Cape Peninsula University of Technology

Research thesis

Follow-up Computed Tomography imaging in patients who have suffered traumatic brain injury in Zimbabwe

By

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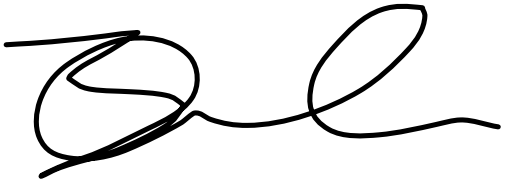
Declaration

I, **Jonathan Dube**, declare that the contents of this thesis represent my original work, and that neither the whole nor part of this thesis has not been submitted for academic examination towards any qualification. Furthermore, it represents my own opinions and not necessarily those of the Cape Peninsula University of Technology.

Signed:  **Date 30 June 2019**

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Dedication

To my parents who died during my college studies. I will always love you.
May their souls rest in peace.

Abstract

Introduction: Traumatic brain injury (TBI) is frequently associated with mortality and morbidity in low-income countries. Computed Tomography Brain (CTB) imaging aid in the management of patients by accurately exploring primary and secondary brain injuries following trauma. However, there is controversy among researchers on the benefits of follow-up CTB imaging (FCTBI) amongst patients presenting with TBI showing a normal baseline scan. As such, in an attempt to address the contention, the primary focus of this research study was to explore the role of FCTBI with regards to the clinical status of such patients. The secondary focus was to determine the timing of performing FCTBI post TBI.

Method: A retrospective cross sectional quantitative design was conducted for this research study. A total sampling strategy was employed on medical records of 85 patients treated at the research site in Zimbabwe. Data were collected over a two year period. Adult patients between the ages of 18 and 75, with TBI and who had a normal first CTBI1 (primary scan done upon hospital admission) were included in this research study. The evolution of different types of brain pathology diagnosed on FCTBI in affected patients were recorded on data collection sheets. An analysis then followed to establish whether the sample patients had developed any neurological complications.

Results: The study showed that in 85 patients with TBI, 36% recorded abnormal radiological findings on FCTBI with subdural haematoma (19%) being the most common intracranial lesion followed by intracerebral haemorrhage (8%), subarachnoid haemorrhage (6%) and lastly, pneumocephalus and epidural haematoma (1% respectively). The most frequent causal mechanism of trauma was road traffic accidents (RTAs) at 58%. Males with TBI comprised a higher proportion (53%) than did females (47%). The performance of CTBI1 at 8 hours post trauma occurrence, within a recommended hospital observation period of 20 hours post trauma occurrence, may provide sufficient time for lesions to evolve and thus determine the appropriate patient management. The young adult age group of 26-35 years was found to be more susceptible to TBI.

Conclusion: FCTBI was found to be of value in timely detection of evolving intracranial lesions which enabled appropriate management of patients. The current study recommends that patients who exhibit a declining Glasgow Coma Scale (GCS) score and deteriorating neurological status undergo a FCTBI.

Key words: traumatic brain injury, follow-up CT brain imaging, neurological complications, abnormal radiological findings, intracranial haemorrhage

Table of Contents

Pages

List of Figures

List of Tables

Addenda

Glossary

Abbreviations and Acronyms

CT	Computed Tomography
CTB	Computed Tomography Brain (imaging modality)
CTBI1	CT Brain Imaging 1 (primary scan done upon hospital admission)
CSF	Cerebrospinal Fluid
DALYs	Disability-adjusted life years
EDH	Epidural Haematoma/Haemorrhage
FCTBI	Follow-up Computed Tomography Brain Imaging (performed during the observation period)
GBD	Global Burden of Disease
GCS	Glasgow Coma Scale
HRV	Heart Rate Variability
ICH	Intracranial Haemorrhage
ICP	Intracranial Pressure
IHME	Institute for Health Metrics and Evaluation
MRCSA	Medical Research Council of South Africa
MRCZ	Medical Research Council of Zimbabwe
MRI	Magnetic Resonance Imaging
MTBI	Mild Traumatic Brain Injury
NTDB	National Trauma Database
PACS	Picture archiving and communication system
PBI	Penetrating brain injury
RTA	Road Traffic Accident
SAH	Subarachnoid Haemorrhage
SBP	Systolic Blood Pressure
SDH	Subdural Haemorrhage/Haematoma
SIGN	Scottish Intercollegiate Guidelines Network
SPSS	Statistical Package for the Social Sciences
TBI	Traumatic Brain Injury
USA	United States of America
WHO	World Health Organisation
ZIMSTAT	Zimbabwe National Statistics Agency
ZMHCW	Zimbabwe Ministry of Health and Child Welfare

CHAPTER 1

Introduction

1.1 Introduction

Computed Tomography Brain (CTB) imaging plays a major role in the diagnosis of traumatic brain injury (TBI)-related pathology and the neurological management thereof. Post traumatic occurrence TBI may result in neurological surgery, admission to hospital or even death (Wintermark *et al.,* 2015). CTB imaging can accurately diagnose secondary brain injuries such as ischemia, cerebral oedema, raised intracranial pressure (ICP) and brain herniation. In the assessment of primary TBI, CTB imaging readily detects extra-axial haemorrhage such as subarachnoid haemorrhage (SAH), subdural haemorrhage (SDH), epidural haemorrhage (EDH) and intra-axial haemorrhage which include cortical contusion, intraparenchymal haematoma and shear injury (Kim & Gean, 2011). CTB imaging is therefore an essential follow-up modality for patient management (Lolli *et al.,* 2016).

