lateral mass fracture of the atlas. *Journal of Injury*, 37(7):663-664.

302. Paungmali, A., O'Leary, S., Souvlis, T. and Vicenzino, B. 2003. Hypoalgesic and sympathoexcitatory effects of mobilization with movement for lateral epicondylalgia. *Journal of Physical Therapy,* 83: 374–383.

303. Payer, M. and Tessitore, E. 2007. Delayed surgical management of a traumatic bilateral cervical facet dislocation by anterior-posterior-anterior approach. *Journal of Clinical Neuroscience*, 14: 782-786.

304. Payer, M., Wetzel, S., Kelekis, A. and Jenny, B. 2005. Traumatic vertical atlantoaxial dislocation. *Journal of Clinical Neuroscience*, 12(6): 704-706.

305. Peebles, J., McWilliams, L. and MacLennan, R. 2001. A comparison of symptom checklist 90-revised profiles from patients with chronic pain from whiplash and patients with other musculoskeletal injuries. *The Spine Journal*, 26:766—70.

306. Penning, L. and Wilmink, J.T. 1987. Rotation of the cervical spine. A CT study in normal subjects. The *Spine Journal,* 12: 732–738.

307. Pepin, J.W., Bourne, R.B. and Hawkins, R.J. 1985. Odontoid fractures with special reference to the elderly patient. *Journal of Clinical Orthopaedics and Related Research*, 178–183.

308. Perri, B., Siddique, K., Baron, E.M. and Lauryssen, C. 2007. Acute Odontoid Fractures: Anterior Odontoid Fixation. *Operative Techniques in Orthopaedics*, 17(3): 163-168.

309. Perry, J. and Nickel, V.L. 1959. Total cervical-spine fusion for neck paralysis. *Journal of Bone and Joint Surgery – American volume,* 41: 37-60.

310. Perry, M.O., Synder, W.H. and Thal, E.R. 1980. Carotid artery injuries caused by blunt trauma. *Annals Surgery*, 192(1): 74-7.

311. Pintar, F.A., Yoganandan, N., Pesigan, M., Reinartz, J.M., Sances, A. Jr. and Cusick, J.F. 1995. Cervical vertebral strain measurements under axial and eccentric loading. *Journal of Biomechanical Engineering*. 117:474–8.

312. Plezbert, J.A. and Oestreich, A.T. 1994. Fracture of a lamina in the cervical spine. *Journal of Manipulative and Physiological Therapeutics,* 17:552–557.

313. Polin, R.S., Szabo, T., Bogner, C.A., Replogle, R.F. and Jore, J.A. 1996. Nonoperative management of Types II and III odontoid fractures: the Philadelphia collar versus the halo-vest. *Journal of Neurosurgery* 38: 450–457.

314. Polston, D.W. 2007. Cervical radiculopathy. *Neurology and Clinical Neurophysiology*, 25(2): 373-85.

315. Portnoy, H.J., McElhaney, J.H., Melvin, J. and Croissant, P.D. 1972. Mechanism of cervical spine injury in auto accidents. *Proceedings of 15th Annual Conference of the Association for the Advancement of Automotive Medicine*, 58.

316. Prasad, P., King, A.I. and Ewing, C.L. 1974. The role of articular facets during +Gx acceleration. *Journal of Applied Mechanics,* 41:321.

317. Preutu, G.M. 1999. Case analysis-Diagnostic and therapeutic issues in a case of multiple Clay Shoveler's fracture with associated thoracic wedge compression fractures. *The British Journal of Chiropractic*, 3(2):31-35.

318. Pringle, R.G. 1974. Fracture of the dens (odontoid process) of the axis. *Journal of Bone and Joint Surgery – British volume,*; 56:200-1.

319. Przybylski, G.J., Clyde, B., Fitz, C., Mitchell, W., Lemke, D. and Daniels, D. 2002. Atlanto-occipital dislocation: diagnosis and management in 30 patients. *The Spine Journal,* 2: 3S-44.

320. Punwar, A.J. 2000. Defining occupational therapy. In Punwar, A.J. and Peloquin, S.M. (eds.) Occupational therapy: Principles and Practice. Philadelphia: Lippincott Williams & Wilkins.

321. Radanov, B., Bicik, I., Dvorak, J., Antinnes, J., Schulthess, G. and Buck, A. 1999. Relationship between neuropsychological and neuroimaging findings in patients with late whiplash syndrome. *Journal of Neurology, Neurosurgery and Psychiatry,* 66:485—9.

322. Ramani, P.S. 2004. *Textbook of Cervical Spondylosis.* New Dehli: Jaypee Brothers Medical Publishers.

323. Razack, N., Green, B.A. and Levi, A.D. 2000. The management of traumatic cervical bilateral facet fracture-dislocations with unicortical anterior plates. *Journal of Spinal Disorders*, 13: 374-81.

324. Reitman C.A. and Esses S.I. 1995. Modalities, Manual therapy, and Education: A review of conservative measures. In Young M.A. and Lavin R.A. (ed.) *Spine: State of the art reviews*. Philadelphia: Hanley & Belfus.

325. Richman, J. D. 1998. Odontoid screw fixation for type II odontoid fractures. *Operative Techniques in Orthopaedics*, 8(1):16-21.

326. Riley, L.H. Jr., Robinson, R.A., Johnson, K.A. and Walker, A.E. 1969. The results of anterior interbody fusion of the cervical spine. Review of ninety-three consecutive cases. *Journal of Neurosurgery,* 30 (2): 127–133.

327. Ripa, D.R., Kowall, M.G., Meyer, P.R. Jr. and Rusin, J.J. 1991. Series of ninety-two traumatic cervical spine injuries stabilized with the anterIor ASIF plate fusion techniques. *The Spine Journal,* 16 (suppl 3): 46-53.

328. Rogers, W.A. 1942. Treatment of fracture-dislocation of the cervical spine. *Journal of Bone and Joint Surgery***,** 24**:** 245.

329. Rogers, W.A. 1957. Fractures and dislocations of the cervical spine. *Journal of Bone and Joint Surgery,* 39: 341-376.

330. Rommel, O., Niedeggen, A., Tegenthoff, M., Kiwitt, P., Botel, U. and Malin, J-P. 1999. Carotid and vertebral artery injury following severe head or cervical spine injury. *Cerebrovascular Disease*, 9:202–9.

331. Rorabeck, C.H., Rock, M.G., Hawkins, R.J. and Bourne, R.B. 1987. Unilateral facet dislocation of the cervical spine. *The Spine Journal*, 12: 23-27.

332. Rosenfeld, J.F., Vaccaro, A.R., Albert, T.J., Klein, G.R., Cotler, J.M. 1998. The benefits of early decompression in cervical spinal cord injury. *American Journal of Orthopedics,* 27(1): 23-28.

333. Rowell R. M. 2006. A case report of a unstable cervical spine fracture: Parallels to the thoracolumbar Chance-type fracture. *Journal of Manipulative and Physiological Therapeutics*, 29(7):586-589.

334. Rubin, M. and Safdieh, J. E. 2007. *Netter's Concise Neuroanatomy*. Philadelphia: Saunders Elsevier.

335. Ryan, M.D. and Henderson, J. 1992.The epidemiology of fractures and fracture-dislocations of the cervical spine. *Injury Journal*, 23: 38–40.

336. Ryan, M.D. and Taylor, T.K.F. 1993. Odontoid fractures in the elderly. *Journal of Spinal Disorders***,** 6: 397-401.

337.Saboe, L.A., Reid, D.C., Davis, L.A., Warren, S.A. and Grace, M.G. 1991. Spine trauma and associated injuries. *Journal of Trauma,* 31(1): 43-48.

338.Schatzker, J. and Rorabeck, C.H. 1971. Fractures of the dens. an analysis of thirty-seven cases. *Journal of Bone and Joint Surgery*, 53-B: 392–404.

339.Schmand, B., Lindeboom, J., Schagen, S., Heijt, R., Koene, T. and Hamburger, H. 1998. Cognitive complaints in patients after whiplash injury: the impact of malingering. *Journal of Neurology, Neurosurgery and Psychiatry,* 64:339—343.

340.Schultz, A.B. and Ashton-Miller, J.A. 1991. Biomechanics of the human spine. In Mow, C.V. and Hayes, W.C. (eds.) *Basic orthopaedic biomechanics*. New York: Raven Press.

