MAGNETIC RESONANCE IMAGING PATTERN AND MECHANISMS OF SPINAL INJURY AT MOI TEACHING AND REFERRAL HOSPITAL, ELDORET, KENYA

BY

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DECLARATION

Declaration by the candidate

This research thesis is my original work and has not been presented in any other university to the best of my knowledge.

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DEDICATION

This work is dedicated to my spouse, Tom Kongiri for his encouragement and support during the research period and his determination to see me succeed. To my sons Bobby and Nathan for giving me the impetus and determination for the study. Above all to God Almighty, who gives me life and without whom none of this would have been possible.

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ABBREVIATIONS AND ACRONYMS

ALL	Anterior longitudinal ligament
CT	Computerized tomography
FSE	Fast Spin Echo
IREC	Institutional Research and Ethics Committee
MRI	Magnetic Resonance Imaging
MTRH	Moi Teaching and Referral Hospital
MVA	Motor Vehicle Accident
PLC	Posterior Ligamentous Complex
PLL	Posterior longitudinal ligament
SCI	Spinal cord Injury
SCIWORA	Spinal Cord Injury without Radiologic Abnormality
SE	Spin Echo
STIR	Short Tau Inversion Recovery
T1WI	T1 weighted Image
T2WI	T2 weighted Image
TE	Time to Echo
TR	Repetition Time

OPERATIONAL DEFINITION OF KEY TERMS

Acute Injury: Injury occurring within a time period of 14 days.

Adult: A person aged 18 years and above who can give informed consent.

Magnetic Resonance Imaging: Magnetic Resonance Imaging is a diagnostic technique that uses magnetic fields to produce a detailed image of the body's soft tissue and bones.

Patterns: Features of spinal injury as seen on Magnetic Resonance Imaging.

Spondylolisthesis: Condition in which one vertebral body slips over another.

Spinal trauma: Injury to the spinal column as a result of physical injury.

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ABSTRACT

Background: Traumatic spinal injury is a debilitating disease as it may lead to paresis or paralysis. Prompt and accurate diagnosis is needed so as to determine the appropriate method of management and prevent further complications. Magnetic Resonance Imaging is a powerful diagnostic tool and has been proven to be superior to other imaging modalities when it comes to characterization of spinal injuries as it has a high resolution, no bone artefacts therefore high specificity and sensitivity leading to high accuracy and therefore has been referred to as the gold standard in neuroradiology. The most common mechanism of spinal trauma has been found to be as a result of motor vehicle accidents but in some countries falls have been the leading cause.

Objective: To determine the mechanism of injury and their association to the Magnetic Resonance Imaging scan findings in adult patients with acute traumatic spinal injury at Moi Teaching and Referral Hospital.

Methods: This was a cross sectional descriptive study carried out in the Radiology and Imaging department of MTRH between March 2019 and February 2020. Census was used to recruit 94 patients with acute spinal injury sent for MRI and who met inclusion criteria. A structured interviewer administered questionnaire was used to collect data on the demographics, history of trauma and imaging findings interpreted by the researcher and at least two radiologists. Categorical variables were analysed as frequencies and their corresponding percentages while the numerical variables were analysed as median and their corresponding interquartile ranges. Chi Square and Fischer's Exact test were used to assess association of MRI findings with causes of spinal injury. P value of less than 0.05 was considered significant. Data was presented in tables and figures.

Results: Majority of the participants were male (77%). Median age was 32 (IQR: 25-41) years. Most patients had spinal injury as a result of motor vehicle accident 80 (85.11%) followed by falls (11.70%) and the least being gunshot injury (1.06%). 69.15% of the subjects sustained spinal cord injuries, 59.57% had marrow oedema while vertebral fractures were present in 54.26%. Only 7.45 % had ligamentous injuries, 35.11% had disc injures and half of the participants had other soft tissues injuries. Cord oedema (55.32%) was the most prevalent pattern on the cord, no hemorrhage was noted and only one patient had cord transection. Lumbar vertebrae had the most fractures at 39.20%, thoracic 31.37%, cervical 27.45% and cervico-thoracic 1.96%. Disc herniation 31.91% were the majority in disc injuries while 3.19% had disc rupture. Two patients had anterior longitudinal ligament injury while 5 had posterior ligamentous complex involvement. Spinal cord injuries, fractures, ligamentous injuries and disc injuries had no association with mechanism of injury (P= >0.99, 0.71, >0.99 and 0.88 respectively).

Conclusion: Majority of the patients (85%) sustained injuries as a result of road traffic accident with the least being gunshot injuries. Spinal cord injuries (69.15%) were the most common followed by bone oedema and fractures. Ligamentous injury was the least common finding. There was no significant association of MRI findings with mechanism of traumatic spinal injury

Recommendation: Similar studies with larger sample size to ascertain the strength of association.

CHAPTER ONE: INTRODUCTION

1.1 Background

The global estimates for traumatic spinal cord injury incidence is about 23 cases per million per annum while in Africa the extrapolated incidence is about 21- 29 cases per million per annum (Yi et al., 2018). It is estimated that 3,000 people die annually from road traffic accidents and three times this number acquire injuries in Kenya. Out of these, there are 1,500 new cases of spinal injuries with about 50,000 to 70,000 of people living with spinal injuries (KNBS, 2017). On the other hand, the number of traumatic spinal cord injuries has been decreasing in developed countries yet they are on an upward trend in developing nations due to poor infrastructure, regulatory challenges and corruption (Lee et al., 2013). About 90 % of spinal cord injuries are caused by trauma and sequelae worsened in 3rd world countries as most patients are brought to the emergency department via personal vehicles instead of Emergency Medical Service and late recognition of the spinal injuries in less developed trauma care centres (Alfredo et al., 2014). Unfortunately, most of these traumas happen in middle age when productivity is at its peak affecting psychological and social health contributing to the economic and social burden borne by relatives and patients (Yi et al., 2018). Mortality risk increases with injury level and severity and is strongly influenced by the availability of timely, quality medical care which is eventually determined by early recognition.

Magnetic Resonance Imaging is a powerful diagnostic tool and has been proven to be superior to other imaging modalities when it comes to characterization of spinal injuries as it has a high resolution and no bone artefact. Its high specificity and sensitivity lead to high accuracy and therefore has been referred to as the gold standard when it comes to neuroradiology (Ghasemi et al., 2015; Kumar & Hayashi, 2016).

It is also useful in the acute setting of trauma in 24-72 hours and later 2-3weeks as a functional prognostic tool in spinal trauma (Singh et al., 2015). Clinical decisions may also be affected by the characterisation of certain lesions seen on MRI such as on-going cord compression, disc herniation and injury to the ligaments (Fehlings et al., 2017). Projection of short and long-term prognosis is beneficial to the patient, caregivers and the health care team as it will guide on the aggressiveness of the management course taken (Bozzo et al., 2011). MRI is preferably done within 48 hours after injury though there is no evidence that if done after this time limit will reduce the sensitivity than the acute one. The recommendation is for concerns on putting patients in collars unnecessarily for a prolonged period as they cause some discomfort (Schueller and Schueller-Weidekamm, 2014). MRI has the advantage of using non-ionizing radiation and non-invasive nature thus a safe diagnostic procedure. MRI scan findings reported by radiologists together with clinical parameters may be potential good predictors of surgical treatment outcomes and overall prognosis.

Studies on MRI and spinal injuries in the country are scarce and this may be due to affordability and secondly, it is a relatively new imaging modality that has been steadily gaining momentum over the last 10 years. The Ministry of health has a project of managed equipment services programme that provides modern health infrastructure, equipment and service to public hospitals and has therefore made MRI more accessible than it was before (Mutua &Wamalwa,2020). It is therefore imperative for interpreting physicians to be well conversant with patterns of MRI in spinal injury.

1.2 Statement of the problem

Spinal injury is a debilitating disease with harrowing sequelae; impacts heavily on the economy after hospitalisation. Most of these cases occur as a result of accidents yet most of these accidents are preventable. Cerván et al., (2016) postulate that insufficient imaging especially in developing countries is one of the most common causes of missed injuries. It has been proven that early MRI findings lead to early, prompt and accurate diagnosis with expeditious management avoiding unnecessary procedures (Rajasekaran et al., 2016). MRI imaging has increased the role of detection of non-contiguous spinal injury as well as the assessment of the spine (Alvand and Bencardino, 2003). Muchow et al., (2006) recommend MRI as the gold standard for cervical spine clearance for clinically suspicious patients.

MRI is still not fully utilised in Kenya due to financial constraints and affordability. In government hospitals, the average cost of doing MRI is about 80 dollars yet WHO estimation of 42% of Kenyans live below a dollar per day which makes it unaffordable to a larger part of the population. (Mutua & Wamalwa, 2020). In a study done at KNH on patterns and outcome of spinal injury, 35% of spinal injury patient who needed MRI ended up not having one as they did not have funds. The authors, therefore, resulted in plain spinal x-ray as the unifying imaging modality for all their subjects (Kinyanjui and Mulimba, 2016). The introduction of the Managed Equipment Services Programme coupled with National Hospital Insurance Fund coverage of imaging, more patients are able access imaging services despite underutilization of MRI services Mutua & Wamalwa, 2020).

While most studies show cord oedema to be the commonest, there are contradictory studies such as the one done in a large teaching hospital in Ghana that found a predominance of cord oedema at 34% but with an equally large percentage of haemorrhage and oedema (33%) as well as haemorrhage alone at 26%, therefore making up a percentage of 61.9 of all patients with haemorrhage (Ochie et al., 2013). Similarly, a study done in India found a comparable percentage of respondents with cord haemorrhage at 38.6% (Qiu et al., 2016). This finding is important as cord haemorrhage has been shown to have poor outcomes when compared to oedema.

1.3 Justification

The practice of doing MRI on patients with spinal injuries in developed countries is routine and it is yet to catch up in developing countries mainly due to financial constraints. Studies have shown that spinal stability also depends on the intrinsic intervertebral connective tissue and significant injury may be overlooked if only bony injury is considered. Consequently, it is paramount that we increase our diagnostic and interpretation to include soft tissue patterns as well as that of the ligaments (Zhuge et al., 2015). Little is known about MRI patterns in traumatic spinal injury populations from developing areas; information mostly comes from industrialized countries. MRI is limited in terms of availability and feasibility to many parts of developing countries (Kanna et al., 2016). Likewise, in Kenya studies on the MRI patterns of spinal injuries are scarce. To date, we did not come across any research conducted on the topic in Eldoret, Kenya. Orege et. al., (2013) did a study on spinal MRI in Eldoret but only concentrated on subjects with low back pain.

MTRH serves the whole of the western and south rift as the only centre with neurosurgeons thus making it difficult for peripheral hospitals to solely manage, since in some cases orthopaedic surgeons may need to collaborate with neurosurgeons for integrated management. Studying these causes and MRI patterns of spinal injury will help policymakers to make and implement guidelines to help in primary and secondary prevention, make MRI easily accessible and affordable and avail more funding for spinal injury cases. Once this is done mortality and morbidity will decrease as a result of proper MRI spinal injury protocol thus reducing delays and hospital stay eventually increasing the economic capacitance of these patients.

It is important to asses if there is a relationship between the causes of traumatic spinal injury and the MRI patterns so as to find out the predictability of the different spinal injury patterns. This can be useful in the set-up of lower level hospital where MRI services may not be available immediately. It is expected that the results of this study will improve understanding of MRI spinal injury patterns therefore contributing to data and adding to existing knowledge on the study area in Kenya.

1.4 Research question

What are the mechanism of injury and their association to the Magnetic Resonance Imaging scan findings in adult patients with acute traumatic spinal injury at Moi Teaching and Referral Hospital?

1.5 Research objectives

1.5.1 Main objective

To determine the mechanism of injury and their association to the Magnetic Resonance Imaging scan findings in adult patients with acute traumatic spinal injury at Moi Teaching and Referral Hospital.

1.5.2 Specific objectives

1. To determine the mechanism of injury in adult patients with acute spinal trauma in Moi Teaching and Referral Hospital.
2. To describe Magnetic Resonance patterns of adult patients with acute spinal trauma in Moi Teaching and Referral Hospital.
3. To determine the association of MRI patterns with mechanism of injury in adult patients with acute spinal trauma in Moi Teaching and Referral Hospital.

CHAPTER TWO: LITERATURE REVIEW

2.1 Socio-demography

Anoushka et al., (2014) posit that prevalence of spinal injury range from country to country but WHO, (2013) generalises that globally there are about 250,000-500,000 spinal injury cases every year which culminate to 40 to 80 cases per million population and mostly involving the young. While most studies show that the rate of spinal injuries in developing countries is high, Yi Kang et al., (2018) found these differences to be non-significant ranging from 13.1 to 163.4 per million people in developed countries to 13.1 to 220 per million population in developing countries with incidence of 490-526 per million populations in developed countries against a figure of 440 in non-developed countries. Studies done in Ghana showed an incidence of 8% while those in the East Africa range between six to eight percent (Ametefe et al., 2016; Mboka et al., 2016).

However, the above figures may be grossly underestimated due to the fatality of spinal injury casualty that may result in death at the time of accident thus unaccounted for (Anoushka et al., 2014). Generally, the incidence is less in developed countries when compared to developing countries mainly due to poor infrastructure and health services in the latter (Vafa Rahimi-Movaghar and Vaccaro, 2013). Males are more likely to incur the above injuries with peak ages of 20-40 years. Above mainly explained by the fact that most motor vehicle drivers are male, secondly, males are involved in occupations that predisposes to accidents and lack compliance with traffic regulation and lack of attention while driving (Kinyanjui and Mulimba, 2016; Morais et al., 2013; Wang et al., 2016).

2.2 Developmental anatomy of the spine

2.2.1 The cervical spine

A basic overview of embryology is required so as to decipher the anatomic variations at the cranio-cervical junction. As the primitive streak is regressing, the paraxial mesoderm segments into somites. At the fourth week of gestation, there are four occipital and eight cervical somites. The somites will eventually differentiate into sclerotomes, myotomes, and dermatomes, which will eventually form the vertebrae, rib cartilage, muscles, tendons, ligaments, and skin of the back.

The cranio-cervical junction is ultimately derived from the four occipital sclerotomes and the first three cervical sclerotomes. There is general agreement that the transition from the skull to the cervical spine is located between the fourth and fifth sclerotomes. The first occipital somite and sclerotome form the basiocciput. The second and third occipital somites and sclerotomes form the jugular tubercles. The caudal aspect of the fourth somite and the rostral part of the fifth somite combine to form the pro-atlas sclerotome. The pro-atlas sclerotome forms the occipital condyles, basion, opisthion, lateral rim of the foramen magnum, apical segment of the dens, and lateral masses of the atlas. Ligamentous structures derived from the proatlas sclerotome include the apical, alar, and cruciform ligaments. The proatlas and C1 sclerotomes both contribute to the posterior arch of the atlas (Woon et al., 2013).

The caudal aspect of the fifth somite and the rostral aspect of the sixth somite form the C1 sclerotome. The C1 sclerotome forms the basal segment of the dens, the anterior arch of the atlas, and contributes to the posterior arch of the atlas.

The C2 sclerotome is derived from the sixth and seventh somites. The centrum of the C2 sclerotome forms the body of the axis. The neural arch forms the posterior arch and facets of the axis. Thus, the axis is formed from three sclerotomes: the proatlas, C1, and C2.

The intervertebral border zones located between the apical and basal segments of the dens and between the basal segment and the body of the dens do not ultimately differentiate into nucleus pulposus and annulus fibrosus, as is the case in the subaxial cervical spine. This mesenchyme eventually forms the upper apicodental and the lower subdental dental synchondroses. Remnants of the regressed subdental disc elements can occasionally be seen following fusion of the C2 ossification centers, referred to as the ossiculum Albrecht (Akbarnia et al., 2010).

The atlas (C1) is typically derived from three primary ossification centers, one anterior and two posterior. The anterior ossification center forms the anterior arch. The posterior ossification centers form the lateral masses and neural arch. Neurocentral synchondroses are located between the anterior and posterior ossification centers on both sides of the midline. The intraneural synchondrosis is located between the two posterior ossification centers, generally at the midline. Ossification of the anterior arch and the neurocentral synchondroses is complete in most individuals by twelve years of age. The posterior arch and intraneural synchondrosis are generally ossified by 4 to 5 years of age. The atlas has no secondary ossification centers (Woon et al., 2013).

2.2.2 The thoracic spine

The thoracic segments are formed from the centrum, and right and left neural arches. The neurocentral synchondroses are located between the central and neural arches. The posterior synchondroses are located between the dorsal tips of the neural arches. The posterior synchondroses close within 2 to 3 postnatal months. The neurocentral synchondroses of the thoracic segments close later than the cervical and lumbar segments and close in a rostral to caudal fashion beginning around 5 to 6 years of age. It is not uncommon to see partially unfused thoracic neurocentral synchondroses in adults (Woon et al., 2013).