Grumme (1998) classified TBI as a closed head injury when the dura mater remains intact or, as open head injury when the dura mater is perforated by foreign bodies. For the purpose of this research study, TBI was referred to as an alteration in brain function or any signs and/or symptoms of brain pathology due to external impact (Menon *et al.,* 2010).

Globally, TBI is a significant public health problem and is associated with an increased social burden, health care expenses, mortality and morbidity (Majdan et al., 2016). A study by Makanza (2013) revealed that 78% of patients with TBI in Zimbabwe experienced head injuries as a result of road traffic accidents (RTAs), which was the leading mechanism of trauma. In addition to this, based on the Global Burden Disease (GBD) classification of 2016, Zimbabwe had the highest rate, 1 275 per 100 000 people, of premature deaths due to RTAs when compared with its trade partnership countries such as Bangladesh, Ghana, Nigeria (Institute for Health Metrics and Evaluation [IHME]), (2017). Syed *et al.* (2007) stated that head injuries may cause intracranial complications which in turn result in life-time disabilities such as impaired cognitive function, post-traumatic stress disorder and depression. Thus, there is a need for early diagnosis and management of patients with TBI. Likewise, due to its widespread availability, CTB imaging has emerged as the gold standard method of examination for the evaluation of TBI (Chawla et al., 2015). An observation made by Parma *et al.* (2014) showed that most initial CTB images obtained in patients with mild TBI are negative i.e. they record normal radiological results, although the intracranial injury may yet be progressing. In view of this, Hemphil *et al.* (1999) suggested that in patients with symptoms that become increasingly severe over the course of treatment (e.g. those taking systemic anticoagulation medication) or even with a normal primary CTB imaging (CTBI1), a follow up CTB imaging (FCTBI) should be performed.

1.2 Research Site

The research site, in Zimbabwe, was purposively selected (Babbie & Mouton, 2001) for this research study during the period 1 June 2015 to 1 June 2017. The research site is a major referral hospital with high patient turnover. The research site serves patients with TBI from both the government and private sector. According to the Zimbabwe Ministry of Health and Child-welfare (ZMHCW) (2009), this site is a Quaternary Hospital (research site level) which treats patients from primary level (small health centres e.g. clinics) and secondary level (i.e. district hospitals) facilities. The hospital is an academic institute affiliated to the University of Zimbabwe and provides training and research for various health care professionals. The neurological centre is staffed with specialists including radiologists and neurosurgeons who play a key role in the management of patients with TBI (i.e. interpret CTB images and manage patients). In addition, the researcher had knowledge of the hospital and its departmental environment which enabled an efficient arrangement for collection and verification of the data.

1.3 Problem Statement

Typically, when a patient with TBI was admitted to the research site, CTB imaging was performed following referral by the neurosurgeon. If CTBI1 was reported as normal by the radiologist or neurosurgeon, and the patient seemed stable, such patients would be discharged from the hospital without further monitoring. However, there were anecdotal reports of patients who returned to the hospital some days later (i.e. after 2 days) with neurological complaints which included: post traumatic headaches, nausea, vomiting, dizziness, confusion, post traumatic seizures and memory loss. On performing further CTB imaging on such patients, chronic haematomas were noted which, in the event that no second traumatic injury to the brain had occurred, could have evolved and progressed in between the time of patients' discharge and the return to the hospital. This therefore implies that some patients may have developed secondary neurological complications following the normal CTBI1 base line. Thus, the primary focus of this research study was to explore the role of FCTBI in patients presenting with TBI at the research site. The secondary focus was to determine the timing of performing FCTBI post TBI in such patients.

1.4 Research Question

The research question for this research study was: "Can follow-up CT imaging of the brain demonstrate the presence of neurological complications which may alter patient management in those who suffered trauma to the brain?"

1.4.1 Research Objectives

The research objectives for this study were to establish the:

1. type of neurological complications that trauma patients experienced following a normal first CT of the brain;
2. neurological symptoms that were realised in trauma patients who had late neurological complications following a normal first CT of the brain;
3. prevalence of mechanisms of trauma sustained by trauma patients with late neurological complications following a normal first CT of the brain;
4. risk factors related to late neurological complications among trauma patients following a normal first CT of the brain;
5. relationship between FCTBI findings and: neurological status, mechanism of trauma, anticoagulation status, GCS scores;
6. timing of performing follow-up CTB imaging in trauma patients who had late neurological complications following a normal first CT of the brain.