341.Schweigel, J.F. 1987. Management of the fractured odontoid with halo thoracic bracing. *The Spine Journal*; 12:838–839.

342.Shaha, A.R., Johnson, R., Miller, J. and Milhorat, T. 1993. Transoral-transpharyngeal approach to the upper cervical vertebra. *American Journal of Surgery*, 166(4): 336-340.

343.Shaik, J. 2008. Interviewed by Natasha Singh. Durban University of Technology, 2 September 2008, 13.00.

344.Shakhar, K., Ben-Eliyahu, S., Loewenthal, R., Rosenne, E. and Carp, H. 2003. Differences in number and activity of peripheral natural killer cells in primary versus secondary recurrent miscarriage. *Journal of Fertility and Sterility*, 80(2): 368–375.

345.Sharma, R. R., Sethu, A. U., Lad, S. D., Turel, K. E. and Pawar, S. J. 2001. Pharyngeal perforation and spontaneous extrusion of the cervical graft with its fixation device: A late complication of C2-C3 fusion via anterior approach. *Journal of Clinical Neuroscience*, 8(5): 464-468.

346.Sherk, H.H. and Nicholson, J.T. 1970. Fractures of the atlas. *Journal of Bone and Joint Surgery - American volume*, 52A:1017-24.

347. Shimaoka, M., Hosotsubo, K., Sugimoto, M., Sakaue, G., Taenaka, N., Yoshiya, I. and Kiyono, H. 1998. The influence of surgical stress on T cells: enhancement of early phase lymphocyte activation. *Journal of Anesthesia and Analgesia,* 87: 1431–1435.

348. Signoret, F., Feron, J.M., Bonfait, H. and Patel, A. 1986. Fractured odontoid with fractured superior articular process of the axis. Report of three cases. *Journal of Bone and Joint Surgery – British volume,* 68:182–4.

349. Singh, B., Balwally, A.N., Har-el, G. and Lucente, F.E. 1998. Isolated cervical tuberculosis in patients with HIV infection. *Otolaryngology-head and neck surgery*, 118(6): 766-770.

350. Skendros, P., Kamaria, F., Kontopoulos, V., Tsitouridis, I. and Sidiropoulos, L. 2003. Intradural, extramedullary tuberculoma of the spinal cord as a complication of tuberculous meningitis. *Infection,* 31: 115–117.

351. Skyba, D.A., Radhakrishnan, R., Rohlwing, J.J., Wright, A. and Sluka, K.A. 2003. Joint manipulation reduces hyperalgesia by activation of monoamine receptors but not opioid or GABA receptors in the spinal cord. *Journal of Pain* 106: 159–168.

352. Smith, G.W. and Robinson, R.A. 1955. Anterolateral cervical disc removal and interbody fusion for cervical disc syndrome. *Bull John Hopkins Hospital***,** 96: 223.

353. Smith, L.N., Booth, N., Douglas, D., Robertson, W.R., Walker, A., Durie, M., Fraser, A., Hillan, E.H. and Swaffield, J. 1995. A critique of 'at risk' pressure sore assessment tools. *Journal of Clinical Nursing,* 4: 153–159.

354. Snell, R.S. 1997. Clinical neuroanatomy for medical students.4$^{th}$ ed. Philadelphia: Lippincott-Raven.

355. Song, K-J. and Lee, K-B. 2008. Anterior versus combined anterior and posterior fixation/fusion in the treatment of distraction-flexion injury in the lower cervical spine. *Journal of Clinical Neuroscience*, 15:36-42.

356. Song, K-J., Lee, K-B. and Kim, K-N. 2007. Treatment of odontoid fractures with single anterior screw fixation. *Journal of Clinical Neuroscience*, 14: 824-830.

357.Sonntag, V.K. 1981. Management of bilateral locked facets of the cervical spine. *Journal of Neurosurgery,* 8: 150-2.

358.Sonntag, V.K.H. and Dickman, C.A. 1992. Craniocervical stabilisation. *Clinical Neurosurgery, Proceedings of the congress of Neurological Surgeons*. Baltimore: Williams & Wilkins.

359.Sonntag, V.K.H. and Hadley, M.N. 1986. Nonoperative management of cervical spine injuries. *Journal of Clinical Neurosurgery*, 34:630-49.

360.Sood, S., Henein, R.R. and Girgis, B. 1998. Pharyngeal pouch following anterior cervical fusion. *Journal of Laryngology and Otology,* 112: 1085–1086.

361.South African Government Information: The land and its people [online]. 2008. Available from: http://www.info.gov.za/aboutsa/landpeople.htm#KZN (Accessed September 2008).

362.South African Government Information: The land and its people [online]. 2008. Available from: http://www.statssa.gov.za/publications/P0302/P03022007.pdf (Accessed September 2008).

363.Sowthwick, W.O. 1980. Management of fractures of the dens, odontoid process. *Journal of Bone and Joint Surgery*, 62-A: 482–6.

364.Standring, S. (ed.) 2005. *Gray's anatomy*. 39th ed. Spain: Elsevier Churchill Livingstone.

365.Stauffer, E.S. 1986. Management of spine fractures C-3 to C-7. *Orthopedic Clinics of North America,* 17: 45–53.

366.Stemper, B.D., Yoganandan, N. and Pintar, F.A. 2005. Effects of abnormal posture on capsular ligament elongations in a computational model subjected to whiplash loading. *Journal of Biomechanics*, 38: 1313-1323.

367.Subach, B.R. and Haid, R.W. 2000. Management of acute odontoid fractures with single-screw anterior fixation. *Neurosurgery,* 47: 794.

368. Subach, B.R. Morone, M.A., Haid, R.W., McLaughlin, M.R., Rodts, G.R. and Comey, C.H. 1999. Management of acute odontoid fractures with single-screw anterior fixation. *Journal of Neurosurgery,* 45: 812–920.

369. Sue, D.E. and Brant-Zawadzki, M.N., 1992. Chance J. Dissection of cranial arteries in the neck: correlation of MRI and arteriography. *Journal of Neuroradiology,* 34:273–8.

370. Szeto, G., Straker, L. and Raine, S. 2002. A field comparison of neck and shoulder postures in symptomatic and asymptomatic office workers. *Journal of Applied Ergonomics* 33: 75-84.

371. Tanriverdi, T., Kizilkilic, O., Hanci, M., Kaynar, M.Y., Unalan, H. and Oz, B. 2003. Atypical intradural spinal tuberculosis: report of three cases. *Spinal Cord,* 41: 403-409.

372. Tashjian, R.Z., Majercik, S., Biffl, W.L., Palumbo, M.A. and Cioffi, W.G. 2006. Halo-vest immobilization increases early morbidity and mortality in elderly odontoid fractures. *Journal of Trauma,* 60:199–203.

373. Teo, E.C. and Ng, H.W. 2001. First cervical vertebra (atlas) fracture mechanism studies using finite element model. *Journal of Biomechanics*, 34(1):13-21.

374. Thompson, W., Lande, R.G. and Kalapatapu, R.K. 2008. Alcoholism. [online] Available from: http://www.emedicine.com/med/psychAddiction.htm [Accessed September 2008].

375. Timothy, J., Towns, G. and Girn, H.S. 2004. Cervical spine injuries. *Journal of Current Orthopaedics*, 18(1): 1-16.

376. Tran, H.S., Moncure, M., Tarnoff, M., Goodman, M., Puc, M.M., Kroon, D., Brathwaite, C.E.M., Eydelman, J. and Ross, S.E. 2000. Predictors of operative outcome in patients with human immunodeficiency virus infection and acquired immunodeficiency syndrome. *The American Journal of Surgery*, 180: 228-233.

377. Trott, P.H., Pearcy, M.J., Ruston, S.A., Fulton, I. and Brien, C. 1996. Three-dimensional analysis of active cervical motion the effect of age and gender. *Journal of Clinical Biomechanics,* 11: 201–206.

378. Troyanovich, S. 1994. C1 burst fracture. *Journal of Manipulative and Physiological Therapeutics,* 17:558–561.

379. Tuberculosis Strategic Plan for South Africa 2007 – 2011. 2008 [online]. Available from: http://www.info.gov.za/gazette/otherdocs/2007/tbst [Accessed 02 September 2008].