There are five typical secondary ossification centers found within each thoracic segment, including ring apophyses along the superior and inferior margins of the vertebral body, the tip of each transverse process, and the tip of the spinous process. Additional secondary ossification centers can be found along the articular and nonarticular surfaces of the transverse processes, upper costal demifacets, and lower costal demifacets (Akbarnia et al., 2010).

Complete fusion of the secondary ossification centers can occur as early as 15 years of age. Incomplete fusion of the secondary ossification centers may be seen in the early part of the third decade. Complete fusion is usually present by the mid-20s. Fusion of the neurocentral synchondroses in the thoracic segments may be incomplete in adulthood. The typical appearance of the ossification centers of the typical thoracic vertebrae at various ages. The typical thoracic vertebrae are derived from three primary ossification centers, a centrum and two neural arches. The neurocentral synchondroses are located between the Centrum and the neural arch ossification centers The intraneural synchondrosis is located between the neural arch ossification centers posteriorly (Woon et al., 2013).

2.2.3 The lumbar spine

Similar to the cervical and thoracic spine, lumbar segments are formed from a centrum and neural arches on both sides of the midline. The centra begin to ossify prior to the neural arches. Ossification proceeds from L1 to L5 and all lumbar segments are visible by the fourth fetal month. At birth, three ossification centers are observed. The neurocentral synchondroses are located between the centra and neural arches. The posterior or intraneural synchondroses are located between the dorsal tips of the neural arches. The posterior synchondroses of L1–L4 fuse at about one year of age. The range of posterior synchondroseal fusion at L5 is more variable, and may take place up to 5 years of age. Non fusion of the laminae of the lower lumbar segments is common, particularly at L5). There is 75% closure of the lumbar neurocentral synchondroses by four years of age and complete closure by 10 years of age. The typical appearance of the lumbar primary ossification centers at various ages. There are seven secondary ossification centers found within each lumbar segment, including ring apophyses along the superior and inferior margins of the vertebral body, two mammillary processes, the tips of the transverse processes, and the tip of the spinous process (Woon et al., 2013).

The sequence of secondary ossification center closure generally starts with the mammillary processes, followed by the transverse processes, spinous processes, and ring apophyses. Complete fusion of the secondary ossification centers is usually attained by the middle of the third decade.

During the embryonic period, 9 to 16 weeks gestation, the vertebral column elongates more rapidly than the spinal cord. This results in a change in the position of the distal spinal cord relative to that of the most caudad segments of the vertebral canal, commonly referred to as ascent of the cord tip. This results in a discrepancy between the sites the lumbar nerve roots exit from the spinal cord at the segmental level and where they exit the spinal canal into the vertebral neural foramina at the vertebral level. For example, the L3 nerve roots exit through the L3–L4 intervertebral foramina, but because of the more rostral termination of the spinal cord, the L3 nerve roots arise from the spinal cord at the T10–T11 vertebral level. The lumbar lordosis is a secondary spinal curve. The primary curve of the spine in utero in the first few months of life is apex posterior kyphotic until the secondary lordosis of the cervical spine develops when infants begin to raise their heads. The lumbar lordosis starts to form in conjunction with upright posture and progresses until 14 to 16 years of age (Akbarnia et al., 2010).

2.2.3 The sacrum and the coccyx spine

The sacrum is made up of five segments that are each formed from five primary ossification centers: a centrum, two neural arches, and two costal processes located lateral to the centrum. Sacral secondary ossification centers include the ring apophyses, transverse processes, spinous processes, mamillary processes, anterior and posterior costal epiphyses. The sacral secondary ossification centers range in number from 35 to 37 (Woon et al., 2013).

The presence or absence of the primary and secondary ossification centers varies according to vertebral level in the sacrum. The primary ossification centers forming the costal processes are absent at S5 and variably present at S4. The secondary ossification centers of the transverse processes are variably present at S4. The secondary ossification centers of the costal epiphyses form anteriorly at S1–S4 and posteriorly S1–S2. The secondary ossification enters of the spinous processes only develop from S1 to S3. The secondary ossification centers forming the mamillary processes only develop at S1 (Gilchrist, 2008).

All primary ossification centers are present at birth and are fused by the age of 6 years, except for the laminae which fuse between 7 and 15 years of age. Non fusion of the S1 laminae is commonly observed variant. Fusion of the sacral vertebral bodies proceeds from caudal to rostral, beginning at age 17 to 18 years and complete by 25 years. There is significant asymmetry in the timing of fusion of the primary and secondary ossification centers that can simulate fractures and other pathology. Complete fusion of the secondary ossification centers is not achieved until the end of the third decade.

At birth, the spine has a dorsal convex C-shape. The thoracic and sacral kyphotic curves are considered to be the primary curves of the spine. As the child assumes an upright posture, ambulates, and sleeps in the supine position, the sacral promontory rotates anteroinferiorly, the sacral kyphosis increases, and the lumbosacral angle increases to an average of 41° with a standard deviation 7.68°in adulthood (Akbarnia et al., 2010).

The sacroiliac joints form by the seventh month of gestation. At birth the sacroiliac joints are flat and oriented to the long axis of the spine. The adult curvature of the sacroiliac joints is formed with the assumption of upright posture and ambulation.

The ossification sequence of the coccygeal segments is not completely understood. The coccygeal segments likely develop from their own primary ossification centers. However, the cornua of the Coccyx1 segment may arise from its own ossification center. The Coccyx1 ossification center is visible within the first post-natal year, Coccyx2 between 3 and 6 years, Coccyx 3 at 10 years, and Coccyx at puberty. The adult configuration of the coccyx takes shape in puberty (Woon et al., 2013).

2.3 Normal imaging anatomy of the spine

2.3.1 The vertebrae

The veterbral spine is composed of a total of 33 vertebrae, consisting of seven cervical, twelve thoracic, five lumbar and five fused sacral bones and three to five fused small bones contributing to the coccyx. Two percent of individuals have four lumbar-type vertebrae, while 8% have six lumbar-type vertebrae with lumbarization of S1 (Goethem et al., 2000).

C1 (atlas) is a bony ring. Posterior arch of the C1 is longer and carries a groove on the superior surface, which is occupied by horizontal V3 segments of the vertebral artery. The lateral masses bear the superior and inferior facets and articulate respectively with occipital condyles superiorly and superior articular facets of C2 inferiorly. C2 has dens or odontoid process that projects upward from the body of the C2. The odontoid process articulates with the posterior aspect of the anterior arch of C1. There are two superior articular facets which are just lateral to the dens to articulate with the inferior articular processes of the C1 The lateral mass has forward facing facet along undersurface, which articulates with the superior articular process of the C3. Subaxial, third to seventh, cervical vertebrae are morphologically similar having a central body with superior and inferior endplates, facets, and transverse processes as well as posterior neural arch. The dorsal neural arch is composed of lateral masses and lamina one on each side. The laminae fuse to give rise to the spinous process. Lateral masses of the cervical vertebra have on either side a foramen transversarium through which the vertebral artery transmits from C6 to C2. There may be more than one foramen transversarium on each side (Goethem et al., 2000).

The typical thoracic or lumbar vertebra has a body, posterior neural arch, facets and transverse processes on each side, and a single midline spinous process. The vertebral bodies increase in size inferiorly. The dorsal neural arch consists of pedicle and lamina. Two superior and inferior articular processes articulate with those of vertebra above and vertebra below, respectively, to form the facet joints.

The spinous process projects posteriorly and inferiorly from the vertebral arch and overlaps the inferior vertebra. The thoracic vertebrae have three facets on each side for the articulation of the ribs. Superior articular facets are directed postero-lateral and allow for rotation, flexion, and extension. The lumbar articular facets are vertical with the superior articular processes directed postero-medially with curved articular surface, which allows the movement in flexion and extension and lateral flexion but limits rotation (McCuen, 2009).

2.3.2 The spinal cord

The spinal cord is long cylindrical extension extending from the medulla oblongata cranially to the lower end which tapers into a cone. In the adult the spinal cord ends at the L1-L2 level and in children it is found a bit lower at the level of L2-L3 It has two enlargements, which occupy the regions of limb plexuses. These are the cervical (C5-T1) and lumbar (L2-S3) enlargements, their vertebral level however is at C3-T1 and T9-L1 respectively; the enlargements are due to greatly increased mass of motor cells, which supply the upper and lower limbs respectively (Bican et al., 2013).

The spinal cord receives its supply from one anterior spinal artery and two posterior spinal arteries from either the vertebral artery or the posterior inferior cerebellar artery. In the lower down region, the spinal arteries receive blood through radicular arteries that reach the cord and the roots of the spinal nerves. The radicular arteries are actually branches from many arteries like the vertebral, cervical, intercostal, lumbar, and even sacral arteries. The largest radicular feeder from the left posterior intercostal artery to the anterior spinal artery is between T9 and T12, called the artery of Adamkewicz. All the radicular and spinal arteries anastomose with each other to form an anastomotic pial plexus called vasocorona. The spinal cord drains to a plexus of veins anterior and posterior to the cord, which in turn drains along the nerve roots to segmental veins. The plexus communicates with: the veins of the medulla at the foramen magnum; the vertebral veins in the neck; the azygous veins in the thorax and the lumbar veins in the lumbar region (Rabischong, 2004).

2.3.3 The ligaments

There are intrinsic and extrinsic types of ligaments supporting the craniocervical junction. MRI can demonstrate normal tectorial membrane and transverse ligaments. The ligaments are a low signal on T1 and T2 and better seen if there is surrounding blood and fluid. Alar ligaments have an oblique vertical course and insert on to the occipital condyles and adjacent superior aspect of the lateral mass of C1, although, in approximately one-third of individuals, it exclusively inserts on occipital condyles. Alar ligaments are not commonly seen on MRI, individually. The transverse ligament is a vital component of the cruciform ligament, the largest, strongest craniocervical ligament. The superior and inferior components of the cruciform ligament provide no significant craniocervical stability. The transverse ligament maintains stability at the craniocervical junction and divides the ring of the atlas into an anterior compartment which houses the odontoid process and posterior chamber which contains the spinal cord and spinal accessory nerves. The transverse ligament fixes the odontoid process anteriorly against the posterior aspect of the anterior arch of C1. The transverse ligament attaches to the lateral tubercles of the atlas bilaterally, dorsal to the odontoid process of C2. Smooth gliding movement occurs between the odontoid process and the transverse ligament owing to the presence of synovial capsule and fibrocartilaginous surface.

There are several other ligaments in the cervical spine including anterior atlantooccipital membrane, anterior atlantoaxial membrane, anterior longitudinal ligament, posterior occipito-atlanto membrane, posterior atlantoaxial membrane, nuchal ligament, flaval ligaments, and interspinous and supraspinous ligament. Ligaments are a low signal on T1 and T2 and better seen when there is a contrast with the surrounding tissue such as blood or fluid or injured (Bican et al., 2013).

The anterior and posterior longitudinal ligaments maintain the structural integrity of the anterior and middle columns. The posterior column is held in alignment by a complex ligamentous system. If one column is disrupted, other columns may provide sufficient stability to prevent spinal cord injury. If two columns are disrupted, the spine may move as two separate units, increasing the likelihood of spinal cord injury (Kumar and Hayashi, 2016).

2.3.4 Intervertebral discs

Intervertebral discs are located between the vertebral bodies and contribute about one-third of the height of the spinal column. The disc is made up of central gelatinous nucleus pulposus and the peripheral annulus fibrosus. The discs are attached to the bony endplates of the vertebral bodies with hyaline cartilage endplates. Nucleus pulposus provides spine mechanical flexibility and strength. It bears the stresses on the spine and redistributes to the annulus fibrosus and the endplates. Annulus fibrosus is a structure made up of collagenous tissue at the periphery of the nucleus pulposus. Cartilaginous endplates provide the mechanical barrier and transport nutrients for the disc (Rodrigues-Pinto et al., 2014).

2.3.5 Paraspinal Muscles

The back muscles consist of smaller individual muscles arranged symmetrically in pairs separated by the spinous processes, interspinales muscles, and ligamentum nuchae. The paravertebral muscles consist of large muscles which extend from the base of the skull to the sacrum. The splenius capitis, semispinalis capitis, and longissimus capitis are the prime extensors of the head and neck. The splenius capitis arises from the C3 to T3 spinous processes and inserts on the superior nuchal line. The splenius cervicis arises from the T3 to T6 spinous processes and first three cervical transverse processes, respectively. Immediately deep to these muscles lie smaller semispinalis capitis and longissimus capitis. Levator scapulae, multifidus, and interspinales muscles are less bulky and located more centrally.

Trapezius muscles are separated from the paraspinal muscles by fat. On cross-sectional imaging, the mid-cervical images demonstrate longissimus capitis and cervicis while the multifidus and semispinalis cervicis more medially. Splenius and semispinalis capitis, as well as cervicis muscles, lie deep to the trapezius muscles in the lower cervical spine. The paraspinal musculature may be the site for inflammatory or neoplastic processes and vascular malformations.

The posterior elements such as lamina and the spinous processes of the vertebral body serve as the framework for the muscles of neck extension. The lower paraspinal muscles provide stabilization to the lumbar spine and act as an initiator for movement. The intersecting imaginary line passing through the transverse processes divides the paraspinal muscles into the anterior and posterior groups based on the imaginary plane passing through the transverse processes (Hu et al., 2014).

Erector spinae group consists of multifidus medially and longissimus intermedius, and iliocostalis laterally. They are also the primary extensors of the trunk at the lumbar spine. The multifidus has five fascicles arising from the spinous processes and laminae and attaches to the mammillary, accessory, and zygapophyseal processes and joint capsule and posterior superior iliac spine and sacrum. The multifidus maintains the stability of the lumbar spine. The superficial fibers are responsible for the spine orientation and the deep portion for intervertebral shear and torsion. The longissimus muscles are slender and lie between the multifidus and the iliocostalis. The bundles of the longissimus arise from the accessory processes from L1 to L4 and extend to both the adjacent transverse processes, the mamillo-accessory ligament, and mammillary process. The bundle from L5 typically continues along the transverse process and over the accessory process to the mamillary process. The L1-L4 fascicles join the fascicle arising from the posterior surface of the L5 transverse process, which converges to form a common tendon of insertion, named as the lumbar intermuscular aponeurosis. The iliocostalis muscle arises from the tips of the transverse processes and the adjacent medial layer of the thoracolumbar fascia, which then inserts on the iliac crest lateral to the posterosuperior iliac spine.

The erector spinae is supplied by lumbar dorsal rami which divide into medial, intermediate, and lateral branches. The medial branches provide the multifidus muscles. The intermediate branches supply the longissimus muscles. Lateral branches of L1-L4 supply the iliocostalis lumborum (Hu et al., 2014).

2.3.6 Prevertebral Soft Tissue

Evaluation of the prevertebral soft tissues is difficult on radiographs and CT due to limited ability to differentiate the anatomical structures from the abnormal soft tissue pathologies such as hematoma, edema, or abscess. Increase in soft tissue thickness has been proved to be a good indicator of underlying ongoing pathology. Rojas et al. described the upper limits for normal cervical prevertebral soft tissue in cervical spine measuring 8.5 mm at C1, 6 mm at C2, 7 mm at C3, and 18 mm each at C6 and C7. Although the typical thickness does not exclude any underlying soft tissue injury or infection. MRI can directly demonstrate the underlying pathology due to its better soft tissue resolution (Mills & Shah, 2015).