1.5 Study Justification

A study conducted by Wu and Jallo (2011) showed that FCTBI was performed on the basis that it reduced the delay in the detection and treatment of acute intracranial injuries. Thus, the aforementioned authors recommended that regardless of the patient's clinical examination, FCTBI should be carried out between 6 and 12 hours following trauma occurrence in order to detect any developing haematoma. It was further reported that EDHs are likely to evolve within 6 hours of injury, thus accentuating the importance of FCTBI in patients with TBI (Wu & Jallo, 2011). Af Geijerstam & Britton (2005) reiterated that if abnormal changes in the brain are missed on CTBI1, the patient could deteriorate after being discharged which might be potentially fatal for the patient. Doddamani *et al.* (2012) appraised the role of routine FCTBI in detecting new brain lesions or enlargement of those already existing, resulting in change of hospital management for a considerable number of patients.

On the other hand, Smith *et al.* (2007) reiterated that early FCTBI in cases of head trauma is not routinely indicated. The insignificance of FCTBI was revealed when most of the findings only demonstrated radiological progression of the initial lesion which did not result in a change in patient management in the absence of neurological deterioration (Haider *et al.,* 2015). According to Af Geijerstam and Britton (2005), there is a very low risk of developing brain pathology following a normal CTBI1. Rosen *et al.* (2018) claimed that FCTBI added unnecessary cost to healthcare expenditure and exposed patients to unnecessary radiation. In a study conducted by Rosen *et al.* (2018), 75 patients that were not scheduled for surgical intervention received FCTBI and findings were such that no alteration in neurological treatment was necessary. Smith

et al. (2007) stated that an assessment based on the severity of radiological findings on CTBI1 and consecutive clinical examinations should act as a guide for the need of a FCTBI within the context of TBI. Rosen *et al.* (2018) demonstrated that clinical care need not change regardless of the FCTBI results when there is no accompanying clinical deterioration. Wu and Jallo (2011) revealed that the timing of serial CTB imaging did not correlate with patient outcomes. Rather, the performing of surgical intervention relative to the time of neurological decline was the determinant factor of patient outcome. The authors concluded that clinical deterioration in FCTBI did not necessarily affect patient outcomes (Wu & Jallo 2011).

Based on the aforementioned discussion it would appear that there is currently no clinical consensus on the usefulness of FCTBI amongst patients with a normal baseline scan following TBI (Joseph *et al.,* 2014). This perceived lack of consensus therefore implies that more research is needed in order to derive evidence-based clinical findings which may negate such opposing opinions and streamline patient management. At the research site in Harare, Zimbabwe, when the initial CT imaging of the brain following trauma excluded intracranial injury, patients were usually discharged without further observation. There is no TBI databank in Zimbabwe and therefore no contemporaneous studies were found that related to the incidence and prevalence of TBI. Thus, this research study was aimed at assessing the prevalence of neurological complications after a normal CTBI1 within a defined sample population. The research study further aimed to ascertain, within the same sample population, whether or not FCTBI contributed to the diagnosis of, and indirectly resulted in the reduction of neurological complications in patients with TBI. The study in broader terms therefore assessed the role of FCTBI in patients who had suffered TBI.

1.6 Overview of the Thesis structure

A brief outline of the thesis structure is presented as follows:

1.6.1 Chapter 2: Literature Review

Chapter 2 presents an in-depth literature review. The chapter commences with discussing the neurological complications experienced by patients with TBI and concludes with a consideration of the role of FCTBI in patients with TBI.

1.6.2 Chapter 3: Research Methodology

In this chapter, the research strategy employed during this study outlines how data were gathered. Thus, the research design and methodology of the study are explained. The data measurement tools, sample design and sampling method, data collection and the ethics considered in this study are discussed.

1.6.3 Chapter 4: Research Results

This chapter outlines how data were analysed. Thereafter, the results from the study are presented.

1.6.4 Chapter 5: Discussion of Study Findings, Recommendations and Conclusions

The findings from the results are discussed and compared with results recorded by research done elsewhere. Research contexts which could have influenced the results are discussed. Challenges and limitations that occurred during the study are referred to. Recommendations on what may be done to improve the prevailing conditions for patients with TBI and areas for further research are described in this section. The conclusions drawn from the study are presented.

1.7 Chapter Summary

Computed Tomography is regarded by many authors and/or researchers as an important imaging tool in the detection of brain pathology in patients with TBI. However, there are varied opinions on the importance and the time of performing FCTBI in such patients. Thus, the main objective of this study was to provide context for the role of FCTBI in patients with TBI in Zimbabwe. The literature review chapter to discuss the research question for this research study will follow.