380. Cervical traction. 2008. South Africa: University of Stellenbosch, Department of Orthopaedics.

381. Unosson, M., Ek, A.C., Bjurulf, P., Von Schenk, H. and Larsson J. 1995 Influence of macronutrient status on recovery after hip fracture. *Journal of Nutritional and Environmental Medicine,* 5: 23–34.

382. Vaccaro, A.R., Madigan, L. and Ehrler, D.M. 2000. Contemporary management of adult cervical odontoid fractures. *Orthopedics,* 23:1109–1113.

383. Vaccaro, A.R. and Silber, J.S. 2001. Post-traumatic spinal deformity. *Spine,* 26(24S): S111–S118.

384. Veras, L.M., Pedraza-Gutierrez, S., Castellanos, J., Capellades, J., Casamitjana, J. and Rovira-Canellas, A. 2000. Vertebral artery occlusion after acute cervical spine trauma. *The Spine Journal,* 25(9):1171–1177.

385. Verettas, D-A.J., Karapantsos, E., Boyatzis, C., Ververidis, A., Kazakos, K.J. and Staikos, C. 2008. Neglected hangman's fracture in association with rupture of the trachea. *The Spine Journal,* 8: 552-554.

386. Vestergaard, P., Tigaran, S., Rejnmark, L., Tigaran, C., Dam, M. and Mosekilde, L. 1999. Fracture risk is increased in epilepsy. *Acta Neurologica Scandinavica*, 99: 269–275.

387. Vicenzino, B., Paungmali, A., Buratowski, S. and Wright, A. 2001. Specific manipulative therapy treatment for chronic lateral epicondylalgia produces uniquely characteristic hypoalgesia. *Journal of Manual Therapy,* 6: 205-212.

388. Vieweg U., Meyer B. and Schramm J. 2000. Differential treatment in acute upper cervical spine injuries: A critical review of a single institution series. *Surgical Neurology*, 54(3):203-211.

389. Vishteh, A.G., Coscarella, E., Nguyen, B., Sonntag, V.K. and Mcdougall, C.G. 1999. Fatal basilar artery thrombosis after traumatic cervical facet dislocation. *Journal of Neurosurgery*, 43:195–9

390. Vohra, R. K. and McCollum, C. N. 1994. Pressure sores. *British Medical Journal,* 309: 853-857.

391. Von Gumpenberg, S. and Harms, J. 1997. Indikationen und Technik der Osteosynthese bei Halswirbelsäulenverletzungen. *Annales der Chirurg* 26: 349–353

392. Wai-Han, C., Kit-Wai, C., French, P., Yim-Sheung, L. and Lai-Kwan, T. 1997. Which pressure sore risk calculator? A study of the effectiveness of the Norton scale in Hong Kong. *In, Journal of Nursing Studies,* 34(2): 165-169.

393. Walter, J., Doris, P. and Shaffer, M.A. 1984. Clinical presentation of patients with acute cervical spine injury. *Annals of Emergency Medicine,* 13:39-42.

394. Wang, G.J., Mabie, K.N., Whitehill, R. and Stamp, W.G. 1984. The nonsurgical management of odontoid fractures in adults. *The Spine Journal,* 9: 229–230.

395. Waxman, S. G. and DeGroot, J. 1995. *Correlative neuroanatomy.* New York: Lange Medical books/McGraw-Hill.

396. Webb, J.C., Munishi, P., Saifuddin, A. and Birch, R. 2002. The prevalence of spinal trauma associated with brachial plexus injuries. *Injury Journal*, 33:587–90.

397. Weber A.L. and Siciliano A. 2000. CT and MR imaging evaluation of neck infections with clinical correlations. *Radiologic Clinics of North America*, 38(5):941-968.

398. Weighardt, H., Heidecke, C. D., Emmanuilidis, K., Maier, S., Bartels, H., Siewert, J.R. and Holzmann, B. 2000. Sepsis after major visceral surgery is associated with sustained and interferon-gamma-resistant defects of monocyte cytokine production. *Surgery,* 127 (3):309–315.

399. Weir, D.C.1975. Roentenographic signs of cervical injury. *Clinical Orthopaedics,* 109: 11-17.

400. Weisberg, N.K., Spengler, D.M. and Netterville, J.L. 1997. Stretch-induced nerve injury as a cause of paralysis secondary to the anterior cervical approach. *Otolaryngology Head and Neck Surgery,* 116: 317–326.

401. Weller, S.J., Malek, A.M. and Rossitch, E. Jr. 1997. Cervical spine fractures in the elderly. *Surgical Neurology,* 47: 274-81.

402. Weller, S.J., Rossitch, E. Jr. and Malek, A.M. 1999. Detection of vertebral artery injury after cervical spine trauma using magnetic resonance angiography. *Journal of Trauma*, 46(4):660–6.

403. Werne, S. 1957. Studies in spontaneous atlas dislocation. *Acta Orthopaedica Scandinavica,* 23 Suppl:9

404. Werne, S.1958. The possibilities of movement in the craniovertebral joints. *Acta Orthopaedica Scandinavica,* 28: 165–173.

405. Wetherington, B. 2005. Electrotherapy: using electrical modalities. [online] Available from: http://www.chiropub.com/issues/2005-08.asp [Accessed 19 September 2008].

406. Wheeless, C.R. 2008. Extension teardrop fracture. [online] Available from: www.wheelessonline.

407. White, M.L. and El-Khoury, G.Y. 2002. Neurovascular injuries of the spinal cord. *European Journal of Radiology*, 42: 117-126.

408. White, A.I. III and Panjabi, M. 1990. *Clinical Biomechanics of the Spine.* 2nd ed. Lippincott, Philadelphia.

409. White, R.J. and Likavec, M.J. 1999. Spinal shock-spinal man. *Journal of Trauma,* 46(5): 979-980.

410. Willis, B.K., Greiner, F., Orrison, W.W. and Benzel, E.C. 1994. The incidence of vertebral artery injury after midcervical spine fracture or subluxation. *Journal of Neurosurgery*, 34(3):435–42.

411. Wolf, A., Levi, L., Mirvis, S., Ragheb, J., Huhn, S., Riagmonti, D. and Robinson, W.L. 1991. Operative treatment of bilateral facet dislocation. *Journal of Neurosurgery*, 75: 883-90.

412. Woodring, J. and Lee, C. 1993. Limitations of cervical radiography in the evaluation of acute cervical trauma. *Journal of Trauma,* 34:32–39.

413. Woolgar, J.D. and Robbs, J.V. 2002. Vascular surgical complications of the acquired immunodeficiency syndrome*. European Journal of Vascular and Endovascular Surgery*, 24: 473-479.

414. World Health Organisation. (1999). *Global tuberculosis control*: *Annual report 1999*. WHO/CDS/CPC/TB/99.259. Geneva: World Health Organisation.

415. Wyatt, L.H. 2005. *Handbook of Clinical Chiropractic Care*. 2nd ed. Massachusetts: Jones and Bartlett Pubishers.

416. Yamaguchi, E., Itoh, A., Furuya, K., Miyamoto, H., Abe, S. and Kawakami, Y. 1993. Release of tumor necrosis factor $\alpha$ from human alveolar macrophages is decreased in smokers. *Chest,* 103: 479-483.

417. Yochum, T.R. and Rowe, L.J. 2004. Trauma. In: *Essentials of skeletal radiology*. Baltimore, USA: Lippincott Williams & Wilkins.

418. Yoganandan, N., Kumaresan, S. and Pintar, F.A. 2001. Biomechanics of the cervical spine Part 2. Cervical spine soft tissue responses and biomechanical modeling. *Journal of Clinical Biomechanics,* 16(1): 1-27.

419. Yoganandan, N., Kumaresan, S. and Pintar, F.A. 2002. Pediatric biomechanics. In: A.M. Nahum and J.W. Melvin, (eds.) *Accidental Injury Biomechanics and Prevention*, Springer: New York.

420. Yoganandan, N., Pintar, F.A. and Cusick, J.F. 1997. Biomechanics of compression–extension injuries to the cervical spine. In: *Proceedings of the 41st Association for the Advancement of Automotive Medicine.* Orlando, FL: Pp. 331–44.

421. Yoganandan, N., Pintar, F.A., Stemper, B.D., Schlick, M.B., Philippens, M. and Wismans, J. 2000. Biomechanics of human occupants in simulated rear crashes Documentation of neck injuries and comparison of injury criteria. *Stapp Car Crash Journal*, 44:189–204.