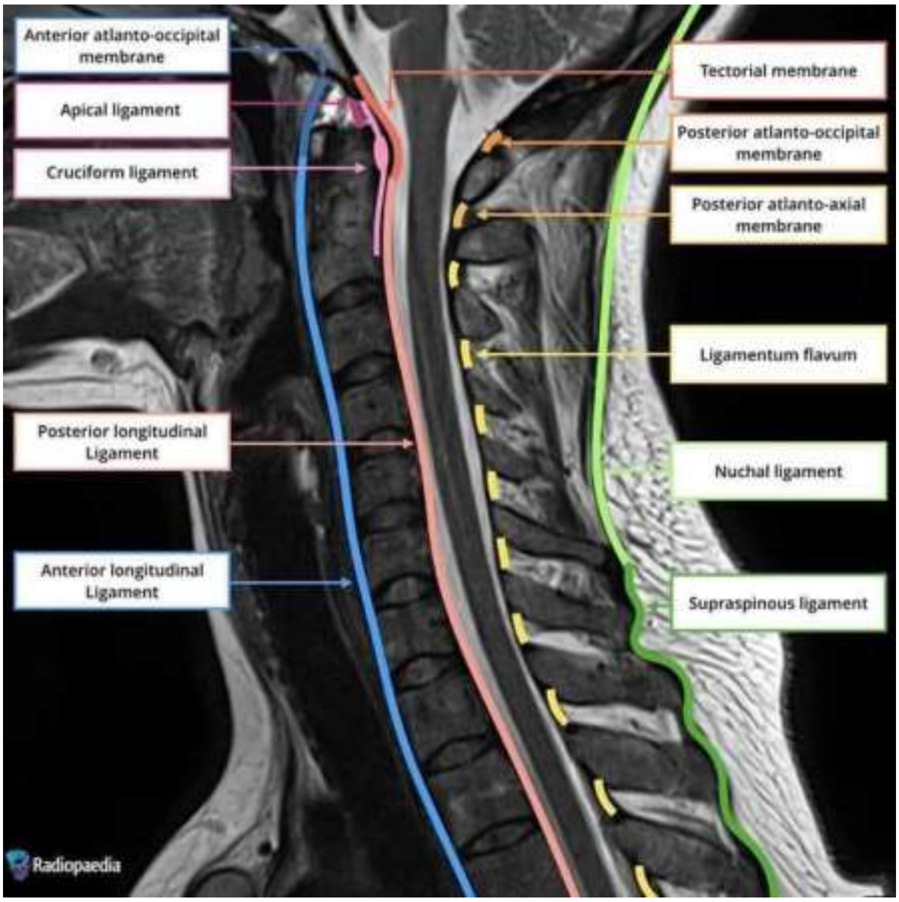

Figure 1: Normal Magnetic Resonance Imaging of the cervical spine showing the various ligaments

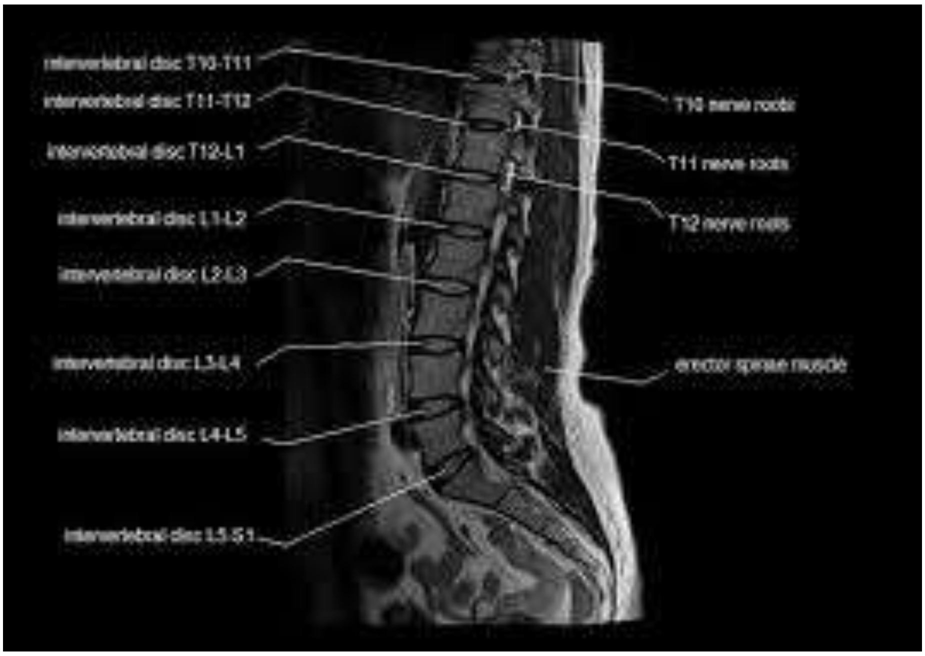

Figure 2: Normal Magnetic Resonance Imaging of the lumbar spine

2.4 Magnetic resonance sequences in spinal trauma

Standard MRI pulse sequences used in spine imaging include T1-weighted, T2-weighted, and STIR-weighted sequences; T2* gradient-echo sequences; 3D imaging techniques; and contrast-enhanced imaging techniques.

In spinal trauma, the nomenclature as it relates to the “standard” pulse sequences used for most musculoskeletal MRI has been simplified by using the following terms: T1-weighted image, T2-weighted image, Fluid-sensitive sequence, such as STIR or fat suppressed T2-weighted image (Mirrowitz,1993).

In contrast to imaging techniques based on Xray absorption, such as conventional radiography and CT, the appearance of biologic tissue with MRI, that is, its relative brightness or darkness, is determined to a great extent by the operator-chosen parameters of the MR pulse sequence used to acquire the images. Thus, CSF may appear bright, dark, or intermediate in signal intensity, depending on the MR pulse sequence and the selective parameters in that sequence. Each MR pulse sequence has its own specific strengths and weaknesses, and typically a combination of pulse sequences is used in a standard examination. Conventional SE (and FSE) sequences make up the bulk of sequences in the MRI assessment of spine anatomy. Intermediate-weighted sequences are useful because they produce images with the highest signal-to-noise ratio and, therefore, provide better resolution than T2-weighted FSE images do.

T1-weighted images, which provide nearly as high a signal-to-noise ratio, are also useful in showing musculoskeletal anatomy. T2-weighted sequences tend to have the poorest signal-to-noise ratio, and therefore the poorest resolution, but they are used primarily for their fluid sensitivity and their ability to detect pathology that has a high fluid content as in the case of ligament tears or bone-marrow edema). T2sequences can also give a rough depiction of anatomy, although it is inferior to that of intermediate weighted and T1-weighted sequences. Fluid-sensitive sequences include T2, fat-suppressed T2-weighted, and STIR sequences. Depending on the clinical situation, each specific MRI sequence has some optimal and some less than optimal characteristics (Symons et al., 2006).

2.4.1 T1-Weighted SE

Standard T1-weighted SE sequences use a short TR (250 to 700 ms) and a short TE (10 to 25 ms) to maximize T1 differences of the tissues being imaged (Symons et al., 2006). The ability to depict anatomic detail, bone-marrow abnormalities (including marrow-infiltrating processes and fractures), blood products, melanin, and enhancement after the administration of gadolinium are the strengths of T1-weighted SE sequences. Proton-poor substances, such as air, and substances that do not have mobile protons, such as cortical bone or other calcified structures produce no detectable signal and produce a relative signal void. Fast-flowing blood may generate a flow void and appear dark on T1-weighted sequences, mostly because of a lack of refocusing of the blood, which is excited by the 90-degree pulse but not by the 180-degree pulse.

Other tissues, such as fat, melanin, fatty bone marrow and blood products appear bright on T1-weighted images. Fluids, such as cerebrospinal; fluid show low signal on standard T1-weighted sequences. Tissues with mixed characteristics such as abscesses, synovium, and complex cysts, tend to show intermediate signal intensity that is somewhere between that of collagenous tissue and fat. Usually, the higher the protein content of the fluid, the brighter the fluid appears on T1-weighted images (Symons et al., 2006).

2.4.2 T2-Weighted SE and T2- Weighted FSE

T2-weighted SE and FSE sequences use a relatively long TE and long TR to maximize the T2 differences in the tissues. Both sequences, when combined with fat suppression, are excellent for detecting edema/ fluid, which appears bright and is often associated
with pathologic processes such as tumors, infection, fractures, and ligamentous injury. The T2-weighted SE and FSE sequences are also good for evaluating ligaments and fluid-filled structures such as cysts. As on T1-weighted SE sequences, air, cortical bone, calcified structures, and fast-flowing blood appear dark on T2-weighted sequences. Hyperacute blood and subacute blood are bright on T2-weighted SE and FSE sequences. These sequences also have
been shown to be useful for differentiating between fluid and tissue with a high fluid content. One of the limitations of standard T2-weighted SE sequences is the relatively long image acquisition times. FSE imaging represents a technical innovation that permits much more rapid imaging by using T2 contrast and multiple 180-degree RF pulses to create multiple echoes during a single TR period. The series of echoes is called the echo train, and the number of echoes produced in a single TR period is known as
the echo train length. Because of their fast acquisition times, T2-weighted FSE sequences have largely replaced standard T2-weighted SE sequences.

The major weakness of T2-weighted SE and T2-weighted FSE sequences is their inability to detect marrow pathology when not combined with fat-suppression techniques. This limitation is due to fat and water both being bright on non-fat suppressed T2-weighted FSE and SE sequences (Mirrowitz,1993).

2.4.3 Fat Suppression with T1-Weigghted and T2-Weighted Images

Fat suppression commonly is achieved by spectral fat suppression or a STIR technique. Spectral fat suppression imaging is restricted to MRI systems with midlevel and high magnetic field strength because of the necessity of identifying distinct fat and water resonance peaks and selectively suppressing the signal arising from adipose tissue, a process that depends on the presence of a relatively strong magnetic field. Combined with T2-weighted or intermediate-weighted imaging, this technique is particularly useful in detecting bone bruises and osseous stress injury; the hyperintense intraosseous fluid that accumulates secondary to osseous contusion and microtrabecular fractures appears particularly conspicuous in contrast to the adjacent suppressed normal marrow fat signal (Potter et al., 1998). On T1-weighted images, fat suppression can enable the differentiation of fat-containing masses from other tissue that may contain elements of increased signal. Additionally, it can be used to verify the presence of fat within a lesion and to increase the conspicuity of enhancing masses on contrast enhanced T1-weighted images.

One of the disadvantages of T2 and T1 sequences is incomplete suppression of the signal from fat, due to local magnetic field inhomogeneities and susceptibility effects. This effect is most prominent with images of curved surfaces, such as in the shoulder and ankle, or of any body part in the presence of metal or air. Additionally, as just mentioned, fat suppression requires higher-strength magnets to ensure proper fat suppression than is generally required for non-fat-suppressed MRI. STIR sequences often are used to overcome the effects of magnetic field inhomogeneities seen with fat-suppression techniques (Potter et al., 1998).

STIR is another MRI pulse sequence commonly used in spine imaging and, like T2-weighted sequences with fat suppression, is excellent for detecting fluid and edema when administered with a long TE. STIR can be used as an alternative to T2-weighted imaging**.** On fluid-sensitive images such as STIR, fluid appears bright and makes the edema and fluid associated with certain types of pathology more conspicuous than they are on non-fluid-sensitive sequences. Such pathology includes fractures, ligament tears, and bone contusions. Unlike T1-weighted and T2-weighted fat-suppressed sequences, STIR uses a 180-degree RF inversion pulse, followed by a 90-degree RF pulse after TI to nullify the signal from fat. Because of this phase refocusing inversion pulse, STIR sequences are less susceptible to magnetic field inhomogeneities and subsequent susceptibility effects, which often result in inhomogeneous fat suppression on SE and FSE sequences. The STIR FSE technique has been shown to be superior to the fat-suppressed FSE technique for cervical and thoracic MR imaging.10 One of the major weaknesses of the STIR sequence, however, is that it suppresses the signal from all tissue with T1 signal characteristics similar to those of fat. Therefore, STIR pulse sequences should not be used with gadolinium contrast because gadolinium has relaxation properties similar to those of fat tissue, and thus all tissue with the same TI as fat will also have its signal suppressed (Mirrowitz,1993).

2.5 Mechanism of spinal injury

The two forces involved in blunt spinal injury are either due to a change in velocity of part of the body or direct force to the head or face against an immovable object with force transmitted down the spine. Acceleration deceleration force, also known as whiplash injuries is a result of a change in velocity causing head and neck movement leading to extension and flexion injury. This abrupt jerking motion causes the head to jerk and be stretched beyond its normal range of motion. This motion results in the straining of the muscles and ligaments of the neck. If the acceleration or deceleration motion is extreme enough, then fractures of the vertebral column occur. The above injury is mostly seen in motor vehicle collision leading to high imparted energy while blunt injuries cause low imparted energy forces. The commonest site of higher energy forces is the cranio-vertebral junction involving fractures of C1/ C2 vertebrae, cervico-thoracic junction and thoracolumbar junction (Kulvatunyou et al., 2012).

The most common cause of spinal injury is due to preventable trauma (WHO, 2013) resulting from motor vehicles accident followed by trauma due to falls (Ghasemi et al., 2015; Wang et al., 2016). This was echoed in a Kenyan study on patterns and outcomes of spinal injury at Kenyatta National hospital (Kinyanjui and Mulimba, 2016). Studies done in Tanzania showed that motorcycles are the major causes of motor-vehicle injuries as they are found to be easily accessible and affordable (Mboka et al., 2016). However other authors such as Kanna et al., (2016); Mohamed et al., (2016) and Rutges et al., (2017) found falls to be the commonest cause of spinal injury. Rutges et al., (2017) found 58% in falls followed at a distance by sports at 4% with a p-value of less than 0.005. Likewise, findings done in the USA and India had falls as the most common at about 40% but followed by motor vehicle accidents at

20% though the former had a small sample size of 25 (Liu et al., 2015; Mabray et al., 2016; Nagvekar et al., 2017).

Gunshot wound is another cause prevalent in the developed countries with an average of 18-30/% because of ease of access to such ammunition (Joseph et al., 2015). Assault is not popular among the causes and has been found to be at 1%-3%. Nonetheless, there is a study in Ghana done by Ochie et al., (2013) which found a high percentage of 6% contrary to all other studies done.

Consequently, the mode of transport to the Hospital affects the triage acuity as patients with spinal injuries who arrive in private vehicles are often triaged to low acuity as compared to those who arrive in ambulance eventually affecting prognosis (Alfredo et al., 2014). On the same note, most patients brought in via EMS tend to have gotten on-site emergency care by skilled personnel getting proper emergency care leading to reduced mortality and morbidity (Srivastava et al., 2015).

2.6 Patterns of Spinal Injury

The most common level of injury is the cervical spine which is normally associated with head injuries in adults (Mabray et al., 2016; Yi et al., 2018) as opposed to children where we have a wide range of difference in terms of injury patterns and mechanism in children (Leonard and Jaffe, 2014). However, few studies like the one done in Mulago hospital found the number of cervical and lumbar spinal injuries to be the same (Okello, Nyati, and Naddumba, 2016).

2.6.1 Spinal cord injuries

Nagvekar R.A and Nagvekar P., (2017) performed a study in India on spinal injury where they came across oedema of the spinal cord as the commonest pattern with the least being transection of the spinal cord at 2%. Similarly, other studies such as the one done by Parashari et al., (2011) had the same findings with cord oedema without haemorrhage as the most common finding at 45% with a p-value of less than 0.005. However, one study that was done in Lagos Nigeria (Ochie, Okpala, Ohagwu, and Eze, 2013) found haemorrhage together with oedema to be the most repetitive pattern at 28%. This is significant as in their study, Parashari et al., (2011) found that spinal cord haemorrhages had the worst prognosis and was also the least pattern in their findings.

Transection injuries are fatal as when they happen they lead to complete spinal paralysis. Luckily they are rare and not picked on many studies but a few with an occurrence of about 2% as seen in the study done by Nagvekar et al., (2017).

2.6.2 Ligamentous injuries

Ligamentous injuries are important aspect of MRI imaging as disruption of all the three columns constitutes to an unstable injury. All non-pathological ligaments except the interspinous and supraspinous ligaments will appear as areas of low signal intensity and the latter seen as a striated appearance with low signal intensity areas combined with high signal intensity areas related to fat on T1W images. Tears of the ligament can either be complete or incomplete, the former is seen as high signal intensity on STIR as there is a lack of intact fibre while the latter will show high and low signal intensity on STIR images due to adjacent oedema and haemorrhage. The various ligament injuries are associated with the mechanism of trauma in that hyperflexion of the spine will culminate in impairment of the anterior column or combined anterior and posterior column. On the other hand, hyperextension will cause posterior column or posterior and middle column damages thus affecting the posterior longitudinal ligament, supraspinous, interspinous, ligamentum flavum and facet joint capsule (Kumar and Hayashi, 2016). When a ligament is stretched beyond the limit or is ruptured, a gap may be seen and the surrounding soft tissue may have increased signal intensity on T2 weighted as a result of an accumulation of free water content from the extracellular fluid and surrounding haemorrhage. Maung et al., (2017) found ligamentous injury to be about 16 % of all injury while other studies have found lower figures of 6% in which all the ligaments were generalised (Mohamed et al., 2016). However, a study done in Spain was more specific and ligamentum flavum was found to be the most common ligament injury at 51% while posterior longitudinal was the least at 45% (Martínez-Pe´rez et al., 2014).

2.6.3 Osseous injuries

The three-column model helps to identify stable versus unstable vertebral injuries. Three vertical parallel columns divide the vertebrae into: anterior, middle and posterior solely to evaluate the stability of the spine. When two adjacent columns are disrupted then the injury is said to be unstable. The anterior column consists of the anterior two-thirds of the vertebral body and anteriorly two-thirds of the intervertebral disc; the middle has both posterior third of the vertebral column and intervertebral disc whilst the posterior column has the remainder which consists of pedicles, facets, articular process, neural arch and interconnecting ligaments (Guarnieri et al., 2016).

There are four injury bony patterns as per the Denis classification: compression, burst, flexion-distraction and fracture-dislocation. When moderate flexion and compression occurs, the anterior longitudinal ligament complex is pulled longitudinally and the anterior vertebral body bears most of the force since this ligament is very strong thus leading to wedge compression fractures. This will be seen on imaging as diminished heights of the anterior edge of vertebral body segments and mostly involves the C5-C7 vertebral bones (Gomleksiz et al., 2015).