CHAPTER 2

Literature Review

2.1 Introduction

The focus of this study was on the role of FCTBI in patients who have suffered TBI. The literature reviewed in this chapter will be relevant to the research objectives as outlined (section 1.4.1) and, identify knowledge gaps from other studies on the role of FCTBI in patients with TBI. The chapter starts by discussing the neurological complications experienced by patients with TBI. Thereafter a discussion follows with regard to the neurological symptoms associated with the neurological complications and the mechanism of trauma sustained by patients with TBI. The factors affecting TBI which *inter alia* include: gender, age, anticoagulant medication, vital signs (i.e. blood pressure, body temperature and heart rate) and the Glasgow Coma Scale (GCS) score will also be discussed. Finally, the literature review considers the timing employed in performing CTB imaging and the usefulness of FCTBI.

2.2 Traumatic Brain Injury Complications

Brain damage following trauma can be classified according to the time course as either primary brain injury which occurs at the time of impact, or secondary brain injury which progresses over the hours or days post injury due to intracranial complications (e.g. brain oedema, foramina herniation). Brain injury can further be classified in terms of tertiary complications (e.g. critical illness polyneuropathy, sepsis) that occur days or weeks post-trauma as an aftermath of a change in catabolic state due to infection or paralysis (Vos *et al.,* 2002). According to Cernak and Noble-Haeusslein (2010) common cerebrovascular changes noted amongst patients with TBI include: SAH, hyperaemia, brain swelling, vasospasm and raised ICP. Intracranial complications from mild head injury are infrequent but can be life threatening (Afzal *et al.,* 2013). In a study conducted by Doddamani *et al.* (2012), progressive intracranial lesions between CTBI1 and FCTBI were noted in 40.5% of patients with TBI. The distribution was as follows: 21.8% recorded mixed lesions, 12.5% SDH and 6.2% EDH. Traumatic SAH was associated with a two-fold increase in mortality whilst intracranial haemorrhage (ICH) recorded a maximum of 80% positive predictive poor functional outcome, and the prognosis worsened with an increase in haematoma size (Kim & Gean, 2011). One of the typical complications linked to SAH is hydrocephalus which in acute phase, can be due to intraventricular haemorrhage (Anzai & Minoshima, 2011).

There are various neurological symptoms which may be associated with patients with TBI which will be discussed in the next section.

2.3 Neurological Symptoms

Vos *et al. (*2002) emphasised that commonly presented post-traumatic complaints by patients with TBI are: dizziness, headache, irritability, insomnia, anxiety, photophobia and loss of memory. Borg *et al.* (2004) defined a headache as any head pain that may be local or diffuse. Láinez and Pesquera (2011) identified post-traumatic headache as the most common neurological symptom following TBI. A study conducted by Lenaerts and Couch (2004) showed frequent occurrences of headaches in patients with TBI; 37%, 27% and 18% of patients had tension, migraine and cervicogenic headaches respectively. A recursive-partitioning analysis by Haydel *et al.* (2000) yielded some symptoms that identified patients with abnormal pathology on CTB imaging. These were: headache ($p = 0.03$), vomiting ($p = 0.02$) and seizure ($p = 0.01$). The authors also defined vomiting as any emesis after TBI. Nee *et al.* (1999) confirmed that an overall incidence of 7% in post-traumatic vomiting found in adult patients was associated with a four-fold increased risk of having a skull fracture. Post-traumatic seizure identified as a risk factor for TBI, was observed in more than 20% of patients (Vespa & Nuwer, 2000). The Task Force on Mild Traumatic Brain Injury (MTBI) in Europe noted that the risk factors for intracranial complications after mild TBI include: severe headaches, amnesia, clinical signs of skull fracture, post traumatic seizures and coagulation disorders (Vos *et al.,* 2002). In addition, Ponsford (2000) observed that adults with mild TBI reported symptoms, particularly of memory loss, fatigue, dizziness and impaired vision one week after trauma occurrence. Therefore, these patients exhibited slow information processing on neuro-psychological testing. Anzai and Minoshima (2011) suggested that post traumatic headaches, seizures and vomiting among others, are the neurological symptoms commonly considered in clinical prediction rules. The Scottish Intercollegiate Guidelines Network (SIGN) also recommended that in patients with full consciousness and no skull fracture, but other neurological symptoms such as severe ongoing headache and vomiting, CTB imaging is justified (Kerr *et al.,* 2005).

2.4 Mechanisms of Trauma Sustained by Patients with TBI

Traumatic Brain Injury originating from assaults and RTAs has been shown to have more severe consequences than do all other aetiologies such as falls (Bauer *et al.,* 2015). Studies have shown that there is a marked mortality rate (19.8%), amongst patients where the major cause of brain injury were RTAs (59%) than was that recorded for falls and assaults (18.7% and 12.9% respectively) (Ohaegbulam *et al.,* 2011). In Zimbabwe, 72% of RTA casualties were estimated to have TBI (Hitimana *et al.,* 2009). It has also been predicted globally that by 2020, RTAs will rank third among the causes of disability adjusted life years lost (DALYs) (Ngallaba *et al.,* 2014). Doddamani *et al.* (2012) also indicated that RTA was the most common cause of trauma in 67% of patients with TBI in India.