422. Yoganandan, N., Sances, A. Jr., Maiman, D.J., Myklebust, J.B., Pech, P. and Larson, S.J. 1986. Experimental spinal injuries with vertical impact. *The Spine Journal,* 11(9): 855–860.

423. Young, M., Thiel, H. and Thorkeldsen, A. 1999. Fracture of the lateral mass of atlas: a case report and literature review*. British Journal of Chiropractic,* 3(3): 56-58.

424. Young, W.F. Axelrod, P and Jallo, J. 2005. Elective Spinal Surgery in Asymptomatic HIV-Seropositive Persons: Perioperative Complications and Outcomes. *The Spine Journal,* 30(2):256-259.

425. Zagra, S., Lamartina, C., Pace, A., Balzarini, E., Zerbi, A., Scoles, P., Ajello, F., Mazzarella, P. and Pillitteri, G. 1988. Posterior spinal fusion in scoliosis: computer-assisted tomography and biomechanics of the fusion mass. *The Spine Journal*, 13 (2): 155–161.

426. Zatsiorsky, V.M. 2002. Kinetics of human motion. Champaign, IL: Human Kinetics Publishers.

427. Zwarenstein, M., Krige, D. and Wolff, B. 1991. The uses of a geographical information system for hospital catch research in Natal/KwaZulu. *South African Medical Journal*, 80(10):497-500.

# APPENDIX A

**Section A**

**1. Demographic data:**

**1.1 Age (in years):** ______________________

**1.2 Gender:**

| | |
|---|---|
| Male | |
| Female | |

**1.3 Occupation:** ________________

**1.4 Co-existing medical conditions:**

| Cardiac conditions | Diabetes mellitus | Endocrine disorders | Gastrointestinal disorders | Infections e.g. TB |
|---|---|---|---|---|
| | | | | |
| Hypertension | Neurological disorders not related to spinal cord injury e.g. Parkinson's | Respiratory disorders | Rheumatic disorders | Other (specify) or state if information not available |
| | | | | |

**1.5 Immune status:**

| | | | | | |
|---|---|---|---|---|---|
| HIV negative | | HIV positive | | Unknown | |

**1.6 Pre-surgical Norton pressure sore assessment:**

| | | | | |
|---|---|---|---|---|
| Physical condition | Good (4) | Fair (3) | Poor (2) | Very poor (1) |
| | | | | |
| Mental condition | Alert (4) | Apathetic (3) | Confused (2) | Stupor (1) |
| | | | | |
| Activity | Ambulant (4) | Walking with help (3) | Chair-bound (2) | Bedridden (1) |
| | | | | |
| Mobility | Full (4) | Slightly limited (3) | Very limited (2) | Immobile (1) |
| | | | | |
| Incontinence | Absent (4) | Occasionally (3) | Usually (2) | Double (1) |

KEY: 1. Score of 14 or below means patient is at risk.
2. With orthopaedic or arthritic patients use "activity" and "mobility" only. Score of 3 or below means patient is at risk.
From: Nursing History: Assessment on Admission **(Appendix E)**

## 2. Cervical spine fracture:

### 2.1 Cause:

| Fall | Assault | Motor vehicle accident | Other (specify) | Unknown |
|---|---|---|---|---|
| | | | | |

### 2.2 Description of the fracture:

#### 2.2.1 Location of cervical spine fracture:

| Vertebral level | Anterior column | Middle column | Posterior column |
|---|---|---|---|
| C1 | | | |
| C2 | | | |
| C3 | | | |
| C4 | | | |
| C5 | | | |
| C6 | | | |
| C7 | | | |

#### 2.2.2 Dislocation:

| C0-C1 | C1-C2 | C2-C3 | C3-C4 | C4-C5 | C5-C6 | C6-C7 | C7-T1 |
|---|---|---|---|---|---|---|---|
| | | | | | | | |

#### 2.2.3 Type of fracture/dislocation:

| | Present | Level |
|---|---|---|
| Anterior atlantoaxial dislocation | | |
| Unilateral facet dislocation | | |
| Bilateral facet dislocation | | |
| Clay shoveler's fracture | | |
| Extension teardrop | | |
| Flexion teardrop | | |
| Traumatic spondylolisthesis – C2 | | |
| Jefferson's fracture | | |
| Odontoid peg fracture | | |
| Compression fracture | | |
| Burst fracture | | |
| Non-contiguous cervical spine injures/fractures | | |
| Other (specify): | | |

## 3. Associated fracture or injury:

### 3.1 Head injury:

| | | | |
|---|---|---|---|
| Present | | Absent | |

### 3.2 Extra-spinal fractures:

| Shoulder | Arm | Elbow | Forearm | Wrist/Hand |
|---|---|---|---|---|
| | | | | |
| Pelvis | Thigh | Knee | Leg | Ankle/Foot |
| | | | | |

**4 Neurological findings:**

**4.1 Spinal shock:**

| | | | |
|---|---|---|---|
| Present | | Absent | |

**4.2 Cranial nerve palsy/deficit:**

| | | | |
|---|---|---|---|
| Present | | Absent | |
| If present, state which one/s: | | | |

**4.3 Pre-surgical Frankel grading:**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| A | | B | | C | | D | | E | |

**5. Surgery:**

**5.1 Surgical procedure:**

| | Done | Level |
|---|---|---|
| Anterior decompression | | |
| Anterior fusion | | |
| Allograft strut | | |
| Autograft | | |
| Corpectomy | | |
| Discectomy | | |
| Posterior decompression | | |
| Posterior fusion | | |
| Rogers wiring | | |
| Other (specify): | | |

**5.2 Instrument used during surgery:**

| | Done | Level |
|---|---|---|
| Bone graft | | |
| Plate fixation | | |
| Screw fixation | | |
| Wiring technique | | |
| Other (specify): | | |

**5.3 Complications during surgery:**

| | |
|---|---|
| None | |
| Cardiac arrest | |
| Death | |
| Respiratory failure | |
| Other (specify): | |

**6. Post-surgical findings:**

**6.1 Post-surgical instrumentations used:**

| | Present | Absent |
|---|---|---|
| Cervical tongs | | |
| Halo-vest | | |

| | | |
|---|---|---|
| Hard collar | | |
| Soft collar | | |
| Traction | | |
| Other (specify): | | |

### 6.2 Post-surgical Frankel grading:

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| A | | B | | C | | D | | E | |

### 6.3 Post-surgical complications:

| | Present | Location | Mild | Moderate | Severe | Absent |
|---|---|---|---|---|---|---|
| Infection | | | | | | |
| Numbness | | | XXXXXX | XXXXXX | XXXXXXX | |
| Paraplegia | | XXXXXX | XXXXXX | XXXXXX | XXXXXXX | |
| Parasthesia | | | | | | |
| Referred pain | | | | | | |
| Quadriplegia | | XXXXXX | XXXXXX | XXXXXX | XXXXXXX | |
| Deep vein thrombosis | | | | | | |
| Pulmonary complications | | | | | | |
| Stroke | | XXXXXX | | | | |
| Cardiac complications | | | | | | |
| Other (specify): | | | | | | |

### 6.4 Post-surgical Norton pressure sore assessment:

| | | | | |
|---|---|---|---|---|
| Physical condition | Good (4) | Fair (3) | Poor (2) | Very poor (1) |
| | | | | |
| Mental condition | Alert (4) | Apathetic (3) | Confused (2) | Stupor (1) |
| | | | | |
| Activity | Ambulant (4) | Walking with help (3) | Chair-bound (2) | Bedridden (1) |
| | | | | |
| Mobility | Full (4) | Slightly limited (3) | Very limited (2) | Immobile (1) |
| | | | | |
| Incontinence | Absent (4) | Occasionally (3) | Usually (2) | Double (1) |

KEY: 1. Score of 14 or below means patient is at risk.
2. With orthopaedic or arthritic patients use “activity” and “mobility” only. Score of 3 or below means patient is at risk.
From: Nursing History: Assessment on Admission **(Appendix E)**

### 7. Post-surgical rehabilitation (in hospital):

| | Yes | No |
|---|---|---|
| Psychology counselling | | |
| Occupational therapy | | |
| Physiotherapy | | |
| Psychiatry consult | | |
| Social worker intervention | | |
| Chiropractic care | | |
| Other: specify | | |

# APPENDIX B1

## Subject Information Sheet

**Title of research:** An epidemiological analysis of traumatic cervical spine fractures at a referral spinal unit – a three-month study.