Flexion with severe axial compression of the cervical spine results in flexion tear-drop fracture. An anterior inferior part of the vertebral body is fractured and the segment displaced anteriorly which makes it look like a teardrop. This type of injury is unstable as all the columns of the vertebrae are involved and often leads to injury to the spinal cord (Gomleksiz et al., 2015).

At the level of the thoracolumbar junction, flexion-distraction leads to chance fractures where vertebral fracture extends anteroposteriorly and mostly involves T10 and L2 vertebrae. Burst fractures are a result of excessive compressive force that is transmitted to the spine axially and a disc fracture into its adjacent lower vertebral body. This results in disruption of the anterior and middle column. On imaging, fragments will narrow the spinal canal and compress the spinal cord. In the upper cervical spine, axial forces transmitted through the occipital condyle causes displacement of masses laterally leading to fracture of anterior and posterior arches and avulsing the transverse ligament (Kumar and Hayashi, 2016).

Hyperextension injuries are uncommon and are defined by osseous and or ligamentous disruption of all columns. This is seen as widening of the intervertebral space, increased interspinous distance and retrolisthesis. This mechanism causes traumatic spondylolysis of the axis at the upper cervical spine causing the hangman fracture which involves the interarticularis part bilaterally and or the pedicles, the body, the facets and the transverse process. The intervertebral disc at C2/C3 is normally ruptured. Extreme shear and rotational forces cause fracture-dislocation that fall under type 4 in Denis classification. Typically occurs when there is a strong force of impact on the person's back while the lower body is rotated to one side. This type of injury is associated with unilateral or bilateral facet joint luxation. Rotation and flexion will cause a unilateral luxation while rotation and compression result in bilateral luxation causing instability of the vertebral column. Mostly the thoracolumbar junction is affected because the physiologic biomechanical reduction of its vertebral joints makes it prone to a rotational injury. Radiologically, a convex rather than a normal concave appearance of the articular surface (reverse Humburg sign) can be identified (Schueller and Schueller-Weidekamm, 2014).

In a local study done in the biggest referral hospital in Kenya, Kenyatta National Hospital, wedge compression fracture was the commonest followed by burst fractures (Kinyanjui and Mulimba, 2016). MRI is sensitive in identifying osseous injury with tiny discernible structural changes such as compression and cortical bone by displaying marrow oedema and haemorrhage as a hyperintense signal on fluid sensitive sequences STIR images. Rajasekran et al., (2016) found MRI to have a higher sensitivity of 56% on MRI in detecting B2 fractures against those mainly caused by hyperextension injuries leading to anterior longitudinal ligament injury against 47% sensitivity in CT with a p-value of less than 0.001. As per the AO spine injury classification, B2 involves injury through the vertebral body leading to a hyperextended position of the spinal cord. In their study on the comparison between CT and MRI, they found the latter revamped diagnosis of 40% of subjects by identifying 18 occult injuries thereby changing the management in 16% of the patients.

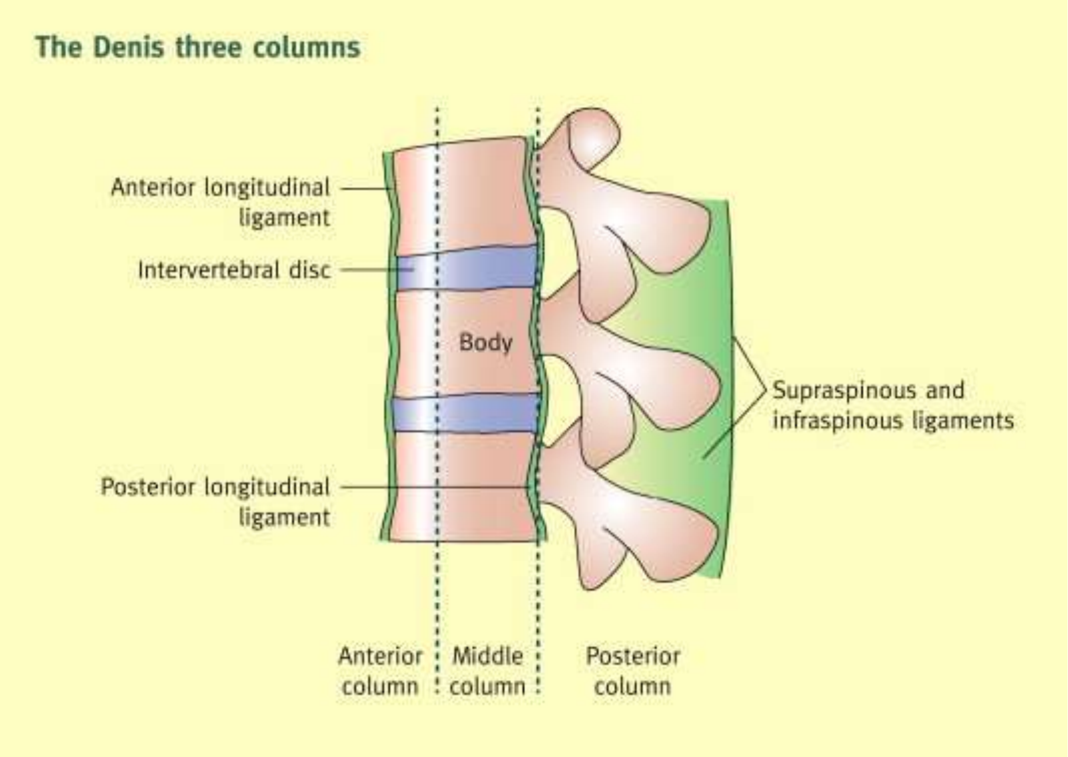

Figure 3: Denis three columns model

(Tambe & Cole, 2012)

2.6.4 Intervertebral disc injuries

Disc herniation as a result of trauma occurs more commonly in the cervical and thoracic region, with an incidence of about 54% between C4 and C7 vertebral bodies. It involves the displacement of the disc material beyond the limits of the intervertebral disc space. In disc herniation, the displacement of the intervertebral disc extends beyond the confines but involves less than 25% of the circumference whereas in disc bulge more than 25% of the circumference is involved. Disc herniation can either be protrusion or extrusion where in the former the base of the protruded disc is wider than the dome and the opposite true for the latter. Flexion-distraction and flexion compression type of force are frequently associated with disc herniation. The normal intervertebral disc on MRI is seen as hypointense on T1 weighted images and intermediate in signal on T2 weighted. When injured, the disc usually has increased signal intensity than the adjacent disc on T2 weighted and the level of injury may be adjacent to other tissues damaged. Disc herniation appears isointense and adjacent to the disc of origin (Kumar and Hayashi, 2016).

2.7 Prevention of spinal injuries

There is a need for strategies for prevention of spinal injuries as these types of injuries have high mortality and morbidity thus affecting the quality of life both to the patients and their families. Kinyanjui and Mulimba, (2016) found mortality of spinal injury to be as high as 40% and more so for the cervical spine trauma. Prevention of spinal injuries can be categorised into two: primary and secondary prevention. Primary prevention tries to avert the cause while the secondary one prevents further complications once primary has occurred.

Cervical spine injuries tend to occur together with head injuries and several experimental studies done have shown that the use of helmets, neck collars, face masks, seatbelts and shoulder pads help reduce the number of spinal injuries for passengers in fast-moving vehicles (Hodgson and Thomas, 1981).

Other authors have proposed that data on spinal injury should be well recorded and published for the policymakers to ascertain the magnitude and therefore implement course and action that will lead to prevention (Cripps et al., 2011).

Control of human factors and employing stringent policies to those who break the law has also been considered as part of the prevention of injuries in general. This includes: only licensed drivers should be on the road, intoxicated drivers heavily punished, regular testing of vehicle roadworthiness for public transport and improved road infrastructure.

For secondary prevention to occur, Emergency Medical Service should attend to patients at accident sites so that only qualified personnel will give medical services to these patients since they are trained on advanced trauma life support. It has been established that 3-25% of spine injuries occur during field stabilisation and transit to the hospital. Improved triaging at all hospital levels helps to prevent further injuries leading to prompt diagnosis and treatment. All trauma patients with spine tenderness should be treated as spinal injury patients till ruled out by imaging. Moreover, those with cervical tendernesss ought to have a cervical collar (Alfredo et al., 2014).

2.8 Mechanism of injury in association with Magnetic Imaging Resonance Pattern

Studies done in associations of mechanisms with injury patterns have only concentrated on fractures and fracture dislocation. Chen et al., (2016) conducted a study associating the level of injury and American Spinal Cord Association Impairment Scale with mechanism of injury but found no significant association after categorising their patients into the fall and non-fall groups. This study delves further to find associations when MRI patterns are compared with the mechanism of injury.

2.9 Management of spinal injuries

In the prehospital trauma setting, it is important to recognize the trauma scene and to get a feeling of the involved energy acting on the patient's body. The first step in this case is to ensure a proper airway without putting any further movement to the cervical spine. Manual immobilization is the safest way to protect the c-spine while airway management. A cervical collar alone is not able to sufficiently protect the cervical spine against dangerous move (Kwan et al., 2002).

2.9.1 The unconscious patient

It must be assumed that the force that rendered the patient unconscious has injured the cervical spine until imaging of its entire length proves otherwise. Until then the head and neck must be carefully placed and held in the neutral or anatomical position and stabilised. A rescuer can be delegated to perform this task throughout. However, splintage is best achieved with a rigid collar of appropriate size supplemented with sandbags or bolsters on each side of the head. The sandbags are held in position by tapes placed across the forehead and collar. If gross spinal deformity is left uncorrected and splinted, the cervical cord may sustain further injury from unrelieved angulation or compression. Alignment must be corrected unless attempts to do this increase pain or exacerbate neurological symptoms, or the head is locked in a position of torticollis, as in atlanto-axial rotatory subluxation. In these situations, the head must be splinted in the position found. Thoracolumbar injury must also be assumed and treated by carefully straightening the trunk and correcting rotation. During turning or lifting, it is vital that the whole spine is maintained in the neutral position (Rajasekaran et al., 2016).

While positioning the patient, relevant information can be obtained from witnesses and a brief assessment of superficial wounds may suggest the mechanism of injury as in the example of wounds of the forehead often accompany hyperextension injuries of the cervical spine(Mahshidfar et al., 2013).

Although the spine is best immobilised by placing the patient supine, and this position is important for resuscitation and the rapid assessment of life threatening injuries, unconscious patients on their backs are at risk of passive gastric regurgitation and aspiration of vomit. This can be avoided by tracheal intubation, which is the ideal method of securing the airway in an unconscious casualty. If intubation cannot be performed the patient should be log rolled carefully into a modified lateral position 70–80˚ from prone with the head supported in the neutral position by the underlying arm. This posture allows secretions to drain freely from the mouth, and a rigid collar applied before the log roll helps to minimise neck movement. However, the position is unstable and therefore needs to be maintained by a rescuer. Log rolling should ideally be performed by a minimum of four people in a coordinated manner, ensuring that unnecessary movement does not occur in any part of the spine. During this manoeuvre, the team leader will move the patient’s head through an arc as it rotates with the rest of the body. The prone position is unsatisfactory as it may severely embarrass respiration, particularly in the tetraplegic patient. The original semiprone coma position is also contraindicated, as it results in rotation of the neck. Modifications of the latter position are taught on first aid and cardiopulmonary resuscitation courses where the importance of airway maintenance and ease of positioning overrides that of cervical alignment, particularly for bystanders (Kobbe et al., 2020).

Patency of the airway and adequate oxygenation must take priority in unconscious patients. If the casualty is wearing a one-piece full-face helmet, access to the airway is achieved using a two-person technique: one rescuer immobilises the neck from below whilst the other pulls the sides of the helmet outwards and slides them over the ears. On some modern helmets, release buttons allow the face piece to hinge upwards and expose the mouth. After positioning the casualty and immobilising the neck, the mouth should be opened by jaw thrust or chin lift without head tilt. Any intra-oral debris can then be cleared before an oropharyngeal airway is sized and inserted, and high concentration oxygen given. The indications for tracheal intubation in spinal injury are similar to those for other trauma patients: the presence of an insecure airway or inadequate arterial oxygen saturation that is less than 90% despite the administration of high concentrations of oxygen. With care, intubation is usually safe in patients with injuries to the spinal cord, and may be performed at the scene of the accident or later in the hospital receiving room, depending on the patient’s level of consciousness and the ability of the rendered safer if an assistant holds the head and minimizes neck movement and the procedure may be facilitated by using an intubation bougie. Other specialised airway devices such as the laryngeal mask airway or Combitube may be used though each has its limitations such as the former device does not prevent aspiration and use of the latter device requires training(Mahshidfar et al., 2013). If possible, suction should be avoided in tetraplegic patients as it may stimulate the vagal reflex, aggravate preexisting bradycardia, and occasionally precipitate cardiac arrest. The risk of unwanted vagal effects can be minimised if atropine and oxygen are administered beforehand. In hospital, flexible fibreoptic instruments may provide the ideal solution to the intubation of patients with cervical fractures or dislocations. Once the airway is protected intravenous access should be established as multiple injuries frequently accompany spinal cord trauma. However, clinicians should remember that in uncomplicated cases of high spinal cord injury especially cervical and upper thoracic, patients may be hypotensive due to sympathetic paralysis and may easily be overinfused. If respiration and circulation are satisfactory patients can be examined briefly where they lie or in an ambulance (Báez & Schiebel, 2006).

A basic examination should include measurement of respiratory rate, pulse, and blood pressure; brief assessment of the level of consciousness and pupillary responses; and examination of the head, chest, abdomen, pelvis and limbs for obvious signs of trauma. Diaphragmatic breathing due to intercostal paralysis may be seen in patients with tetraplegia or high thoracic paraplegia, and flaccidity with areflexia may be present in the paralysed limbs. If the casualty’s back is easily exposed, spinal deformity or an increased interspinous gap may be identified (Ahn et al., 2011).

2.9.1 The conscious patient

The diagnosis of spinal cord injury rests on the symptoms and signs of pain in the spine, sensory disturbance, and weakness or flaccid paralysis. In conscious patients with these features resuscitative measures should again be given priority. At the same time a brief history can be obtained, which will help to localise the level of spinal trauma and identify other injuries that may further compromise the nutrition of the damaged spinal cord by producing hypoxia or hypovolaemic shock. The patient must be made to lie down, some have been able to walk a short distance before becoming paralysed, and the supine position prevents orthostatic hypotension. A brief general examination should be undertaken at the scene and a basic neurological assessment made by asking patients to what extent they can feel or move their limbs. After completion of the primary survey, transport priority has to be set. In critically injured patients, with severe, life-threatening injuries, a whole body immobilization might be skipped to accelerate transfer to definitive surgical care (Kobbe et al., 2020).

2.9.2 Evacuation and transfer to the hospital

In the absence of an immediate threat to life such as fire, collapsing masonry, or cardiac arrest, casualties at risk of spinal injury should be positioned on a spinal board or immobilizer before they are moved from the position in which they were initially found. Immobilisers are short backboards that can be applied to a patient sitting in a car seat whilst the head and neck are supported in the neutral position. In some cases, the roof of the vehicle is removed or the back seat is lowered to allow a full-length spinal board to be slid under the patient from the rear of the vehicle. A long board can also be inserted obliquely under the patient through an open car door, but this requires coordination and training as the casualty has to be carefully rotated on the board without twisting the spine, and then be laid back into the supine position. Spinal immobilisers do not effectively splint the pelvis or lumbar spine but they can be left in place whilst the patient is transferred to a long board. Both short and long back splints must be used in conjunction with a semi rigid collar of appropriate size to prevent movement of the upper spine (Mahshidfar et al., 2013).

If the correct collars or splints are not available manual immobilisation of the head is the safest option. Small children can be splinted to a child seat with good effect—padding is placed as necessary between the head and the side cushions and forehead strapping can then be applied.

If lying free, the casualty should ideally be turned by four people: one responsible for the head and neck, one for the shoulders and chest, one for the hips and abdomen, and one for the legs. The person holding the head and neck directs movement. This team can work together to align the spine in a neutral position and then perform a log roll allowing a spinal board to be placed under the patient. Alternatively, the patient can be transferred to a spinal board using a scoop stretcher which can be carefully slotted together around the casualty. In the flexion-extension axis, the neutral position of the cervical spine varies with the age of the patient. The relatively large head and prominent occiput of small children, of less than 8 years of age, pushes their neck into flexion when they lie on a flat surface (Lubelski et al., 2017).This is corrected on paediatric spinal boards by thoracic padding, which elevates the back and restores neutral curvature. Conversely, elderly patients may have a thoracic kyphosis and for this a pillow needs to be inserted between the occiput and the adult spinal board if the head is not to fall back into hyperextension. In all instances, the aim is to achieve normal cervical curvature for the individual. However, an uncooperative or distressed child might have to be carried by a paramedic or parent in as neutral a position as possible, and be comforted en route.