It is noteworthy that a study by Bauer *et al.* (2015) which included trauma to military civilians and accidents at industrial sites suggested that lesions in blast-related TBI are distinct from other TBI aetiologies. The aforementioned authors described these lesions as focalised and scattered throughout the brain parenchyma, independent of the blast loading direction. Thus, blast injury is a complicated disease process which may evolve over time, particularly with TBI (Bochicchio *et al.,* 2008). According to Kobeissy *et al.* (2013) penetrating brain injury (PBI) is caused by mechanical tear and rupture of blood vessels which lead to evolution of SDH, ICH, brain oedema posttraumatic vasospasm, traumatic aneurysm and arteriovenous occlusion. Despite normal GCS score or minimal evidence of external trauma, surgeons treating victims from blast injury should maintain a high index of suspicion for TBI (Bochicchio *et al.,* 2008). A study of battered women conducted by Jackson *et al.* (2002) reported that 92% had brain injuries following blows to the head with 40% of this proportion experiencing a loss of consciousness. Another study by Talbot *et al.* (2005) indicated that 25.5% of a patient sample who had fallen, screened positive for depressive symptoms. The activity most frequently cited as causing falls was ambulation especially on uneven surfaces. Harvey and Close (2012) indicated that falls were the most common mechanism of trauma, with an increased rate of fall-related TBI of 8.4% per year ($p < .001$ at 95% confidence interval). There are two broad mechanisms of TBI in existence described by Bauer *et al.* (2015). These are impact, whereby the immediate force has contact with the skull leading to injury; and impulse whereby a force causes the movement of the head without making contact to the head. Regardless of the type of mechanism, Bauer *et al.* (2015) were of the view that head injury severity is a result of rotational and linear force. Furthermore, mechanisms of brain trauma lead to delayed white matter injury which is perceived as a major element impacting on the quality of life of patients with TBI (Bruns & Hauser 2003).

2.5 Factors Associated with TBI Outcome

Patients identified with abnormalities in GCS score, systolic blood pressure (SBP), and heart rate were inclined toward a high TBI mortality when compared to those with abnormal GCS score alone (Reisner *et al.,* 2014). Naidoo (2013) also commented that age, male gender and low socioeconomic status are major risk factors for TBI. This research study explored several factors that affect TBI and were as follows:

2.5.1 Gender

It is important to consider gender as a risk factor in TBI outcome (Farace & Alves 2000). An analysis of the National Trauma Database (NTDB) indicated males to be more susceptible to the evolution and progression of ICH in TBI cases (Kisat *et al.,* 2012). Bauer *et al.* (2015) noted that males typically in adolescence and young-adult age were at high risk of TBI when compared to their female counterparts. It has been shown that males <65 years of age had an incidence of

TBI (73%) which was three times more than did females (27%) (Farace & Alves, 2000). A study conducted by Lannsjö *et al.* (2012) indicated that males comprised a greater proportion (60%) of patients with TBI than did females (40%). A South African study conducted by Munivenkatappa *et al.* (2016) also reported a high male: female (>4:1) ratio for patients with TBI. This may be due to the fact that male neurons are more vulnerable to pharmacological insults that simulate brain injury. Hence male cells are unable to regulate intracellular glutathione levels after TBI, thereby causing the evolution of intracranial lesions (Vagnerova *et al.,* 2008). According to the Zimbabwe National Statistics Agency (ZIMSTAT) (2013), 59% of the employed population is comprised of males and they are the most common road users involved in RTAs.

However, Bay *et al.* (2009) reiterated that it is important to acknowledge that females do comprise a substantial proportion of patients presenting with TBI. Females are also considered to present with greater levels of memory and cognition challenges, pain, chronic stress, motor and depressive-somatic symptoms than are males (Bay *et al.,* 2009). Findings from a research study in the United States of America (USA) reported that case fatality rates in patients with TBI revealed a significant increase amongst females which was 1.75 times more than males (Kraus *et al.,* 2000). In support of this, a study conducted by McMillan and Teasdale (2007) in Scotland showed that TBI-induced mortality rate for females (13.5%) was greater than that recorded for males (8.5%). Even though there are different opinions on which gender is more commonly involved in TBI, Lannsjö *et al.* (2012) reported no significant relatedness between CTB imaging and gender.