**Principle investigators:** Dr J Shaik (M. Tech. Chiro.; M. Med. Sci. (SM) Supervisor)
Natasha Singh (Researcher)

**Co-investigator:** Professor S Govender (MBBS, FRCS, MD) (Co-supervisor)

**Introduction:** I am a Master's student at the Department of Chiropractic, Durban University of Technology. I am studying the different ways patients present with neck fractures.

**Purpose:** This study will enable doctors and surgeons to have a better understanding of fractures of the neck. It is anticipated that the doctors will be able to better manage patients with neck fractures as a result of knowledge gained from this research.

**Procedures:** In order to gather information for this study, I will look at your patient file and medical records. This includes my checking your immune status. **This means that I will require to know your HIV status**. I might also be in the theatre when you undergo surgery. From time to time I might also enquire from the nursing staff and doctors about your condition.

**Reasons why you may be withdrawn from this study without your consent**
You may be withdrawn from this study:

- if you are not willing to participate in this research.
- if you do not sign the informed consent form.

**Benefits:** Your cooperation in this study will provide registrars/surgeons with vital information pertaining to the potential complications that may develop as well as provide them with an opportunity to develop ways in which these may be combated.

**Risk/Discomforts:** There will be to no risks and/or discomforts to any of the participants in this study. Your participation in this study will not affect the treatment you will receive at the hospital. You will receive the normal treatment as any other patient who presents with neck fractures at the hospital i.e. you will not receive any better or lesser care as a result of participating in this research.

**Remuneration:** You will not receive any payment or gifts of any kind for taking part in this study.

**Costs of Study:** There are no costs to you for taking part in this study.

**Confidentiality:** All information gathered from your medical records will be kept strictly confidential. Other than myself, only my supervisors will have access to this information to verify my records. **Your HIV status and other medical records will never be disclosed to anyone. Your name will not appear on any of the sheets on which I will record your information or any research articles which may arise from this research.**

**Research related injury**: There will be no research related injury to you.

**Persons to contact for problems or questions:**

Dr J Shaik 031 373 2588 (Supervisor)

Prof. S. Govender (031 260 4297) (Co-Supervisor)

Mrs. K. Young 031 373 2094 (Head of Department of Chiropractic, Durban University of Technology)

Prof N. Gwele 031 373 2102 (Dean of the Faculty of Health Sciences, Durban University of Technology and Chair of the Faculty of Health Sciences Research and Ethics Committee)

# APPENDIX B2

## Iminingwane ngesifundo

**Isihloko socwaningo**: Ukuhlaziywa kwezingq lobungozi lwesifo sokuphuka kwamathambo emgogodlweni (ukucubungula okunyanga ntathu)

**Abahloli abakhulu**: uDokotela J. Shaik

**Umbhekeli**: Natasha Singh (Umcubunguli)

**Abalekeleli bahloli:** Professor S Govender

**Isingeniso**: Ngingumfundi owenza iziqu eziphakeme (Master's) emnyangweni we Chiropractic enyunivesi yezobuchwepheshe yase Thekwini. Iziguli ezibhekana nazo uma zilimele kabuhlungu entayeni.

**Inhloso:** Lolucwaningo luzokwenza ukuthi odokotela nochweheshe babe nokugonda okukahle mayelana nokulimala nokuphuka okwenzeka ezintanyeni. Kulindeleke ukuthi odokotela bakwazi ukubhekana kahle neziguli ezilemele entanyeni ngenxa yoherazi oluzotholokala ngenxa yaholucwaningo.

**Inqubo ezolandelwa**: Ukuze ngithole u lwazi oluningi nolubalulekile ngalolucwaningo, kuzomele ngifundisise imibiko ka dokotela ngesiguli sakho. Lokhu kumbandakanya ukuhlola isimo samasosha egazi. Lokhu kusho ukuthi kuzomele ngazi isimo sakho sesandulela ngculazi. Kungenzeka futhi ngibekhona uma usuhlinzwa. Ngizo phinde ngibuye ngilokhu ngixoxisana namanesi mayelana nesimo sakho.

**Izizathu ezigenza ukuthi ungabusalibamba iqhaza kulolucwaningo**:
Ungakhishwa kulolucwaningo ngalezizathu

- ❖ Uma ungathandi ukuzimbandakanya nalolucwaningo
- ❖ Uma ungasayini ifomu lokuzibophezela

**Okuhle ngocwaningo**: Ukuzimbandakonya kwakho kulolucwaningo knyohlomisa odokotela nabasebenza ngezimpilo ngolwazi olubalulekile ngobungozi kanye nethuba lokuqhamuka nezindlela zokugwema lobubungozi.

**Ubungozi/Ukungaphatheki kahle**: Ngeke kube khona bungozi noma ukungaphatheki kahle kunoma ngubani ozobamba iqhaza kulolucwaningo. Ukubamba kwakho iqhaza njeke kube namthelela omubi ikutholeni ukunyangwa esibhedlela. Uyoqhubeka ngokusizwa njenzazo zonke iziguli ezilimele entanyeni la esibhedlela. Ngeke ubonelelwe noma ujeziselwe ukubamba iqhaza kulolucwaningo.

**Inkokhelo:** Ngeke ukukhokhelwe noma uthole sipho ngokubambi iqhaza kulolucwaningo.

**Abantu ongabathinta uma uhlangabezana nezinkinga nona uma unemi buzo:**
U –Dokotela J. Shaik 031 373 2588 (Supervisor)

Prof. S Govender 031 260 4297 (Co-supervisor)

Mrs K Young 031 373 2094 (Head of Department of Chiropractic, Durban University of Technology)

Prof. N Gwele 031 373 2102 (Dean of the Faculty of Health Sciences, Durban University of Technology and Chair of the Faculty of Health Sciences Research and Ethics Committee)

# APPENDIX C1

## Information Sheet for the Nursing Staff at King George V Hospital, Spinal Unit

**Title of research:** An epidemiological analysis of traumatic cervical spine fractures at a referral spinal unit – a three-month study.

**Principle investigators:** Dr J Shaik (M. Tech. Chiro.; M. Med. Sci. (SM) Supervisor)
Natasha Singh (Researcher)

**Co-investigator:** Professor S Govender (MBBS, FRCS, MD) (Co-supervisor)

**Introduction:** I am a Master's student at the Department of Chiropractic, Durban University of Technology. I am studying the different ways patients present with neck fractures.

**Purpose:** The study will enable doctors and surgeons to have a better understanding of fractures of the neck. It is anticipated that the doctors will be able to better manage patients with neck fractures as a result of knowledge gained from this research.

**Procedures:** In order to gather information for this study, I will look at the medical and surgical records of patients who present neck fractures at the spinal unit. I may also be in the theatre with the surgical staff during operative procedures. All patients who take part in my study will need to read the subject information letter and sign the informed consent form. The exceptions to this will be patients who are unconscious or are in a state of reduced levels of consciousness or are in such a state that they will be not be able to give informed consent.

**Your role in this study:** In the event of any patient who is a candidate for participation in this research but is unable to read the isiZulu translation of the subject information letter or informed consent form, I will require your assistance in terms of explaining the research procedure to the patient as outlined in the subject information letter. You may also be required to translate information that needs to be relayed between the patient and the researcher. It is also important that you explain to such patient that his/her medical records including his/her HIV status will be kept absolutely confidential and his/her name will not appear on any of the data sheets.

**Reasons why you may be withdrawn from this study without your consent**
You may be withdrawn from this study:

- if you are not willing to participate in this research.
- if you do not sign the informed consent form.

**Benefits:** Indirectly your cooperation in this study will provide registrars/surgeons with vital information pertaining to the potential complications that may develop as well as provide them with an opportunity to develop ways in which these may be combated.