For transportation, the patient should be supine if conscious or intubated. In the unconscious patient whose airway cannot be protected, the lateral or head-down positions are safer and these can be achieved by tilting or turning the patient who must be strapped to the spinal board. To stabilize the neck on the spinal board, the semi-rigid collar must be supplemented with sandbags or bolsters taped to the forehead and collar. Only the physically uncooperative or thrashing patient is exempt from full splintage of the head and neck as this patient may manipulate the cervical spine from below if the head and neck are fixed in position. In this circumstance, the patient should be fitted with a semi-rigid collar only and be encouraged to lie still. Such uncooperative behaviour should not be attributed automatically to alcohol, as hypoxia and shock may be responsible and must be treated (Báez & Schiebel, 2006).

If no spinal board is used and the airway is unprotected, the modified lateral position is recommended with the spine neutral and the body held in position by a rescuer. In the absence of life-threatening injury, patients with spinal injury should be transported smoothly by ambulance, for reasons of comfort as well as to avoid further trauma to the spinal cord. They should be taken to the nearest major emergency department but must be repeatedly assessed en route; in particular, vital functions must be monitored. In transit the head and neck must be maintained in the neutral position at all times. If an unintubated supine trauma patient starts to vomit, it is safer to tip the casualty head down and apply oropharyngeal suction than to attempt an uncoordinated turn into the lateral position. However, patients can be turned safely and rapidly by a single rescuer when strapped to a spinal board and that is one of the advantages of this device. Hard objects should be removed from patients' pockets during transit, and anaesthetic areas should be protected to prevent pressure sores (Kobbe et al., 2020).The usual vasomotor responses to changes of temperature are impaired in tetraplegia and high paraplegia because the sympathetic system is paralysed. The patient is therefore poikilothermic, and hypothermia is a particular risk when these patients are transported during the winter months. A warm environment, blankets, and thermal reflector sheets helps to maintain body temperature.

If the patient has been injured in an inaccessible location or has to be evacuated over a long distance, transfer by helicopter has been shown to reduce mortality and morbidity. If a helicopter is used, the possibility of immediate transfer to a regional spinal injuries unit with acute support facilities should be considered after discussion with that unit (Ahn et al., 2011).

2.9.3 Primary Survey in the hospital

Once the patient arrives at the nearest major emergency department, a detailed history must be obtained from ambulance staff, witnesses, and if possible the patient. Simultaneously, the patient is transferred to the trauma trolley and this must be expeditious but smooth. If the patient is attached to a spinal board, this is an ideal transfer device and resuscitation can continue on the spinal board with only momentary interruption. Alternatively, a scoop stretcher can be used for the transfer but this will take longer. In the absence of either device, the patient can be subjected to a coordinated spinal lift but this requires training (Lubelski et al., 2017).

A full general and neurological assessment must be undertaken in accordance with the principles of advanced trauma life support. The examination must be thorough because spinal trauma is frequently associated with multiple injuries. As always, the patient's airway, breathing and circulation, ABC in that order, are the first priorities in resuscitation from trauma. If not already secure, the cervical spine is immobilised in the neutral position as the airway is assessed. Following attention to the ABC, a central nervous system assessment is undertaken and any clothing is removed (Dimar et al., 2010).

2.9.4 Secondary Survey in the hospital

Once the immediately life-threatening injuries have been addressed, the secondary, head to toe, survey that follows allows other serious injuries to be identified. Areas that are not being examined should be covered and kept warm, and body temperature should be monitored. In the supine position, the cervical and lumbar lordoses may be palpated by sliding a hand under the patient. A more comprehensive examination is made during the log roll. Unless there is an urgent need to inspect the back, the log roll is normally undertaken near the end of the secondary survey by a team of four led by the person who holds the patient's head. If neurological symptoms or signs are present, a senior doctor should be present and a partial roll to about 45˚ may be sufficient. A doctor who is not involved with the log roll must examine the back for specific signs of injury including local bruising or deformity of the spine, as in the case of a gibbus or an increased interspinous gap, and vertebral tenderness. The whole length of the spine should be palpated, as about 10% of patients with an unstable spinal injury have another spinal injury at a different level (Báez & Schiebel, 2006).

Priapism and diaphragmatic breathing invariably indicate a high spinal cord lesion. The presence of warm and well-perfused peripheries in a hypotensive patient should always raise the possibility of neurogenic shock attributable to spinal cord injury in the differential diagnosis. At the end of the secondary survey, examination of the peripheral nervous system must not be neglected. The log roll during the secondary survey provides an ideal opportunity to remove the spinal board from the patient. It has been demonstrated that high pressure exists at the interfaces between the board and the occiput, scapulae, sacrum, and heels. It is generally recommended that the spinal board is removed within 30 minutes of its application whenever possible (Lubelski et al., 2017).

The head and neck can then be splinted to the trauma trolley. If full splintage is required following removal of the spinal board, especially for transit between hospitals, use of a vacuum mattress is recommended. This device is contoured to the patient before air is evacuated from it with a pump. The vacuum causes the plastic beads within the mattress to lock into position. Interface pressures are much lower when a vacuum mattress is used and patients find the device much more comfortable than a spinal board (Mahshidfar et al., 2013).

2.9.5 Medical and surgical management

A high dose steroid regime to protect the spinal cord is not used when there is a concomitant pulmonary injuries and an unclear neurological status.

The neuroprotective effect of high-dose steroids has been questioned, while pulmonary and gastro-intestinal complications have been reported. So recent guidelines recommend this as an optional treatment regimen only in an isolated spinal cord injury, not in the multiple trauma setting (Dimar et al., 2010).

Early surgical decompression and stabilization of spinal injuries within <72 h has shown to improve patient outcome in terms of hospital stay, ICU-stay, ventilator hours and sepsis rate. Especially thoracic spine fractures in combination with a severe thoracic injury will benefit from early surgical treatment. The effect of early decompression on neurologic outcome is still under discussion, but data supporting a positive effect are increasing (Bliemel et al., 2014).

CHAPTER THREE: METHODOLOGY

3.1 Study Site

The study was conducted at the Radiology department of MTRH, the second largest teaching and referral hospital in Kenya located in Eldoret town. It is 350 Kilometers Northwest of Nairobi, the capital city of Kenya. The institution is a level 6, tertiary, health facility serving the western part and the greater North rift part of Kenya with a catchment population of over 13 million people. The radiology department is equipped with a 0.3 Tesla mind-ray mag-sense MRI machine (MTRH website).

3.2 Study design

This was a cross-sectional descriptive study.

3.3 Study Population

The study population included adult patients with spinal injury sent for MRI studies at the Moi Teaching and Referral Hospital.

3.4 Sample size determination

As per the Fisher et al., (1998) formula

$$n = \frac{z2\ p\ (1-p)}{d^2}$$

n = desired sample size.

z = Standard normal variance corresponding to 1.96

p = prevalence rate of spinal injury was 8.0% in a study done by Okello et., al (2013) in Uganda .

d= the level of significance desired.

When this formula is applied at d = 0.05, z = 1.96, and p = 0.08

$$n = \frac{(1.96)2 \times 0.08\ (1-0.08)}{(0.05)^2}$$

Therefore n = 114

The number of traumatic spinal injury patients who did MRI spine imaging in the previous year were 75. A sample size of 114 was calculated but since the previous population was less than the total number of sample size calculated, a census study was therefore favoured. A total 94 patients with acute traumatic spinal injury were then recruited.

3.5 Eligibility criteria

3.5.1 Inclusion criteria

1. All adult patients with acute spinal injuries referred to radiology department of MTRH for MRI spine.

3.5.2 Exclusion criteria

1. Patients who had spinal surgeries prior to Magnetic resonance Imaging.
2. Patients with pathological fractures, spinal deformity or tumour metastasis to the spine.

3.6 Study Procedure

All patients presenting for MRI examination and who met the inclusion criteria were explained to in a language they understood about the purpose risks and benefits of the study and were given a chance to consent to be part of this study. Socio-demographic data was recorded in a structured interviewer-administered questionnaire and Spinal MRI findings filled in a table format. All eligible patients consented and were subjected to MRI scans performed by a trained radiographer as per the protocol outlined in the department.

3.7 Recruitment schema

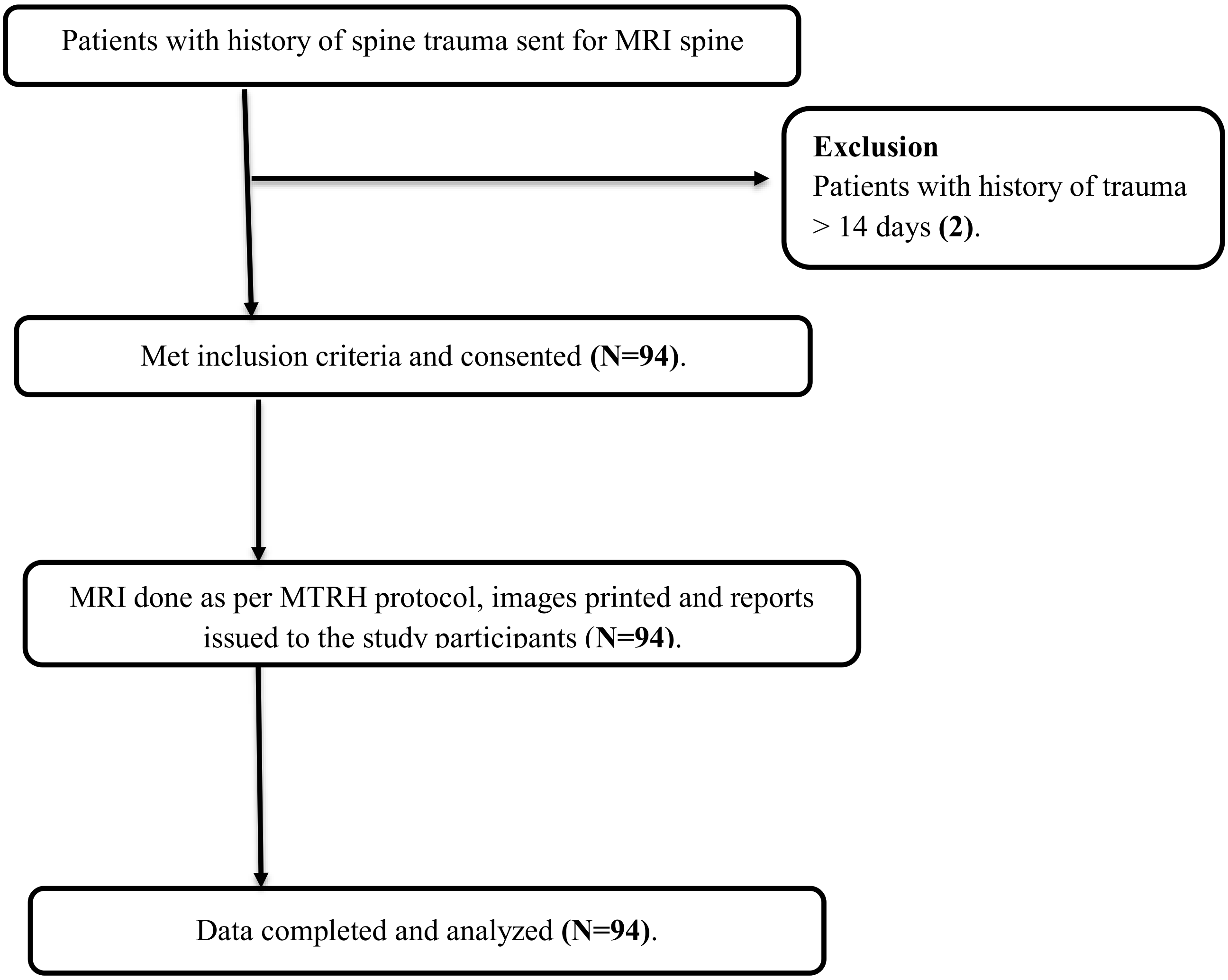

Figure 4: Recruitment schema

3.8 Data collection and management

3.8.1 Data collection

Data was collected between March 2019 and April 2020 through a structured questionnaire integrated with a standardized data collection tool. MRI findings were then reviewed by the researcher and confirmation done by at least two consultant radiologists.

This was then transferred to a Microsoft Access database and double entry was used to increase the accuracy of the data entered. Patients were assigned serial numbers to protect their identity and only the supervisors and the investigator had access through password-protected documents.

3.8.2 Quality control

All MRI of the spine was done in the MRI room with specified protocols present. The images were reported by the investigator and confirmed by two radiologists who then independently viewed the films. In case of disagreement, a third consultant reviewed the images and a diagnosis was made after a consensus had been reached.

3.8.3 Data analysis

Data collected was coded and entered in Microsoft Excel spreadsheet and thereafter cleaned before exporting to Stata/MP Version 13 for statistical analysis. Descriptive statistics were done to explore and summarize the variables; for categorical variables- bar graphs were plotted to show the distribution; frequencies and proportions were reported in tables. For continuous/discrete variables were analysed using means, standard deviations, or inter-quartile range was computed where applicable and presented in tables. Chi-Square and Fischer's Exact test were used to assess the association of MRI findings with causes of spinal injury.

3.9 Ethical considerations

Approval of the study was sought from the Institutional Research and Ethics Committee and the CEO, Moi Teaching and Referral Hospital. The patients who met the inclusion criteria were requested to fill in an informed consent form. Participants had the freedom to exit at any point in time if they no longer wanted to be involved in the study. No incentives were given to participants. Confidentiality was maintained throughout the study. A serial number was used instead of the patients' names.

The results of the research will be presented to the Hospital's management and the university's department of Radiology and Imaging for use as necessary. It will also be available for academic reference in the College of Health Sciences Resource Centre. The results of this research shall be availed for publication in a reputable journal of medicine for use by the wider population in the general improvement of patient management and as a reference for future studies.

CHAPTER FOUR: FINDINGS

4.1 Sociodemographic

There were a total of 94 participants, majority of whom were males (77.7%), the median age was 32 years with a range from 18 to 82 years.

Table 1: Demographic characteristics

Variable	Category	Frequency	Percentage
Age	Median(IQR)	32(25, 41)	
Age group	18-29	40	42.55
	30-39	27	28.72
	40-49	15	15.96
	50+	12	12.77
Sex	Male	73	77.66
	Female	21	22.34

4.2 Mechanism of injury

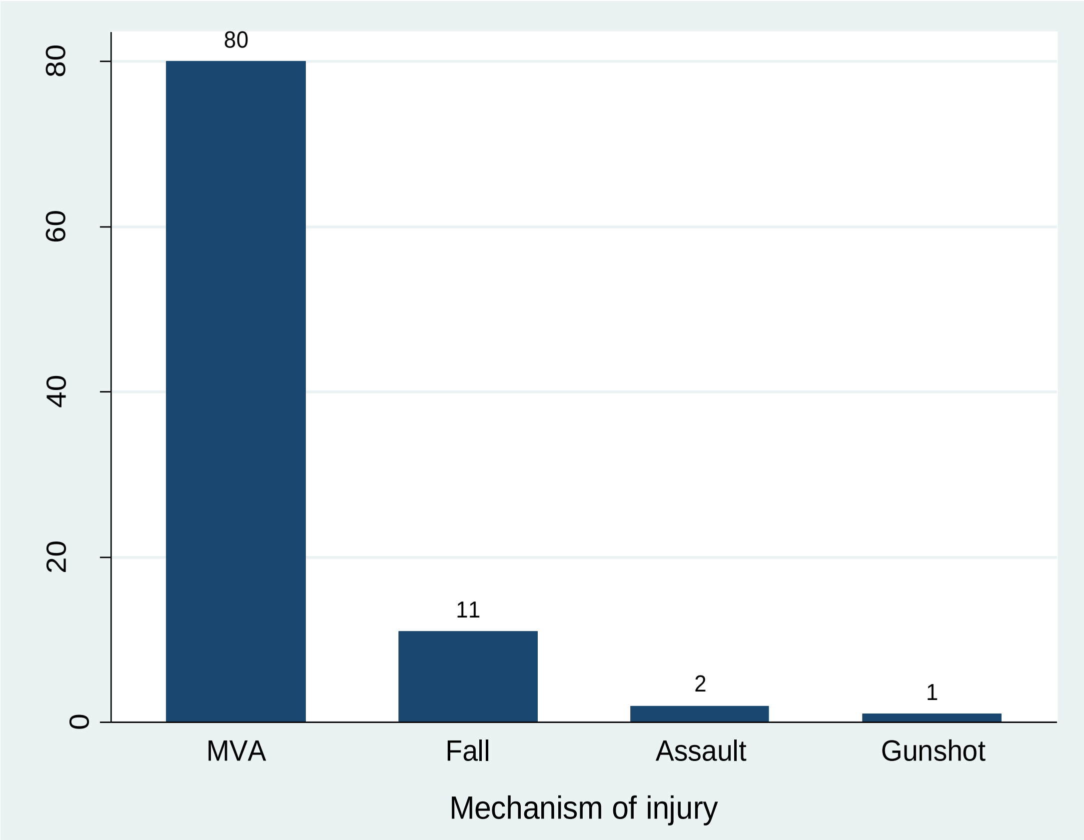

Figure 5: Mechanism of injury

Most participants had motor vehicle accidents as their cause of injury, followed by falls and assault while gunshot wound were the least common.