2.5.2 Age

Traumatic Brain Injury is ranked fifth among the leading causes of mortality in young adults <40 years of age in Eastern China (Puvanachandra & Hyder 2009). In Zimbabwe, there appears to be a lack of statistics on TBI. Globally, RTA was ranked the tenth cause of mortality in all age groups from 0 to 65 years and older (IHME, 2017). Bouillon *et al.* (1999) concurred that brain trauma is the injury of the young where the peak age group was 21 to 30 years. A prospective study of patients with TBI who presented for a CTB imaging in Nigeria showed that 33.9% of such patients recorded ages ranging from 20 to 49 years (Ohaegbulam *et al.,* 2011). Conclusions drawn from these statistics are ascribed by Ohaegbulam *et al.* (2011) as most likely due to high exposure to occupational and social risks of this active and productive age group. Studies from the USA, France and Eritrea have shown a higher incidence of brain injuries (19.8%) during the first, second and third decades of life (Munivenkatappa *et al.,* 2016). Traumatic Brain Injury occurred more frequently in the young and middle-aged groups with a distribution of 37% and 30% respectively compared to 15.8% for older patients (Talbot *et al.,* 2005). According to Bauer *et al.* (2015), the poor prognosis for TBI in old age could be attributed

to a decline in sensory and motor pathways, cognitive impairments and deconditioning. Mack *et al.* (2003) emphasised that reduced elasticity and increased frailty of blood vessels as well as the abating mechanical properties of bridging veins in the elderly, make them more prone to shear and tear during the course of TBI. Additionally, the elderly are less likely to exhibit signs or symptoms of raised ICP as a result of cerebral atrophy. Therefore, CTB imaging is recommended for all elderly patients who sustain even mild TBI (Mack *et al.,* 2003). In a prospective study conducted by Hukkelhoven *et al.* (2003), proportions of unfavourable outcome or mortality increased with age by 39% and 21% respectively for patients < 35 years, and 74% and 52% respectively for patients > 55 years. Therefore, age was considered to be an independent predictor for mortality in patients with TBI (Mosenthal *et al.,* 2002).

2.5.3 Use of Anticoagulants Among Patients with TBI

According to Stein and Smith (2004), the incidence of blood coagulation in patients with TBI varies between 15% and 100% and is demonstrated by progressive changes observed on CTB imaging as it was linked to neurological complications. Mina *et al.* (2002) identified patients with TBI on anticoagulants such as warfarin or aspirin to have an estimated fivefold increased risk of mortality than in patients not taking anticoagulants. Ho *et al.* (2013) attributed the increased risk of mortality to secondary haemorrhage progression in patients on anticoagulants. Moreover, Joseph *et al.* (2014) stated that a routine FCTBI is an examination that is three times more important in patients on anticoagulants. Ferrera and Bartfield (1999) reiterated that patients on warfarin have a high risk of life-threatening haemorrhage even after relatively mild TBI. In a study conducted by Franko *et al.* (2006), the mortality rate in patients with TBI who used anticoagulants, was higher and statistically more significant than in the control group ($p < 0.001$). The aforementioned authors concluded that warfarin anticoagulation was associated with a six-fold increase in TBI mortality. Similarly, Cohen *et al.* (2006) recommended that all patients on anticoagulant medication and presenting with TBI brain pathology on CTBI1, should be hospitalized for neurological observation without performing a routine FCTBI. The authors suggested that FCTBI be reserved for those patients manifesting new and/or worsening clinical symptoms. Conversely, Menditto *et al.* (2012) emphasized that in patients with mild TBI with normal radiological screening on CTBI1, and receiving warfarin, should undergo a 24-hour observation protocol followed by FCTBI employed to detect any occurrence of delayed bleeding.

2.5.4 Vital Signs

Vital signs are clinical measurements that indicate the state of a patient's essential body functions (Storm-Versloot *et al*. 2014).The following vital signs are discussed:

2.5.4.1 Blood Pressure

The current management of TBI in a neurosurgical care unit is focused on alleviating the cascade of secondary brain injuries. This is done by means of maintaining sufficient perfusion to the brain (Kim & Gean, 2011). Kim and Gean (2011) stressed that this approach requires vigilant neuro-monitoring and regulation of blood pressure and oxygenation to prevent hypotension which can increase mortality and morbidity. Low SBP may be an important secondary risk factor after a TBI episode (Fuller *et al.,* 2014). Hypotension during the course of a patient's neurological management; or a SBP of < 90 mmHg, have powerful negative effects on patient outcome and may result in secondary brain injury (Chi *et al.,* 2003). Cooper *et al.* (2004) agreed that in patients with severe TBI, hypotension is markedly linked to poor outcome. A study conducted by Bouillon *et al.* (1999), showed a significant increase in mortality rate from 37% to 65% in brain injured patients who presented with SBP of less than 90 mmHg. As such, Carney *et al.* (2017) emphasized the importance of maintaining a minimum systolic pressure of 90 mmHg for patients with TBI. However, recent studies originating from the largest European trauma registry suggested the need to redefine hypotension at increased levels and revise the current cut-off of 90 mmHg for SBP (Fuller *et al.,* 2014). In support of this, a review by Ley *et al.* (2012) on a Trauma System database showed that patients with TBI and hospitalized with SBP thresholds > 190 and 180 mmHg indicated a likelihood of higher mortality rates in the young and middle age groups respectively. However, considering opinions from various authors, a tentative conclusion is that both hypotension and hypertension can be associated with an increase in mortality rate in patients with TBI.