**Risk/Discomforts:** There will be to no risks and/or discomforts to you if you take part in this study.

**Remuneration:** You will not receive any payment or gifts of any kind for taking part in this study.

**Costs of Study:** There are no costs to you for taking part in this study.

**Confidentiality:** All information gathered from the subjects medical records will be kept strictly confidential. Other than myself, only my supervisors will have access to this information to verify my records. **The subject's HIV status and other medical records will never be disclosed to anyone. His or her name will not appear on any of the sheets on which I will record this information or any research articles which may arise from this research.**

**Research related injury**: There will be no research related injury to you.

**Persons to contact for problems or questions:**

Dr J Shaik 031 373 2588 (Supervisor)

Prof. S. Govender (031 260 4297) (Co-Supervisor)

Mrs. K. Young 031 373 2094 (Head of Department of Chiropractic, Durban University of Technology)

Prof N. Gwele 031 373 2102 (Dean of the Faculty of Health Sciences, Durban University of Technology and Chair of the Faculty of Health Sciences Research and Ethics Committee)

# APPENDIX C2

**Ipheshana lolwazi olubhekiswe kumanesi ase King George V Hospital, Spinal Unit**

**Isihloko socwaningo:** Ukuhlaziywa kwezinga lobungozi lwesifo sokuphuka kwamathambo emgogodleni (Ukucubungula okunnyanga – ntathu)

**Abahloli abakhulu**: U –Dokotela J. Shaik

**Umbhekeli:** Natasha Singh (Umcubunguli)

**Abalekeleli bahloli**: Professor S Govender

**Isingeniso:** Ngingumfundi owenza iziqu eziphakeme (Master's) emnyangweni we Chiropractic enyunivesi yezobuchwepheshe yase Thekwini. Iziguli ezibhekana nazo uma zilimele kabuhlungu entayeni.

**Inhloso:** Lolucwaningo luzokwenza ukuthi odokotela nochweheshe babe nokugonda okukahle mayelana nokulimala nokuphuka okwenzeka ezintanyeni. Kulindeleke ukuthi odokotela bakwazi ukubhekana kahle neziguli ezilemele entanyeni ngenxa yoherazi oluzotholokala ngenxa yaholucwaningo.

**Inqubo ezolandelwa**: Ukuze ngithole uhrazi oluningi nolubalulekile ngalolucwaningo, kuzomele ngifundisise imbiko yodokotela ngesiguli sakho esilashelwa. Ukuphuka intamo egunjjm elibhekene nokulimala kwemigogodla. Kungenzeka ngibekhana futhi uma isiguli sesihlinzwa ngo dokotela. Zonke iziguli ezibamba iqhaza kulolucwaningo komele. Zifundisise ipheshana elichazayo bese ziyasayina. Abangeke basayiniswe yelabo kuphela abangeke bebesesimweni so kukwazi ukuzitha thela izinqumo noma labo izinga labo lwempilo elingavumi.

**Iqhaza lakho kulolucwaningo**: Uma kwenzeka ukuthi omunye weziguli abambe iqhaza kulolucwaningo akakwazi ukufunda isizulu, ngiyocela ukuba umchazela inqubo ezolandelwa yitolucwaningo. Kungenzeka futhi kufanele uhumushe ulwazi okufanele. Lwaziwe umcubunguli kanye nesiguli. Kuyobaluleka futhi sichazelwe isiguli ukuthi isimo salo sesandulela ngculazi siyogcinwa siyimfihlo futhi ngeke sivezwe kunona yimuphi umbhalo.

**Izizathu ezingenza ungabulisabamba iqhoza kulolucwaningo ngaphandle kokwaziswa:**
Ungayekiswa ukubamba iqhaza kulolucwaningo ngalezizathu:
- ❖ Uma ungazimisele ukubamba iqhaza
- ❖ Uma ungafuni ukusayina infomu yokuvuma ukubamba iqhaza

**Okuyinzwzo:** Ukubamba kwakho iqhaza. Kulolucwaningo kuzosiza odokotela nabasebenzi bezempilo ngolwazi olubalulekile mayelana nokungaba. Ubungozi ezigulini kanye no kungenziwa ukugwema lobubungozi.

**Ubungozi:** Ngeke kube nabungozi ukubamba kwakho iqhaza kulolucwaningo.

**Inkokhelo:** Ngeke ukho khelwe noma uthole zipho ngo kubamba kwakho iqhaza kulolucwaningo.

**Lubiza malini lolucwaningo**: Akakho ozokakhokha ngo kubamba iqhaza

**Imfihlo:** Lonke ulwazi olutholakele kulolucwaningo luyohlala luyimfihlo. Ngaphandle kwami, yilabo abangiphethe kuphela abayoba nolwazi nalolulwazi. Isimo sakho sesandulela ngculazi ngeke siboniswe nanoyedwa umuntu. Igama lesigali ngeke luvezwe ndawo.

**Ucwaningo oluphathelene nokulimala:**
Ngeke kubekhona cwaningo oluphathelene nokulimala kwakho.

**Okumele bathinthwe uma kunezinkinga noma imibuzo:**
U –Dokotela J. Shaik 031 373 2588 (Supervisor)

Prof. S Govender 031 260 4297 (Co-supervisor)

Mrs K Young 031 373 2094 (Head of Department of Chiropractic, Durban University of Technology)

Prof. N Gwele 031 373 2102 (Dean of the Faculty of Health Sciences, Durban University of Technology and Chair of the Faculty of Health Sciences Research and Ethics Committee)

# APPENDIX D1

**Information Sheet for Doctors and Registrars at the Spinal Unit**

**Title of research:** An epidemiological analysis of traumatic cervical spine fractures at a referral spinal unit - a three-month study.

**Principle investigators:** Dr J. Shaik (M. Tech. Chiro.; M. Med. Sci. (SM) (Supervisor)
Natasha Singh (Researcher)

**Co-investigator:** Professor S. Govender (MBBS, FRCS, MD) (Co-supervisor)

**Introduction:** I am a Master's student at the Department of Chiropractic, Durban University of Technology. My study concerns the profiling of cervical spine fractures at the Spinal Unit.

**Purpose:** The study will enable doctors and surgeons to have a better understanding of fractures of the neck. It is anticipated that the doctors will be able to better manage patients with neck fractures as a result of knowledge gained from this research.

**Procedures:** The subjects who will participate in this study are those who present at the Spinal Unit with cervical spine trauma. **These patients must have given me written informed consent to inspect their medical and surgical records before I can gather any data pertaining to my study.** In order to collect data for this study, I will need to look at these patients' files and medical records. This includes my checking their immune status i.e. **their HIV status**. I might also be in the theatre when these patients undergo surgery. Permission to conduct this study has already been granted by the Superintendent of the Hospital.

**Your role in this study:** I will require your assistance in terms of introducing me to prospective patients whose clinical data may be useful for this study. I may require you to provide me with the relevant clinical data of patients who have given me informed consent to utilise their medical records as data for my study. **Under no circumstances will you be asked to provide a patient's clinical data if he/she has not given written informed consent.**

**Reasons why you may be withdrawn from this study without your consent**
You may be withdrawn from this study:

- if you are not willing to participate in this research.
- if you do not sign the informed consent form.

**Benefits:** Your cooperation in this study will provide registrars/surgeons with vital information pertaining to the potential complications that may develop as well as provide them with an opportunity to develop ways in which these may be combated.

**Risk/Discomforts:** There will be no risks and/or discomforts to you for participating in this study. You will treat all patients who present at the Spinal Unit with cervical spine injury as per normal orthopaedic and medical management protocols.

**Remuneration:** You will not receive any payment or gifts of any kind for taking part in this study.

**Costs of Study:** There are no costs to you for taking part in this study.

**Confidentiality:** All information gathered from patient medical records will be kept strictly confidential. Other than myself, only my supervisors will have access to this information to verify my records. **The patient's HIV status and other medical records will never be disclosed to anyone.** Neither your name nor the patient's name will appear on any of the data sheets or any research articles which may arise from this research.

**Research related injury**: There will be no research related injury to you.

**Persons to contact for problems or questions:**
Dr J Shaik 031 373 2588 (Supervisor)

Prof. S. Govender (031 260 4297) (Co-Supervisor)

Mrs. K Young 031 373 2094 (H O D Department of Chiropractic)

Prof N Gwele 031 (Dean of the Faculty of Health Sciences, Durban University of Technology and Chair of the Faculty of Health Sciences Research and Ethics Committee)

# APPENDIX D2

## Ulwazi olubhekiswe ko dokotela

**Isihloko socwaningo**: Ukuhlaziywa kwezinga lobungozi lwesifo sokuphuka kwamathambo omgogodla.

**Abahloli abakhulu**: U –Dokotela J. Shaik

**Umbhekeli:** Natasha Singh (Umcubunguli)

**Abalekeleli:** Professor S Govender

**Isingeniso**: Ngungumfundi owenza iziqu ze Master's emnyangweni we Chiropractic, enyunivesi thi yezobuchwepheshe eThekwini. Lolucwaningo luphathelene no kubheka zonke izihlobo zokuphuka kwamathambo emigogodla.