Table 2: Spinal region imaged

Region	Frequency	Percentage
Cervical	35	37.23
Lumbar	26	27.66
Cervico-thoracic	13	13.83
Whole Spine	12	12.77
Thoraco-lumbar	6	6.38
Thoracic	1	1.06
Cervico-lumbar	1	1.06

Out of the 94 patients imaged, 37.23% had cervical spine MRI done while the least was thoracic and one patient who had injuries on the both the cervical and lumbar.

4.3 Patterns of spinal injury

Table 3: Patterns of spinal injury

Spinal injury category	Frequency	Percentage
Spinal cord injury	65	69.15
Fracture	51	54.26
Malalignment	18	19.15
Disc injury	33	35.11
Ligament involvement	7	7.45
Soft tissue injury	47	50.00
Posterior Element fracture	5	5.32
Marrow oedema	56	59.57
Normal spine	18	19.15

The commonest structure injured was the spinal cord while the least were ligaments.

Table 4: Specific injury type

Spinal injury category	Category	Frequency	specific %
Spinal cord injury (n=65)	Edema	52	80.00%
	Compression	37	56.92
	cord swelling	1	1.54%
	Transection	1	1.54%
Fracture site (n=51)	Lumbar	20	39.22%
	Thoracic	16	31.37%
	Cervical	14	27.45%
	Cervico-thoracic	1	1.96%
Malalignment site (n=18)	Cervical	12	66.67%
	Lumbar	5	27.78%
	Thoracic	1	5.56%
Disc injury (n=33)	Herniation	30	90.90%
	Rupture	3	9.09%
Ligament involvement (n=7)	ALL	2	28.57%
	PLL	1	14.29%
	PLC	4	57.14%

The commonest MRI pattern injury on the spinal cord was edema while the least was involvement of the posterior ligamentous complex on the ligaments.

4.3 Comparison of mechanism of injury with MRI pattern

Table 5: Comparison of mechanism of injury with type of vertebral injury

Spinal injury category	Cause of Injury MVA (n=80)	Cause of Injury Others (n=14)	p-value
Spinal cord injury	57(71%)	8(57%)	0.351[f]
Fracture	42(53%)	9(64%)	0.563[c]
Malalignment	14(17%)	2(14%)	>0.99[f]
Disc injury	26(33%)	7(50%)	0.234[f]
Ligament involvement	6(8%)	1(7%)	0.481[f]
Soft tissue injury	39(49%)	8(57%)	0.562[c]
Posterior element fracture	3(4%)	2(14%)	0.159[f]
Marrow oedema	47(59%)	9(64%)	0.697[c]
Normal spine	14(18%)	4(29%)	0.459[f]

[c]Chi Square test; [f]Fisher's Exact test

There was no association when mechanism of injury was compared with the patterns of injury.

Table 6: Association of mechanism of with MRI patterns of injury

Vertebral injury	Injury mechanism MVA (n=80)	Others (n=14)	p-value
Vertebral injury			
Spinal cord injury (n=65)			
Oedema	47 (82.5%)	5 (62.5%)	>0.99[f]
Compression	34 (59.6%)	3 (37.5%)	
Cord swelling	1 (1.8%)	0	
Transection	1 (1.8%)	0	
Fracture site (n=51)			
Lumbar	15 (35.7%)	5 (55.6%)	0.711[f]
Thoracic	14 (33.3%)	2 (22.2%)	
Cervical	12 (28.6%)	2 (22.2%)	
Cervico-thoracic	1 (2.4%)	0	
Malalignment site (n=16)			
Cervical	9 (64.3%)	1 (50%)	>0.99[f]
Lumbar	4 (28.6%)	1 (50%)	
Thoracic	1 (7.1%)	0	
Disc injury (n=33)			
Herniation	25 (96.2%)	5 (71.4%)	0.88[f]
Rupture	1 (3.8%)	2 (28.6%)	
Ligament involvement (n=7)			
ALL	2 (33.3%)	0	>0.99[f]
PLL	1 (16.7%)	0	
PLC	3 (50%)	1(100%)	

There was no significant association when mechanism of injury was compared with the specific patterns of injury.

MRI IMAGES

Figure 6: T2WI Sagittal and Axial cervical spine MRI of a 32-year old male involved in a motor vehicle accident. The images show traumatic spondylolisthesis C6 over C7 with associated transection of the spinal cord, cord oedema and resultant compression of the spinal cord.

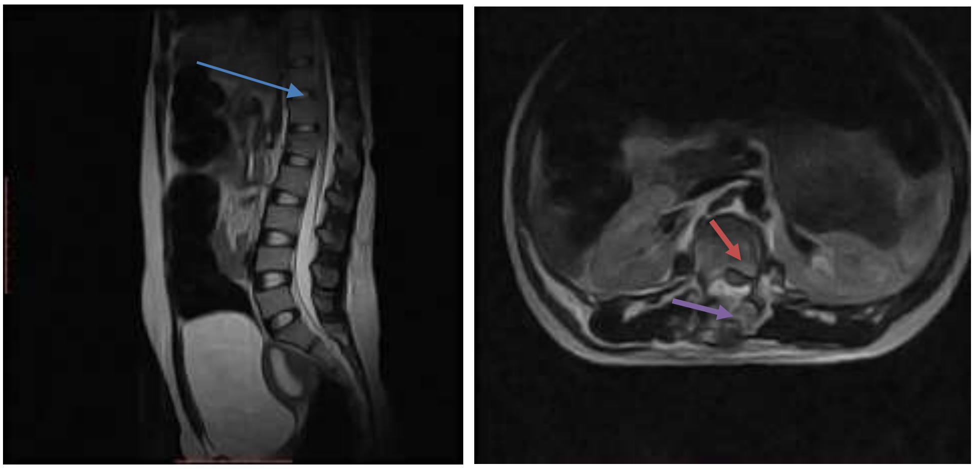

Figure 7: T2WI Sagittal and Axial of a 24-year-old female involved in a road traffic accident. Depicted is L1 vertebral height body loss due to fracture with associated bone oedema and retropulsion of osseous fragments causing cord compression

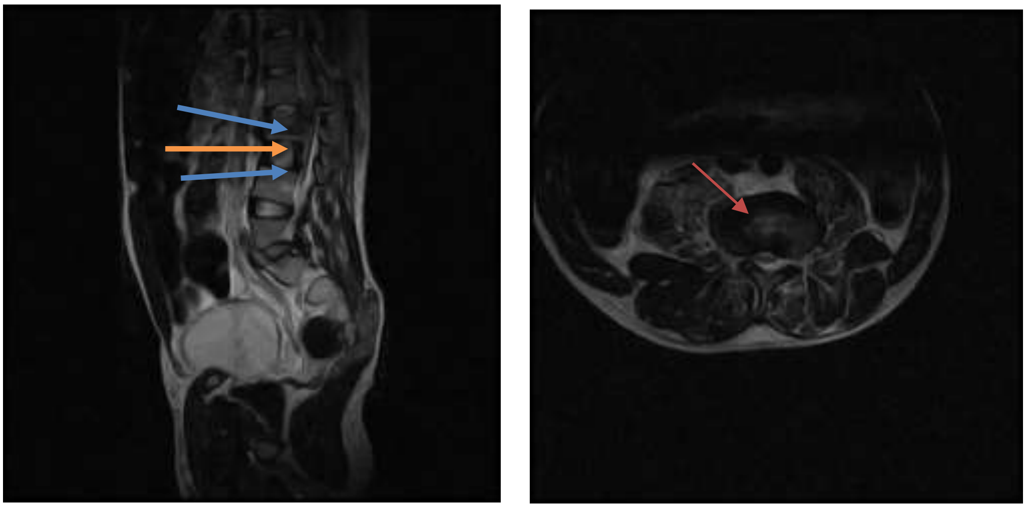

Figure 8: T2WI Sagittal and axial of a 28-year-old male who sustained a fall from height. Fractures seen on L2 and L3 vertebral bodies with bone oedema. L2-L3, L3-L4 disc rupture.

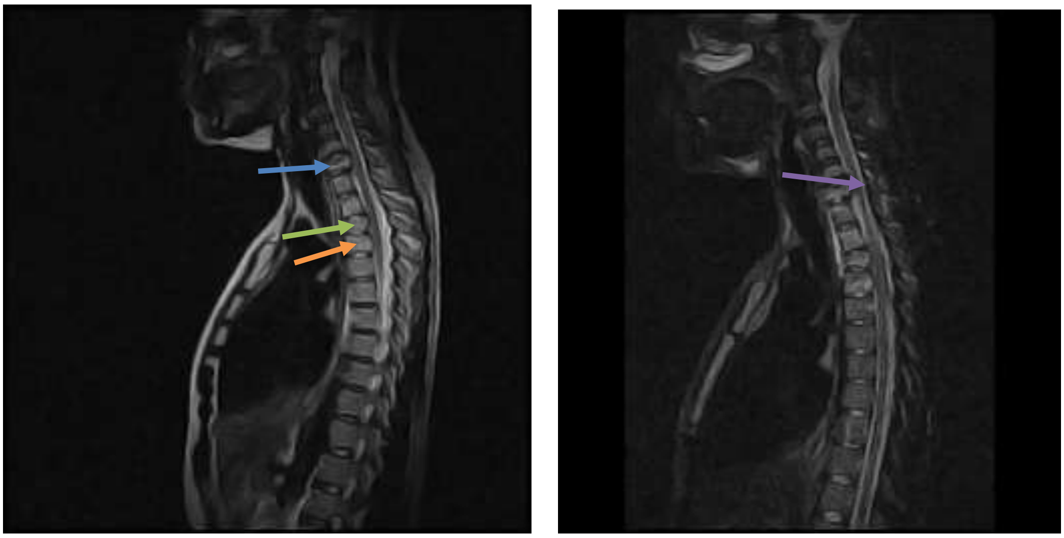

Figure 9: T2WI and STIR Sagittal images of a 39-year-old female involved in a road traffic accident. There are fractures of C7, T3 and T4 vertebral bodies with associated posterior displacement and cord compression. Multilevel bone oedema is demonstrated in the STIR image.

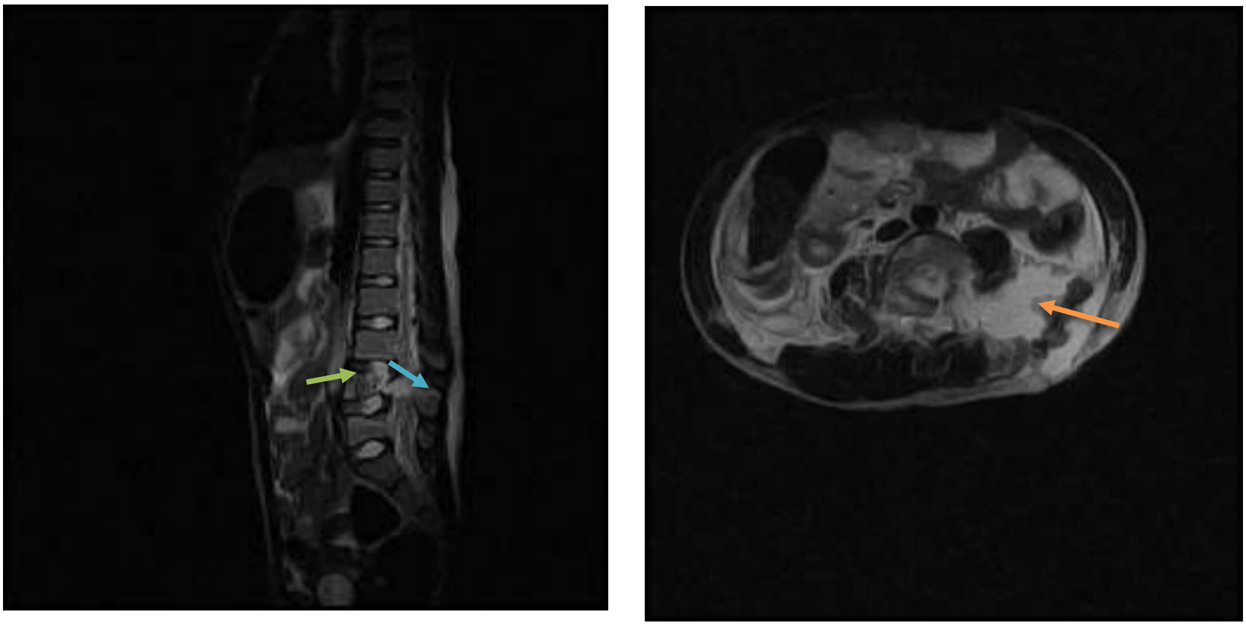

Figure 10: T1W1 and T2WI Sagittal images of an 18-year-old male with gunshot injury. The images depict L4 lumbar vertebral body fracture with posterior element fracture and adjacent thecal sac injury. The image on the right shows paravertebral soft tissue injury with subcutaneous oedema.

CHAPTER FIVE: DISCUSSION

5.1 Demographic characteristics

There were a total of 94 participants, majority being males 73(77.67%). This compares to many studies whose results showed male dominance when it comes to spinal injuries. Okello et al., (2013), a study done in Mulago found 45 males out of 59 making a male-female ratio of 3.2 to 1. Likewise, a study done in India by Nagvekar et al., (2017) found 86 males out of a sample of 120 making a percentage of 72 for the male. Males are also involved in an occupation that predisposes to accidents and lack compliance with traffic regulation and lack of attention while driving. They have also been known to engage in risky/ violent activities that can predispose to spinal injury. (Kinyanjui and Mulimba, 2016; Morais et al., 2013; Wang et al., 2016). None of the other studies had female dominance.

The median age was 32 years with a range from 18 to 82 years. This was akin to studies done in KNH and Ghana in large teaching hospitals where they had a median of 37.6 and 31 respectively (Ametefe et al., 2016; Kinyanjui & JAO Mulimba, 2016). Similarly, studies done by Nagvekar et.al., (2017) found IQR of 21-40 whereas in this study the IQR was 25-41. It has been found that spinal injuries mostly affect persons below 40s and peak being in their 30s as this is the age bracket of the active workforce (Ochie et al., 2013).

5.2 Mechanism of traumatic spinal injury

The dominant etiologic factor was motor vehicle accident at 85% followed by falls at 11%. This result is comparable to Martinez et al., (2014) who did their study in Spain and Ochie et al., (2013) in Ghana who had more than half of their population sustaining MVA at 69%and 61% respectively. On the contrary Mabray et al., (2016) did their study in California and found only 29% of their population to have motor vehicle accidents as a cause of their injuries. On the same note Adrian et al., (2016) in England found motor vehicle accidents to contribute to 40% out of a sample of 797. The difference could be as a result of the former doing only thoracolumbar MRI while the latter only studied MRI patterns for patients with blunt cervical trauma in negative CT findings.

The falls finding is similar to a study done by Liu et al., (2015) in China where he got 11%. Similarly, Joseph et al., (2016) did a study in South Africa and also got 12% of his participants with falls. However, there are a few contradicting studies that found falls to be most common such as one done in Tanzania and India that had frequencies of 48% and 63% respectively (Moshi et al., 2017; Nagvekar et al., 2017). The difference from our findings could be attributed to the Tanzanian study was done in the rural part of the country where motor vehicles were few and therefore less of such accidents (Moshi et al., 2017). In addition to this, Nagvekar et al., (2017) explain their falls finding as a result of the many manual labourers who they recruited, some of whom were construction workers. The average age of patients who sustained injuries due to falls was 34 slightly higher than the average of other causes as 32. Therefore, no major difference in terms of age as a causative agent. Fall from height has mainly been documented in the young and is more often than not work-related (Chen et al., 2016).

Assault came in third with two patients and this was similar to studies done in India and Canada at Toronto Western Hospital & University of Maryland where they found 15 and 3% respectively (Arnold & Fehlings, 2007; Magu et al., 2015). This was distinguishable from studies done in Michigan, Ghana and South Africa in which the first two had a percentage of 11%and 59% for the latter. (Mohamed et al., 2016; Ochie et al., 2013; Joseph et al., 2016)). The difference could be accounted for in that the former only surveyed patients who had a negative CT scan while Mohammed et al, (2016) isolated blunt cervical trauma patients. Joseph et al., (2015) goes further and explains that assault as a cause of spinal injury has been documented as a major cause in towns/countries with a high crime rate.