2.5.4.2 Body Temperature

Charmaine (2008) highlighted that an increase in body temperature of 1-2 ^{o}C immediately after TBI is generally regarded to be harmful. Raised body temperature may be a biomarker of the extent of brain injury (Sacho & Childs 2008). In a publication by Spiotta *et al.* (2008), the mean ICP in 72 patients with TBI was shown to be similar in patients with a brain temperature of 39.8 ^{o}C than in those with normothermia. Hypothermia that is maintained at 32 ^{o}C or 33 °C for 24 hours immediately after severe TBI may improve the outcome in a significant proportion of patients. This is thought to be due to the repression of the post-traumatic inflammatory response (Marion *et al.,* 1997). Conversely, Sacho and Childs (2008) have shown that temperatures of 32.8 ^{o}C correlate with a 100% mortality rate among patients and have a prognostic factor for poor outcome. Moreover, clinical studies revealed that patients with TBI with temperatures below 37 ^{o}C and above 39 ^{o}C are associated with an increased risk of death (Saxena *et al.,* 2015). Therefore, a preliminary conclusion can be drawn that both hyperthermia and hypothermia are associated with adverse outcomes in TBI cases (Sacho & Childs 2008).

2.5.4.3 Heart Rate Variability

Heart rate variability (HRV) is defined as a degree of variation in the mean heart rate (King *et al.,* 1997). Shalev *et al.* (1998) reported that HRV expresses the extent of the response to traumatic events such as TBI, which can be missed by psychometrics. Therefore, HRV could be an important predictor of an inevitable brain death in patients with severe TBI (Rapenne *et al.,* 2001). Both temperature and cardiac autonomic function are distorted during the subacute period after a mild TBI (Griesbach *et al.,* 2013). A study conducted by Francis *et al.* (2016) indicated that an improvement in reduced HRV in patients with TBI coexists with observed functional recovery. Reduced (HRV) reflects a compromised vagal nerve function and impaired emotion regulation capacity (Liddell *et al.,* 2016). Thus, according to a theory by Liddell *et al.* (2016), reduced resting HRV in patients with TBI has been associated with mental disorder, depression and anxiety; aggression and anger; comorbidity and poor physical health.

2.5.5 Glasgow Coma Scale

The GCS score is an essential component for the practical assessment of impaired consciousness (Teasdale, 2014). As noted by Afzal *et al.* (2013), TBI severity, based on the GCS score is classified at the time of injury as mild (13-15), moderate (9-12), or severe (8 or less). Chi *et al.* (2003) commented that GCS scores obtained in hospital correlate significantly with patient outcomes post severe TBI. Stiel *et al.* (2001) have recommended that patients should undergo CTB imaging if there is no improvement to a GCS level of 15 within 2 hours of TBI occurrence as this places such patients at risk of having neurological complications.

However, Almenawer *et al.* (2013) refuted claims that GCS score can be used as a guide to define mild TBI as it does not exclude serious intracranial injuries. A study by Rosen *et al.* (2018) showed that some patients who had an initial GCS score of 15 were treated with primary surgical therapy based on the clinical presentation and the appearance of their CTB imaging findings. By virtue of this, such patients were considered to have moderate to severe TBI despite the fact that they were awake, with a GCS score of 15 (Rosen *et al.,* 2018). Sanei *et al.* (2007) were in support of the former view by demonstrating that many patients with a GCS score of 15 following TBI, had considerable brain pathology. Similarly, Kerr *et al.* (2005) explained that the intake of alcohol complicates the interpretation of GCS score in a significant proportion of patients with TBI. Joseph *et al.* (2015) recommended a standard medical treatment for patients with mild TBI with a GCS score of 13-15, not excluding those with moderate or severe conditions, to consist of a: hospital observation period, neurosurgical consultation and a FCTBI.