**Inhloso:** Ucwaningo luzosiza ukuthi odokotela nabasebenza ngezempilo babe nolwazi olugcwele mayelana no kuphuka kwamathambo emigogodla nentamo nanokuthi angalashwa kanjani. Kulindeleke ukuthi ngemva kocwaningo odokotela nochwepheshe babe nolwazi olunzulu ngo kulashwa kokulimala kwamathambo entamo no mgogodla.

**Inqubo:** Abazobamba iqhaza kulolucwaningo yilozoziguli ezihambela isikhungo sabahlukunyezwe ukalima kwamathambo entamo nomgogodla. Leziziguli kuyomele zisayine phansi ukuthi ziyavuma ukuthi ngihlole imininingwane yokugula kwazo ngaphambi  kokuthi ngiqhubeke no cwaningo.  Ukuze ngithole ulwazi oluningikuyomele ngibuke imilando yesempilo yaleziziguli. Lokhu kubandakanyaka noku thola ngolwazi lwesimo sesandulela ngculazi seziguli. Kangenzeka ngibe segunjini lokuhlinza uma leziziguli zihlinzwa. Imuume yokwenza lolucwaningo isivele inikeziwe ngu nsumpa we si bhedlela.

**Iqhaza lakho kulolucwaningo:** Ngizocela usizo lwakho lokuba ungithule ezigulini isimo sempilo yazo engasiza kulolucwaningo. Ngiyobuye ngicele inginikeze yonke iminingwana yezempilo yolezoziguli esezinginikezile invume yokuba ngesebenzise imininingwane yazo yezempilo. Ngeke nangephutha ngicele imininingwane yezempilo yesiguli ngaphandle kwemvume yaso.

**Izizathu ezingenza ukuba ungabusaqhubeka no kubamba iqhaza kulolucwaningo:**
Ungayekiswa ukubamba iqhaza ngalezizathu:

- Uma ungathondi ukubamba iqhaza
- Uma ungasayini ifomu lokuzibophizelela ukubamba iqhaza

**Inzuzo:** Ukubamba kwakho iqhaza kulolu. Cwaningo kuyosiza odokotela ngolwazi olunzulu ngobungozi nokugwena ubungozi nokulima entanyeni nasemgogodleni.

**Ubungozi**: Ngeke kube nabungozi ngo kubamba kwakho iqhaza kulolucwaning. Uyoqhubeka no kwelapha izigulu zakho ezephuke amathambo omgogdla nawentamo ulandela indlela ejwayelekile.

**Inkokhelo:** Akukho nkokhelo noma zipho ngokubamba kwakho iqhaza kulolucwaningo.

**Lubiza malini ucwaningo:** Ngeke ukhokhe lutho ngokubamba iqhaza kulolucwaningo.

**Imfihlo:** Iminigwane etho lakele emafayeleni esiguli iyoganwa iyimfihlo. Ngaphandle kwami, abangaphezu kwami kuphela abahoba no wazi/wesimo sesiguli. Isimo sesandulela ngculazi sesiguli ngeke sivezelwe nanoyedwa umuntu. Igama lakho noma lesiguli ngeke livezwe.

**Abantu ongabathinta uma uhlangabezana nezinkinga nona uma unemi buzo:**
U –Dokotela J. Shaik 031 373 2588 (Supervisor)

Prof. S Govender 031 260 4297 (Co-supervisor)

Mrs K Young 031 373 2094 (Head of Department of Chiropractic, Durban University of Technology)

Prof. N Gwele 031 373 2102 (Dean of the Faculty of Health Sciences, Durban University of Technology and Chair of the Faculty of Health Sciences Research and Ethics Committee)

# Appendix E

## NURSING HISTORY : ASSESSMENT ON ADMISSION

| PATIENT PARTICULARS *(Block letters or use sticker)* | | | | | | Reason for Admission: | Other Diseases : Allergies: |
|---|---|---|---|---|---|---|---|
| Surname: | | | | | Hospital: | | |
| First Names: | | | | Age: | Hospital No.: | | |
| Sex *(Mark with X)* | Male | Female | Ward: | | Admission Date: | | |

| Property *(Mark with X)* | Yes | No | Home Accommodation: |
|---|---|---|---|
| Family / Others at this Residence: | | | |

| OBSERVATIONS | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Vital Signs | Temperature: | Pulse: | Respiration: | Blood Pressure: | Blood Glucose: | H.B.: | Height: | Mass: |
| Urinalysis | Glucose: | Albumin: | Ketones: | Blood: | P.H.: | Deposits: | | |

| ASSESSMENT OF: | REMARKS: |
|---|---|
| 1. Pain : Comfort | |
| 2. Breathing | |
| 3. Circulation | |
| 4. Eating and Drinking | |
| 5. Posture and Movement | |
| 6. Elimination | |
| 7. Rest and Sleep | |
| 8. Safety | |
| 9. Hygiene and Skin | |
| 10. Sensory : Interpersonal Needs | |
| 11. Learning Needs | |

## NORTON PRESSURE SORE ASSESSMENT

Key: 1. Score of 14 or below means patient is at risk.
2. With orthopaedic or arthritic patients use "activity" and "mobility" only. Score of 3 or below means patient is at risk.

| Physical Condition | Mental Condition | Activity | Mobility | Incontinence | Score | Date |
|---|---|---|---|---|---|---|
| 1. Good 4. | 1. Alert 4. | 1. Ambulant 4. | 1. Full 4. | 1. Absent 4. | 1st | |
| 2. Fair 3. | 2. Apathetic 3. | 2. Walk with help 3. | 2. Slightly limited 3. | 2. Occasional 3. | 2nd | |
| 3. Poor 2. | 3. Confused 2. | 3. Chairbound 2. | 3. Very limited 2. | 3. Usually Urinary 2. | 3rd | |
| 4. Very Bad 1. | 4. Stuporous 1. | 4. Bedfast 1. | 4. Immobile 1. | 4. Double 1. | 4th | |

Signature ..............................

Rank ..............................

Date ..............................

Supervisor ..............................

CAT.NO. 23 - 46319 / P - 431178 / 05 MAY 96

# Appendix F


## DEPARTMENT OF HEALTH
### PROVINCE OF KWAZULU-NATAL

### KING GEORGE V HOSPITAL

PO DORMERTON,4015
75 STANLEY COPLEY DRIVE, SYDENHAM, DURBAN

| | | |
|---|---|---|
| Enquiries : Dr S Maharaj | Telephone Number : (031) 2087121<br>Extension : 356 | Fax Number : (031) 2099586 |
| Email : h021299@dohho.kzntl.gov.za | Your Reference : | Date : 23/ 03/ 2006 |


Miss N Singh
DIT : Student Number 20100732

Dear Miss N Singh

**RE: UNDERGRADUATE REQUEST FOR PERMISSION TO INITIATE RESEARCH AT KING GEORGE V HOSPITAL**

1. Your letter dated 23 March 2006 refers.

2. Permission is granted for initiating the above mentioned study, provided you obtain ethical approval. Please find attached indemnity form for completion and submission prior to undertaking the study.

3. Your attention is once again drawn to the maintenance of confidentiality as discussed and you need to obtain consent from each research subject.