Gunshot injury was the least at 1%. This finding is in tandem with studies done locally where assault contributed to less than one percent (Okello et al., 2016). Conversely, Joseph et al., (2014) found more gunshot injuries (30%) and this has been attributed to the high crime rate in South Africa. Sports injury was not a cause in this study and this could be explained as the types of sports done in this region are not the predominant mechnanism (Ball et al., 2019; Chan et al., 2016). Moolly et al., (2011) also point out in their study that different sports will cause specific injury as shown in their study where skiers had cervical injuries while snowboarders sustained lumbar. (Hubbard et al., 2011). Likewise, Ametefe et al., (2016) did a study in Ghana and indicated no gunshot or sport and leisure injury as an important negative.

5.3 MRI patterns of traumatic spinal injuries

Spinal cord injuries contributed to 69% of all injuries with spinal cord oedema being evidently repetitive at 55% followed at a distance by cord swelling in isolation and one case of cord transection. Similar findings have been echoed by several authors; studies done in India had findings of 60% and 68.9% of all the spinal cord injuries (Nagvekar & Nagvekar, 2017; Srinivas et al., 2017). The study also compares to Mboka et al., 2016 in which none of their patients had haemorrhage. On the contrary, Ochie et al., (2013) found a predominance of cord oedema at 37% but with an equally large percentage of haemorrhage and oedema 33% as well as haemorrhage alone at 28%, therefore, making up a percentage of 61% of patients with haemorrhage. This is significant as haemorrhage leads to reduced quality of life and high mortality. The difference could have resulted from the study design that they used a retrospective study and therefore there was no verification on their collection of data. Nonetheless, haemorrhage is not a common characteristic feature in spinal injuries. Furthermore, this type of injury is associated with poor outcomes. Only 1.54% translating to one patient had cord transection. This relates with the study done in India by Nagvekar et al., (2017) where only 2% of their population had cord transection. This is a rare fatal type of injury which when does occur leads to poor morbidity and increases chances of complications eventually leading to high mortality.

Out of the 94 patients recruited more than half had fractures (n=51) and out of these lumbar fractures were the most common at 39.22% followed by thoracic then cervical fractures. Only one combination of cervico-thoracic fracture on one patient was observed. Similar findings were observed in the United Kingdom where lumbar fractures were more with a percentage of 48% followed by thoracic (30%) then cervical 22% (Green & Saifuddin, 2004). This contradicts local studies that found cervical fracture preponderance with thoracic being the least due to protection of the thoracic region by the rib cage (Deng, 2014; Kinyanjui & JAO Mulimba, 2016). Nevertheless, it is important to note that the above studies mainly used CT scan for evaluation of their subjects. On the contrary, Singh et al., (2015) found all but one of their subjects with fractures though they did not further classify the regions that were affected and they had a very small sample population of 25. This also differed slightly from studies done in Mulago hospital where they found cervical and lumbar fractures being affected equally at 36.6%. The disparity could have resulted from the fracture observations being done from either MRI, CT scan or X-rays We may have missed patients with cervical fractures who did not do x-ray as cervical injury are usually associated with head injuries and most unstable patients are not taken for MRI as it is a lengthy procedure and more expensive when compared to CT scan. Overall, cervical spinal injuries were most common as there was a bigger percentage of patients who had cervical malalignment but did not have fractures.

Fifty-nine percent of the population had marrow oedema, a figure slightly higher when compared to the number of patients with bone fractures only. All patients with fractures also had marrow oedema and this is because we only recruited acute injuries. This auger well with other studies where the numbers are higher than the bony fractures (Mohamed et al., 2016; Morais et al., 2013). 5.26% had bone marrow oedema without fractures and this is in tandem with Dionel et al., (2013 and Mohammed et al., (2016), studies that were done in Brazil and the USA respectively where they got 8.7% and 7.4% respectively. In contrast, Roop et al (2018) had 96% of the patient with bone marrow oedema but had a very small sample size of 25.

Disc injuries were evident in 33 patients (35%) and out of these a bigger percentage was observed to have a disc herniation (31.91%) while the least was disc rupture (3.19%.). This was comparable to Nagvekar et al., (2017) in India where they had 21% of their subjects sustaining disc herniations. In contrast, Martínez-Pe´rez et al., (2014) and Mohamed et.al., (2016) found slightly more than half of the population, 57.4and 58% respectively with disc injury though their participants were only blunt cervical trauma in the former and negative CT findings in the later. Similarly, Singh et al., (2015) found all but one patent with disc herniation although they only had a population of 25.

There are very few studies on spinal ligaments done and we did not come across any African studies on the above. Mohamed et al., (2016) found cervical spine ligament injury on 9% of his population and this was close to our study that had 7.4% of ligamentous injury. Maung et al., (2017) had findings that differed in that they found cervical ligamentous injury in 127 patients with a population of 767 accounting for 16%. This difference could be accounted for in that their study was only in patients with negative CT. Other soft tissue injuries including paravertebral soft tissues and subcutaneous soft tissue ad muscles contributed to half of the population. This tallied with other studies where at least half of the population sustained other soft tissue injuries (Singh et al., 2015).

5.4 Association of mechanism of injury with Magnetic Resonance Imaging patterns in traumatic spinal injury

Fisher's exact test was used to compare the causes of spinal injury with MRI patterns of spinal injury. We divided them into two groups: Motor Vehicle Accidents vs others (falls and gunshot). There were no significant findings in any of the various injuries in spinal types injuries on the bones, disc or ligamentous injuries where we had a p-value of more than 0.005 in all the above injuries. There are scarce studies on this comparison but a study closely related to this is one done by Chen et al., (2016) in the USA. They compared spinal injuries in the fall category and the injuries were not associated with the fall only but how the patient landed on the floor and the subsequent flexion or extension injuries. This history is however sometimes difficult to get especially when the injuries are associated with head injuries and or with memory loss.

We did not come across any contradictory studies.

5.5 Study limitations and delimitations

5.5.1 Limitations

1. Hospital based study so only patients who sought hospital services were studied.
2. Overlapping features of spinal injury with degenerative disease but this was taken care of by the detailed history taking done.

5.5.2 Delimitations

1. Census study captures as many cases as possible of spinal injury with Magnetic Resonance Imaging done.
2. MRI captured injuries of soft tissues not otherwise depicted by other imaging modalities.

CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

1. Most of the participant had spinal injuries as a result of motor vehicle accidents (85%) followed by falls (11%), with only one sustaining gunshot injury.
2. Spinal cord injuries were the most common (85%) followed by bone oedema and fractures. Ligament injuries were the least common findings (7.4%).
3. There was no association of MRI patterns of spinal injury with mechanism of injury with a p-value of more than 0.05.

6.2 Recommendations

Government to make emphasis to the general populace on measures to curb motor vehicle accidents as it was a glaring cause of injury.

Recommendation to MTRH radiology department to include sagittal STIR on cervical spine for easier comparison of the ligaments on other sequences.

Similar studies with larger sample size to so as to strengthen the association.

REFERENCES

Ahn, H., Singh, J., Nathens, A., MacDonald, R. D., Travers, A., Tallon, J., Fehlings, M. G., & Yee, A. (2011). Pre-Hospital care management of a potential spinal cord injured patient: A systematic review of the literature and evidence-based guidelines. *Journal of Neurotrauma*, *28*(8), 1341–1361.

Akbarnia, B. A., Yazici, M., & Thompson, G. H. (2010). The growing spine: Management of spinal disorders in young children. *Springer Journal*, *4*(9), 1–629.

Urdaneta, A. E., Stroh, G., Teng, J., Snowden, B., Barrett, T. W., & Hendey, G. W. (2013). Cervical spine injury: analysis and comparison of patients by mode of transportation. *The Journal of emergency medicine*, *44*(2), 287-291.

Alvand, H., & Bencardino, J. T. (2003). Magnetic resonance imaging of sports injuries of the spine. *Topics in Magnetic Resonance Imaging*, *14*(1), 69–86.

Ametefe, M. K., Bankah, P. E., Yankey, K. P., Akoto, H., Janney, D., & Dakurah, T. K. (2016). Spinal cord and spine trauma in a large teaching hospital in Ghana. *Spinal Cord*, *54*(12), 1164–1168.

Anoushka, S., Tetreault, L., Kalsi-Ryan, S., Nouri, A., & Fehlings, M. G. (2014). Global prevalence and incidence of traumatic spinal cord injury. *Clinical Epidemiology*, *6*, 309–331.

Miyanji, F., Furlan, J. C., Aarabi, B., Arnold, P. M., & Fehlings, M. G. (2007). Acute cervical traumatic spinal cord injury: MR imaging findings correlated with neurologic outcome—prospective study with 100 consecutive patients. *Radiology*, *243*(3), 820-827.

Ball, J. R., Harris, C. B., Lee, J., & Vives, M. J. (2019). Lumbar Spine Injuries in Sports: Review of the Literature and Current Treatment Recommendations. *Sports Medicine - Open*, *5*(1), 26.

Bican O,Minagar A,Pruitt AA, The spinal cord: a review of functional neuroanatomy. Neurologic clinics. 2013 Feb

Bliemel, C., Lefering, R., Buecking, B., Frink, M., Struewer, J., Krueger, A., Ruchholtz, S., & Frangen, T. M. (2014). Early or delayed stabilization in severely injured patients with spinal fractures? Current surgical objectivity according to the trauma registry of DGU: Treatment of spine injuries in polytrauma patients. *Journal of Trauma and Acute Care Surgery*, *76*(2), 366–373.

Bozzo, A., Marcoux, J., Radhakrishna, M., Pelletier, J., & Goulet, B. (2011). The Role of Magnetic Resonance Imaging in the Management of Acute Spinal Cord Injury. *Journal of Neurotrauma*, *28*(8), 1401–1411.

Cerván, A. M., Haba, D., Solera, M. R., & León, M. S. H. (2016). Trauma Cases and Reviews Missed Spinal Lesions in Traumatized Patients. *ClinMed Journal*, *2*(1), 2–6.

Chan, C. W. L., Eng, J. J., Tator, C. H., Krassioukov, A., Chan, C. W. L., Eng, J. J., Tator, C. H., & Krassioukov, A. (2016). Epidemiology of sport-related spinal cord injuries : A systematic review Epidemiology of sport-related spinal cord injuries : A systematic review. *The Journal of Spinal Cord Medicine*, *0268*(April), 255–264.

Chen, Y., Tang, Y., Allen, V., & De Vivo, M. J. (2016). Fall-induced spinal cord injury: External causes and implications for prevention. *Journal of Spinal Cord Medicine, 39*(1), 24–31.

Cripps, R. A., Lee, B. B., Wing, P., Weerts, E., MacKay, J., & Brown, D. (2011). A global map for traumatic spinal cord injury epidemiology: Towards a living data repository for injury prevention. *Spinal Cord*, *49*(4), 493–501.

Deng, S. C. D. (2014). Traumatic Spinal Cord Injuries in Mulago Hospital. *Makerere University Repository*.

Dimar, J. R., Carreon, L. Y., Riina, J., Schwartz, D. G., & Harris, M. B. (2010). Early versus late stabilization of the spine in the polytrauma patient. *Spine Journal, 35*(21), 187–192.

Fehlings, M. G., Tetreault, L. A., Wilson, J. R., Kwon, B. K., Burns, A. S., Martin, A. R., Hawryluk, G., & Harrop, J. S. (2017). A Clinical Practice Guideline for the Management of Acute Spinal Cord Injury: Introduction, Rationale, and Scope. *Global Spine Journal*, *7*(3), 84S-94S.

Ghasemi, A., Haddadi, K., & Shad, A. A. (2015). Comparison of Diagnostic Accuracy of MRI With and Without Contrast in Diagnosis of Traumatic Spinal Cord Injuries. *Md-Journal, 94*(43), 1–6.

Gilchrist, R. V. (2008). Developmental and Functional Anatomy of the Lumbar Spine. *Springer Journal*, *4*(10), 855–870.

Goethem, J. W. M. Van, Parizel, P. M., Verlooy, J., & Schepper, A. M. A. De. (2000). The value of MRI in the diagnosis of postoperative spondylodiscitis. *Neuroradiology*, *8*(42), 580–585.

Gomleksiz, C., Egemen, E., Yaman, O., Oktenoglu, T., & Ozer, A. F. (2015). Thoracolumbar Fractures: A Review of Classifications and Surgical Methods. *Journal of Spine*, *4*(5), 4–6.

Green, R. A. R., & Saifuddin, A. (2004). Whole spine MRI in the assessment of acute vertebral body trauma. *Skeletal Radiology*, *33*(3), 129–135.

Hodgson, V., & Thomas, L. (1981). Mechanisms of Cervical Spine Injury during Impact to the Protected Head. *The 24th Stapp Car Crash Conference*, *89*(1980), 17–42.

Hu, Z. J., Fang, X. Q., & Fan, S. W. (2014). Iatrogenic injury to the erector spinae during posterior lumbar spine surgery: Underlying anatomical considerations, preventable root causes, and surgical tips and tricks. *European Journal of Orthopaedic Surgery and Traumatology*, *24*(2), 127–135.

Hubbard, M. E., Jewell, R. P., Dumont, T. M., & Rughani, A. I. (2011). Spinal injury patterns among skiers and snowboarders. *Neurosurgical Focus*, *31*(5), 1–5.

Joseph, C., Delcarme, A., Vlok, I., Wahman, K., Phillips, J., & Nilsson Wikmar, L. (2015). Incidence and aetiology of traumatic spinal cord injury in Cape Town, South Africa: A prospective, population-based study. *Spinal Cord*, *53*(9), 692–696.

Kanna, R. M., Gaike, C. V., Mahesh, A., Shetty, A. P., & Rajasekaran, S. (2016). Multilevel non-contiguous spinal injuries: incidence and patterns based on whole spine MRI. *European Spine Journal*, *25*(4), 1163–1169.

Kinyanjui, J., & JAO Mulimba. (2016). Pattern and outcome of spinal injury at Kenyatta National Hospital. *East African Orthopaedic Journal*, *10*(1), 3–6.

KNBS. (2017). *Economic Survey 2017*.

Kobbe, P., Krug, P., Andruszkow, H., Pishnamaz, M., Hofman, M., Horst, K., Meyer, C., Scheyerer, M. J., Faymonville, C., Stein, G., Hildebrand, F., & Herren, C. (2020). Early Spinal Injury Stabilization in Multiple-Injured Patients: Do All Patients Benefit? *Journal of Clinical Medicine*, *9*(6), 1760.

Kulvatunyou, N., Friese, R. S., Joseph, B., O'Keeffe, T., Wynne, J. L., Tang, A. L., & Rhee, P. (2012). Incidence and pattern of cervical spine injury in blunt assault: It is not how they are hit, but how they fall. *Journal of Trauma and Acute Care Surgery*, *72*(1), 271–275.

Kumar, Y., & Hayashi, D. (2016). Role of magnetic resonance imaging in acute spinal trauma: A pictorial review. *BMC Musculoskeletal Disorders*, *17*(1), 1–11.

Kwan, I., Bunn, F., & Roberts, I. (2002). Spinal immobilisation for trauma patients. *Praxis*, *91*(36), 1447–1447.

Leonard, J. R., & Jaffe, D. M. (2014). Cervical Spine Injury Patterns in Children.

Liu, Q., Liu, Q., Zhao, J., Yu, H., Ma, X., & Wang, L. (2015). Early MRI fi nding in adult spinal cord injury without radiologic abnormalities does not correlate with the neurological outcome : a retrospective study. *Spinal Cord*, *53*(February), 750–753.

Mabray, M. C., Talbott, J. F., Whetstone, W. D., Dhall, S. S., Phillips, D. B., Pan, J. Z., Manley, G. T., Bresnahan, J. C., Beattie, M. S., Haefeli, J., & Ferguson, A. R. (2016). Multidimensional Analysis of Magnetic Resonance Imaging Predicts Early Impairment in Thoracic. *Journal of Neurotrauma*, *962*, 954–962.

Magu, S., Singh, D., Yadav, R. K., & Bala, M. (2015). Evaluation of traumatic spine by magnetic resonance imaging and correlation with neurological recovery. *Asian Spine Journal*, *9*(5), 748–756.

Mahshidfar, B., Mofidi, M., Yari, A. R., & Mehrsorosh, S. (2013). Long backboard versus vacuum mattress splint to immobilize whole spine in trauma victims in the field: a randomized clinical trial. *Prehospital and Disaster Medicine*, *28*(5), 462–465.

Martínez-Pe´rez, R., Paredes, I., Cepeda, S., Ramos, A., Castan˜o-Leo´n, A. ., García-Fuentes, C., Lobato, R. ., Go´mez, P. ., & Lagares, A. (2014). Spinal Cord Injury after Blunt Cervical Spine Trauma : Correlation of Soft-Tissue Damage and Extension of Lesion. *American Journal of Neuroradiology*, *35*(May), 1029–1034.

Maung, A. A., Johnson, D. C., Barre, K., Peponis, T., Mesar, T., Velmahos, G. C., Mcgrail, D., Kasotakis, G., Gross, R. I., Rosenblatt, M. S., Sihler, K. C., Winchell, R. J., Cholewczynski, W., Butler, K. L., Odom, S. R., & Davis, K. A. (2017). Cervical spine MRI in patients with negative CT : A prospective , multicenter study of the Research Consortium of New England. *Journal of Trauma and Acute Care Surgery*, *82*(2), 263–269.

Mboka, J., Sohal, P, K., & Kazema, R. (2016). Aetiology and Imaging Findings in Traumatic Spinal Injury Among Patients Attending Muhimbili Orthopedic Institute of Dar es Salaam. *East and Central Africa Journal of Surgery*, *21*(3), 11–16.

Mohamed, M. A., Majeske, K. D., Sachwani-daswani, G., Coffey, D., Elghawy, M., Pham, A., Scholten, D., Wilson, K. L., Mercer, L., & Mccann, M. L. (2016). Impact of MRI on changing management of the cervical spine in blunt trauma patients with a ‘ negative ’ CT scan. *British Medical Journal*, *1*, 1–6.

Morais, D. F., de Melo Neto, J. S., Meguins, L. C., Mussi, S. E., Filho, J. R. L. F., & Tognola, W. A. (2013). Clinical applicability of magnetic resonance imaging in acute spinal cord trauma. *European Spine Journal*, *23*(7), 1457–1463.

Moshi, H., Sundelin, G., Sahlen, K. G., & Sörlin, A. (2017). Traumatic spinal cord injury in the north-east Tanzania – describing incidence, etiology and clinical outcomes retrospectively. *Global Health Action*, *10*(1).

Muchow, R. D., Resnick, D. K., Abdel, M. P., Munoz, A., & Anderson, P. A. (2006). Magnetic Resonance Imaging (MRI) in the Clearance of the Cervical Spine in Blunt Trauma : A

Meta-Analysis. *The Journal of Trauma Injury, Infection, and Critical Care*, *64*(1), 179–189.

Mutua, J., & Wamalwa, N. (2020). *Leasing of Medical Equipment Project in Kenya: Value for Money Assessment*. https://www.africaportal.org/publications/leasing-medical-equipment-project-kenya-value-money-assessment/

Nagvekar, R. A., & Nagvekar, P. (2017). Low tesla MRI in acute spinal injuries : a study in a teaching hospital. *International Journal of Advances in Medicine*, *4*(1), 108–111.

Ochie, K., Okpala, O. C., Ohagwu, C. C., & Eze, C. U. (2013). Profile of MRI Findings and Neurologic Impairment in Spinal Cord Injury Patients at Lagos University Teaching Hospital , Nigeria Department of Radiography / Radiological Sciences , Faculty of Health Sciences and Technology ,. *World Journal of Medical Sciences*, *8*(4), 418–423.

Okello, E., Nyati, M., & Naddumba, E. . (2016). Prevalence and presentation of spinal injury in patients with major trauma admitted in Mulago hospital. *East and Central Africa Journal of Surgery*, *21*(2), 11–16.

Orege, J. A., Abuya, J. M., & Onditi, E. G. D. (2013). Common Magnetic Resonance Imaging (MRI) patterns in patients with low back pain in Eldoret , Kenya. *Journal of Scientific and Innovative Research*, *2*(2), 260–279.

Parashari, U., Khanduri, S., Bhadury, S., Kohli, N., Parihar, A., Singh, R., Srivastava, R., & Upadhyay, D. (2011). Diagnostic and prognostic role of MRI in spinal trauma, its comparison and correlation with clinical profile and neurological outcome, according to ASIA impairment scale. *Journal of Craniovertebral Junction and Spine*, *2*(1), 17–26.

Potter, H. G., Linklater, J. M., Allen, A. A., Hannafin, J. A., & Haas, S. B. (1998). Magnetic resonance imaging of articular cartilage in the knee. An evaluation with use of fast-spin-echo imaging. *Journal of Bone and Joint Surgery*, *80*(9), 1276–1284.

Qiu, Z., Wang, F., Hong, Y., Zhang, J., Tang, H., & Li, X. (2016). Clinical Predictors of Neurological Outcome within 72 h after Traumatic Cervical Spinal Cord Injury. *Nature Publishing Group*, *10*, 1–10.

Rabischong, P. (2004). *Comprehensive Anatomy of the Spinal Cord*. 268–276.

Rajasekaran, S., Vaccaro, A. R., & Mugesh, R. (2016). The value of CT and MRI in the classification and surgical decision-making among spine surgeons in thoracolumbar spinal injuries. *European Spine Journal*, *2*(7), 21–28.

Rodrigues-Pinto, R., Richardson, S. M., & Hoyland, J. A. (2014). An understanding of intervertebral disc development, maturation and cell phenotype provides clues to direct cell-based tissue regeneration therapies for disc degeneration. *European Spine Journal*, *23*(9), 1803–1814.

Rutges, J. P. H. J., Kwon, B. K., Heran, M., Ailon, T., Street, J. T., & Dvorak, M. F. (2017). A prospective serial MRI study following acute traumatic cervical spinal cord injury. *European Spine Journal*, *26*(9), 2324–2332.

Schueller, G., & Schueller-Weidekamm, C. (2014). The traumatized vertebral spine reloaded: Injury mechanisms and their radiologic patterns. *Seminars in Musculoskeletal Radiology*, *18*(3), 240–245.

Singh, R., Kumar, R., Setia, N., & Magu, S. (2015). A prospective study of neurological outcome in relation to findings of imaging modalities in acute spinal cord injury. *Asian Journal of Neurosurgery*, *10*(3), 181–189.

Srinivas, B., Rajesh, A., & Purohit, A. (2017). Factors affecting outcome of acute cervical spine injury: A prospective study. *Asian Journal of Neurosurgery*, *12*(3), 416.

Srivastava, R. N., Garg, R. K., & Agarwal, A. (2015). Epidemiology of Traumatic Spinal Cord Injury: A SAARC Perspective. *International Journal of Molecular Biology & Biochemistry*, *3*(1), 2349–2341.

Symons, F. S., Nelson, F. A., & Roberts, T. P. (2006). MR Pulse Sequences : What Every Radiologist Wants to Know but Is Afraid to Ask. *RadioGraphics 2006;*, *2*(26), 513–538.

Tambe, A. D., & Cole, A. A. (2012). Spinal fractures in adults. *Surgery (United Kingdom)*, *30*(7), 333–338.

Vafa Rahimi-Movaghar, M. K. S. b H. A., D, R. K. M. R. R. faziar M.-L., & Vaccaro, F. S. A. R. (2013). Epidemiology of Traumatic Spinal Cord Injury in Developing Countries : *Neuroepidemiology*, *3876*(41), 65–85.

Wang, H., Liu, X., Zhao, Y., Ou, L., Zhou, Y., Li, C., Liu, J., Chen, Y., Yu, H., Wang, Q., Han, J., & Xiang, L. (2016). Incidence and pattern of traumatic spinal fractures and associated spinal cord injury resulting from motor vehicle collisions in China over 11 years: An observational study. *Medicine*, *95*(43), 5220–5225. http://www.ncbi.nlm.nih.gov/pubmed/27787384%0Ahttp://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC5089113

WHO. (2013). International Perspective on Spinal Cord Injury. *World Health Organisation*, 341–360.

Woon, J. T. K., Perumal, V., Maigne, J. Y., & Stringer, M. D. (2013). CT morphology and morphometry of the normal adult coccyx. *European Spine Journal*, *22*(4), 863–870.

Yi, K., Han, D., Hengxing, Z., Zhijian, W., Lu, L., Dayu, P., & Shiquing, F. (2018). Epidemiology of worldwide spinal cord injury : a literature review. *Journal of Neurorestoratology*, *6*, 6–12.

Zhuge, W., Ben-galim, P., Hipp, J. A., & Reitman, C. A. (2015). Efficacy of MRI for Assessment of Spinal Trauma Correlation With Intraoperative Findings. *Journal Spinal Disorder Techniques*, *28*(4), 147–151.

APPENDICES

Appendix I: Consent

Investigator: My name is Dr. Daisy Denga. I am a qualified doctor, registered with the Kenya Medical Practitioners and Dentists Board. I am currently pursuing a Masters degree in Radiology and Imaging at Moi University. I would like to recruit you into this research which is to study the causes and Magnetic Resonance Imaging patterns of spinal injuries in patients presenting at Moi Teaching and Referral hospital.

Purpose: This study will seek to determine the causes and Magnetic Resonance Imaging patterns of spinal injuries in patients presenting at Moi Teaching and Referral hospital.

Procedure: All patients with spinal injuries referred for spinal MRI and for whom consent has been given will be recruited into the study. Demographic data, clinical and radiologic data will be obtained and recorded on data collection forms. Data collecting material will be kept in a locked cabinet during the study period.

Benefits: There will be no direct benefits of participating in this study. Study subjects will be accorded same quality of management as non-study subjects.

Risks: There are no anticipated risks to the participants attributable to this study.

Confidentiality: All information obtained in this study will be treated with utmost confidentiality and shall not be divulged to any unauthorized person.

Rights to Refuse: Participation in this study is voluntary, there is freedom to refuse to take part or withdraw at any time. This study has been approved by the Institutional Research and Ethics Committee (IREC) of Moi University/Moi Teaching and Referral Hospital.

Sign or finger print if you agree to take part in the study

Patient: .... Investigator:........................... Date: ....

Kiswahili version

Mimi ni Daktari Daisy Denga. Nimehitimu na kusajiliwa na bodi ya madaktari nchini Kenya (Kenya Medical Practitioners and Dentists Board).

Nakualika kushiriki katika utafiti wa kubainisha chanzo cha majeraha kwa uti wa ugongo na matokeo yakipelelezo cha MRI. Wagonjwa amabao watakuja watasajiliwa ikiwa watatia hiari yao.

Hapatakuwepo na manufaa yoyote zaidi na yale ya kawaida kwa wale watakao kubali kusajiliwa katika utafiti huu. Majibu ya utafiti huu yatawekwa katika hospitali na hakuna yeyote isipokuwa mgonjwa ambaye atapewa majibu haya.

Kila mgonjwa ana haki ya kukataa kujumuishwa katika utafiti huu.

Utafiti huu umeidhinishwa na kitengo that upelelezi cha hospitali ya MTRH

Mgonjwa……………..…mpelelezi :……………………….Tarehe :……………...

Appendix IV: Data Collection Form

SOCIO –DEMOGRAPHICS

Date………………… Date of Birth ……………

Code/Serial Number………… Age ……………

Gender Male ☐ Female ☐

County of Residence…………

Date of Injury……………..

PRESENTING HISTORY

Cause of Spinal Injury- MVA ☐ Assault ☐

Falls ☐ Gunshot ☐

Others-specify

Region imaged ………………………

MRI EXAMINATION FINDING

Spinal Cord

	Oedema	Haemorrhage	Mixed	Others
Cervical				
Thoracic				
Lumbar				

Vertebral Bodies Fractures

Cervical	Cervico-thoracic	Thoracic	Thoraco-lumbar	Lumbar	Lumbo-sacral	Sacral

Marrow oedema

	Cervical	Cervico-thoracic	Thoracic	Thoraco-lumbar	Lumbar	Lumbo-sacral	Sacral

Vertebral column malalignment

Cervical	
Thoracic	
Lumbosacral	

Posterior element fracture

Cervical	Cervico-thoracic	Thoracic	Thoraco-lumbar	Lumbar	Lumbo-sacral	Sacral

Spinal ligament injuries

	ALL	PLL	PLC	Others
Cervical				
Thoracic				
Lumbar				

Intervertebral disc

	Disc herniation	Disc tear
Cervical		
Thoracic		
Lumbar		

Other soft tissue injuries (Prevertebral /para vertebral/subcutaneous)

	oedema	tears	Others

Appendix V: MRI Protocol

Explanation of the procedure done to the patient to allay anxiety and get an informed consent. The patient then put on a hospital garment and all metallic wares removed.
MR examination of the spine was performed using 0.36 Tesla Magsense 360 machine at the MTRH MRI department using spine phased array coils. Sagittal and axial T1-weighted image (repetition time/echo time (TR/TE of 400- 600/15-25 ms), T2-weighted turbo image (TR/TE of 3,000-4000/100-120 ms) and STIR (TR/TE of 2000/60/80-90 ms) was acquired. A slice thickness of 4.5 mm, a slice gap of 0.2, a field of view between 280-400mm and a matrix of 256 by 256 will be used for the sagittal and axial images.

The patient laid supine on the MRI couch and the head placed in the head and spine coil then immobilized with cushions. Other cushions were placed under the legs for extra comfort. Laser beam localizer was centred over the mid neck (2.5cm below the chin for cervical spine), mid-sternum for thoracic spine and mid abdomen (4 inches above the iliac crest) for lumbosacral spine. A 3- plane T1weighted low resolution scan localizer was used to localize and plan the sequences.

Sagittal slices were planned on coronal plane using the position block place parallel to the spinal cord with a field of view that covers the spine region being examined. Axial images were planned on sagittal plane with position block perpendicular to the spinal cord and parallel to the intervertebral discs on coronal plane and a field of view covering the spine. Saturation band were placed in front of the spine to prevent motion artifacts. The images were printed onto laser film hard copies and stored directly as DICOM (Digital Imaging and Communications in Medicine) files in the MR workstation and in CD-ROMs.

Appendix VI: IREC Approval

MU/MTRH-INSTITUTIONAL RESEARCH AND ETHICS COMMITTEE (IREC)

MOI TEACHING AND REFERRAL HOSPITAL
P.O. BOX 3
ELDORET
Tel: 33471/2/3

MOI UNIVERSITY
COLLEGE OF HEALTH SCIENCES
P.O. BOX 4606
ELDORET

14th March, 2019

Reference: IREC/2018/310
Approval Number: 0003267

Dr. Denga Daisy Adhiambo,
Moi University,
School of Medicine,
P.O. Box 4606-30100,
ELDORET-KENYA.

INSTITUTIONAL RESEARCH & ETHICS COMMITTEE
14 MAR 2019
APPROVED
P. O. Box 4606-30100 ELDORET

Dear Dr. Denga,

RE: FORMAL APPROVAL

The MU/MTRH- Institutional Research and Ethics Committee has reviewed your research proposal titled: -

"Magnetic Resonance Imaging Patterns and Causes of Spinal Trauma in Patients at Moi Teaching and Referral Hospital, Eldoret, Kenya".

Your proposal has been granted a Formal Approval Number: ***FAN: IREC 3267*** on 14th March, 2019. You are therefore permitted to begin your investigations.

Note that this approval is for 1 year; hence will expire on 13th March, 2020. If it is necessary to continue with this research beyond the expiry date, a request for continuation should be made in writing to IREC Secretariat two months prior to the expiry date. You will be required to submit progress report(s) on application for continuation, at the end of the study and any other times as may be recommended by the Committee.

Furthermore, you must notify the Committee of any proposal change (s) or amendment (s), serious or unexpected outcomes related to the conduct of the study, or study termination for any reason. You will also be required to seek further clearance from any other regulatory body/authority that may be appropriate and applicable to the conduct of this study.

Sincerely,

DR. S. NYABERA
DEPUTY-CHAIRMAN
INSTITUTIONAL RESEARCH AND ETHICS COMMITTEE

cc	CEO	-	MTRH	Dean	-	SOP	Dean	-	SOM
	Principal	-	CHS	Dean	-	SON	Dean	-	SOD

Appendix VII: Hospital Approval

An ISO 9001:2015 Certified Hospital

MOI TEACHING AND REFERRAL HOSPITAL

Telephone :(+254)053-2033471/2/3/4
Mobile: 722-201277/0722-209795/0724-800461/0734-683361
Fax: 053-2061749
Email: ceo@mtrh.go.ke/directorsofficemtrh@gmail.com

Nandi Road
P.O. Box 3 – 30100
ELDORET, KENYA

Ref: ELD/MTRH/R&P/10/2/V.2/2010

20th March, 2019

Dr. Denga Daisy Adhiambo,
Moi University,
School of Medicine,
P.O. Box 4606-30100,
ELDORET-KENYA.

APPROVAL TO CONDUCT RESEARCH AT MTRH

Upon obtaining approval from the Institutional Research and Ethics Committee (IREC) to conduct your research proposal titled:-

"Magnetic Resonance Imaging Patterns and Causes of Spinal Trauma in Patients at Moi Teaching and Referral Hospital, Eldoret, Kenya".

You are hereby permitted to commence your investigation at Moi Teaching and Referral Hospital.

MOI TEACHING AND REFERRAL HOSPITAL
CEO
APPROVED
20 MAR 2019
P. O. Box 3 - 30100, ELDORET

20/03/2019

DR. WILSON K. ARUASA, *MBS*
CHIEF EXECUTIVE OFFICER
MOI TEACHING AND REFERRAL HOSPITAL

cc - Senior Director, (CS)
- Director of Nursing Services (DNS)
- HOD, HRISM

All correspondence should be addressed to the Chief Executive Officer
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