4. Arrangements should be made for you to work with health care workers in the hospital.

S Bmaharaj

**DR S B MAHARAJ**
**MEDICAL MANAGER**

DURBAN UNIVERSITY of TECHNOLOGY

# APPENDIX G1

## INFORMED CONSENT FORM

(To be completed by patient / subject )

| | |
|---|---|
| **Date** | : 12/09/07 |
| **Title of research project** | : An epidemiological analysis of traumatic cervical spine fractures at a referral Spinal Unit – a three-month study |
| **Name of supervisor** | : Dr J Shaik ( **M. Tech. Chiro.; M. Med. Sci. (SM)** ) |
| **Tel ?** | : 031 373 2588 |
| **Name of research student** | : Natasha Singh |
| **Tel ?** | : 074 208 4079 |

**<u>Please circle the appropriate answer</u>** **YES /NO**

| | | | |
|---|---|---|---|
| 1. | Have you read the research information sheet? | Yes | No |
| 2. | Have you had an opportunity to ask questions regarding this study? | Yes | No |
| 3. | Have you received satisfactory answers to your questions? | Yes | No |
| 4. | Have you had an opportunity to discuss this study? | Yes | No |
| 5. | Have you received enough information about this study? | Yes | No |
| 6. | Do you understand the implications of your involvement in this study? | Yes | No |
| 7. | Do you understand that you are free to withdraw from this study? | Yes | No |
| | at any time | Yes | No |
| | without having to give any a reason for withdrawing, and | Yes | No |
| | without affecting your future health care. | Yes | No |
| 8. | Do you agree to voluntarily participate in this study | Yes | No |
| 9. | Who have you spoken to? ______________________________ | | |

**Please ensure that the researcher completes each section with you**
**If you have answered NO to any of the above, please obtain the necessary information before signing**

**<u>Please Print in block letters:</u>**

Patient /Subject Name:_________________________ Signature: ___________________

Parent/ Guardian:______________________________ Signature:___________________

Witness Name:_________________________________ Signature:___________________

Research Student Name:_________________________ Signature:___________________

# APPENDIX G2

**USHICILELO Cii**

**INCWADI EGUNYAZAYO**

**Usuku** **:** 12/09/07

**Isihloko socwaningo** **:** An epidemiological analysis of traumatic cervical spine fractures at a referral Spinal Unit – a three- month study

Igama lika Supervisor : Dr J Shaik ( M. Tech. Chiro.; M. Med. Sci. (SM) )
**:** 031 373 2588

**Igama lomfundi ongumcwaningi** **:** Natasha Singh
**:** 074 208 40709

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**Uyacelwa ukuba ukhethe impendulo** **Yebo Cha**

1. Ulifundile yini iphepha elinolwazi ngocwaningo? Yebo Cha
2. Ube naso yini isikhathi sokubuza imibuzo mayelana nocwaningo? Yebo Cha
3. Wanelisekile yini izimpendulo ozitholile emibuzweni yakho? Yebo Cha
4. Ube nalo yini ithuba lokuthola kabanzi ngocwaningo? Yebo Cha
5. Uyithole yonke imininingwane eyanele ngalolucwaningo? Yebo Cha
6. Uyayiqonda imiphumela yokuzimbhandakanya kwakho kulolucwaningo? Yebo Cha
7. Uyaqonda ukuthi ukhululekile ukuyeka lolucwaningo? Yebo Cha
   noma inini Yebo Cha
   ngaphandle kokunika isizathu sokuyeka Yebo Cha
   ngaphandle kokubeka impilo yakho ebungozini Yebo Cha
8. Uyavuma ukuvolontiya kulolucwaningo? Yebo Cha
9. .Ukhulume nobani? -------------------------------------------

**Uma uphendule ngokuthi cha kokungaphezulu, sicela uthole ulwazi ngaphambi kokusayina.**

**BHALA NGAMAGAMA AMAKHULU:**

Igama lesiguli:______________________________ Sayina:____________________

Umzali/Umgad:______________________________ Sayina: ____________________

gama Witness:______________________________ Sayina: ____________________

Igama lomfundi ongumcwaningi:____________________ Sayina: ____________________

# APPENDIX H

D U R B A
TECHNOLOG

## ETHICS CLEARANCE CERTIFICATE

| | | | |
|---|---|---|---|
| **Student Name** | **Miss N Singh** | **Student No** | **20100730** |
| **Ethics Reference Number** | **FHSEC 036/07** | Date of FRC Approval | **19 November2007** |
| Research Title: | **An epidemiological analysis of traumatic cervical spine fractures at a referral spinal unit – a three month study** | | |

*In terms of the ethical considerations for the conduct of research in the Faculty of Health Sciences, Durban University of Technology, this proposal meets with Institutional requirements and confirms the following ethical obligations:*

1. The researcher has read and understood the research ethics policy and procedures as endorsed by the Durban University of Technology, has sufficiently answered all questions pertaining to ethics in the DUT 186 and agrees to comply with them.
2. The researcher will report any serious adverse events pertaining to the research to the Faculty of Health Sciences Research Ethics Committee.
3. The researcher will submit any major additions or changes to the research proposal after approval has been granted to the Faculty of Health Sciences Research Committee for consideration.
4. The researcher, with the supervisor and co-researchers will take full responsibility in ensuring that the protocol is adhered to.
5. ***The following section must be completed if the research involves human participants:***

| | YES | NO | N/A |
|---|---|---|---|
| ❖ Provision has been made to obtain informed consent of the participants | ✓ | | |
| ❖ Potential psychological and physical risks have been considered and minimised | ✓ | | |
| ❖ Provision has been made to avoid undue intrusion with regard to participants and community | ✓ | | |
| ❖ Rights of participants will be safe-guarded in relation to:<br>- Measures for the protection of anonymity and the maintenance of Confidentiality. | ✓ | | |
| - Access to research information and findings. | ✓ | | |
| - Termination of involvement without compromise | ✓ | | |
| - Misleading promises regarding benefits of the research | ✓ | | |

SIGNATURE OF STUDENT/RESEARCHER — DATE: 17 JULY 2008

SIGNATURE OF SUPERVISOR/S — DATE: 17 JULY 2008

SIGNATURE OF HEAD OF DEPARTMENT — DATE: 17 JULY 2008

SIGNATURE: CHAIRPERSON OF RESEARCH ETHICS COMMITTEE — DATE: 17 July 2008.

# APPENDIX I

HEALTH
KwaZulu-Natal

**Health Research & Knowledge Management sub-component**
10 – 103 Natalia Building, 330 Langalibalele Street
Private Bag x9051
Pietermaritzburg
3200
Tel. 033 – 3953189
Fax.: 033 – 394 3782
Email : gugu khumalo@kznhealth.gov.za
www kznhealth gov za

**Reference : HRKM100/07**
**Enquiries :** Mrs G Khumalo
**Telephone :** 033 – 3953189

13 December 2007

Dear Ms N. Singh

**Subject: Approval of a Research Proposal**

1. The research proposal titled **'An Epidemiological Analysis of Traumatic Cervical Spine Fractures at a Referral Spinal Unit- A Three Month Study'** was reviewed by the KwaZulu-Natal Department of Health. The proposal is hereby **approved** for research to be undertaken at King George V Hospital.

2. You are requested to undertake the following:
   a. Make the necessary arrangement with identified facilities before commencing with your research project.
   b. Provide an interim progress report and final report (electronic and hard copies) when your research is complete.

3. Your final report must be posted to **HEALTH RESEARCH AND KNOWLEDGE MANAGEMENT, 10-102, PRIVATE BAG X9051, PIETERMARITZBURG, 3200** and e-mail an electronic copy to gugu.khumalo@kznhealth.gov.za

For any additional information please contact Mrs G Khumalo on 033-3953189.

Yours Sincerely

Dr S.S.S. Buthelezi
Chairperson: Provincial Health Research Committee
KwaZulu-Natal Department of Health

4 November 2008

TO WHOM IT MAY CONCERN

On Natasha Singh's request, her dissertation titled: An epidemiological analysis of traumatic cervical spine fractures at a referral spinal unit – A three-month study was referred by me to the Information Communications Technology (ICT) Help Desk at the Durban University of Technology to assist with layout and spacing of her Reference List. Ms N. Ramroop from ICT worked with the document and then referred it for further assistance to her colleagues, but they were unsuccessful in maintaining the single line spacing in the reference list as requested by Ms N. Singh.

Dr P. Singh
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Durban University of Technology
PO Box 1334, Durban, 4000

Tel.: 031 3736767
0827064642

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## EDITORIAL CERTIFICATION

This document certifies that the dissertation titled: An epidemiological analysis of traumatic cervical spine fractures at a referral spinal unit – A three-month study by Natasha Singh was edited for proper English language, grammar, punctuation and spelling by Dr Penny Singh in October 2008. Neither the research content nor the author's intentions were altered in any way during the editing process.

Dr Penny Singh is a Language Editor with the Postgraduate Development and Support Centre at the Durban University of Technology and a senior lecturer in English/Communication at the Durban University of Technology.

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