2.6 Timing of FCTBI

Several studies have discouraged having a CTBI1 immediately after a trauma occurrence as shorter intervals of <90 minutes predicted independently worse radiological findings on FCTBI (Velmahos *et al.,* 2006). Hence, there is a danger of missing neurological pathology when patients with mild head injuries undergo CTB imaging very early after trauma (Syed *et al.,* 2007). Syed *et al.* (2007) found in their study that 14% to 20% of patients admitted with a diffuse brain injury developed a mass lesion within 12 to 24 hours post injury. In patients with a non-surgical injury, CTBI1 is typically followed by FCTBI within 24 to 48 hours of admission to check for acute development of intracranial lesions (Figg *et al.,* 2003). The efficacy of a routine FCTBI after the first 48 hours is arguable and may be governed by the clinical status of the patient rather than performed as a routine protocol (Doddamani *et al.,* 2012). Likewise, a case study of a 74-year-old male with mild TBI had a negative CTBI1 performed at 5 hours, but FCTBI at 24 hours, post trauma occurrence, detected a large right posteromedial parietal intra-parenchymal haemorrhage with vasogenic oedema, and a right anterolateral SDH (Chung & Khan, 2015). Lee *et al.* (1997) are of the view that CTBI1 done within 24 hours of the injury should demonstrate absolutely the majority of evolving or worsening lesions. According to one study, 56% of ICH >3 cm in diameter progressed within 6 hours of TBI (Kim & Gean, 2011). A higher rate of surgical operation was noted in patients who had CTBI1 performed within 6 hours of a trauma occurrence (Doddamani *et al.,* 2012). Therefore, the foregoing authors suggested that in these patients, FCTBI should be performed within 12 hours of trauma rather than the recommended 24 hours. Anzai and Minoshima (2011) emphasized that gross mass effect was noticed within 12 hours of a TBI occurrence in some of the patients who had severe cerebral contusion. A considerable number of patients who require surgical intervention do not exhibit clinical changes in the first 8 hours. Hence the value of a FCTBI within a 12 hour time period is well justified (Thorson *et al.,* 2013). On the contrary, following the introduction of the Scottish Intercollegiate Network (SIGN), Kerr *et al.* (2005) concluded that adult patients with TBI who present with any of the risk factors (e.g. moderate GCS score) must have CTB imaging within 8 hours of arrival to the hospital even if they seem to be well. According to Doddamani *et al.* (2012) a FCTBI purely based on a decline in clinical status may result in missing potentially curable lesion changes. As indicated by contradictions in the above reviewed literature, no conclusion can be drawn on the adequate timing of performing a FCTBI.

2.7. Role of CTB Imaging in Patients with TBI

A comprehensive meta-analysis on patients with mild TBI conducted by Wintermark *et al.* (2015), indicated that in the 41 studies evaluated, a negative CTBI1 and FCTBI caused a change in neurological treatment in a minority of patients i.e. 2.3% and 3.9% for prospective and

retrospective studies respectively. Although these data did not underpin the usefulness of FCTBI in mild TBI cases, FCTBI had a significant impact in some patients. Peloso *et al.* (2004) wrote that there is a debate on the recommendations as to whether CTB imaging in neurologically deteriorating patients with TBI should be routine with hospital admission, or that hospital admission should be the routine with CTB imaging for such patients. Smith *et al.* (2007) pointed out that early FCTBI in patients with TBI is not routinely indicated instead, implementation of the procedure should be guided by the severity of radiological findings detected on CTBI1 and consecutive clinical examination. In a study conducted by Sharifuddin *et al.* (2012) it was concluded that in patients who had unchanged or no neurological deterioration, a routine FCTBI did not influence the diagnosis of subsequent neurological decline. Another study conducted by Kaups *et al.* (2004) showed that in patients with TBI without any clinical deterioration, a FCTBI did not prompt a change in neurological management; hence such studies were considered unnecessary by these authors. In addition, Af Geijerstam and Britton (2005) stated that compelling neurological complications in mild TBI are unusual following normal CTBI1. As such, triaging of patients with TBI for hospitalized admission with early CTBI1 can be employed, and when radiological findings are found to be normal, such patients can be safely discharged without further observation (Livingston *et al.,* 2000). A study by Velmahos *et al.* (2006) showed that all patients (4%) who required surgical intervention, had clinical deterioration preceding FCTBI. Another study by Brown *et al.* (2007), showed that in patients undergoing FCTBI that was prompted by either neurological deterioration or obtained routinely (without neurological change), 38% and 1% respectively, required hospital treatment.

However, Hempill *et al.* (1999) argued that normal CTBI1 radiological findings do not guarantee that intracranial lesions will not progress in the future. Stiell *et al.* (2001) are of the opinion that neurosurgeons and radiologists concur that normal radiological findings on CTBI1 do not preclude the later evolution of ICH, albeit this is rare. Furthermore, Lee *et al.* (1997) stated that the incidence of a late brain pathology not detected on CTBI1 ranges from 1 to 52%. Stein *et al.* (2009) indicated that patients can regress or even die following a clinically mild TBI. A FCTBI may result in hospital treatment changes even in patients with no decline in clinical status and as indicated in a prospective study conducted by Doddamani *et al.* (2012) such repeat studies are of paramount importance. Hence, FCTBI is a useful diagnostic examination in patients with minimal TBI as it may result in a change in hospital treatment in a small but significant proportion of patients (Nagy *et al.,* 1999). In the end, there is still no agreement on the usefulness of a FCTBI as some clinicians suggest that it should be part of routine practice, whereas others are content that only clinically deteriorating patients should undergo the examination (Joseph *et al.,* 2014).

2.8 Chapter Summary

The role of FCTBI in patients with TBI was not clear as there were different opinions on its usefulness. However, most authors concurred that factors such as gender, age, anticoagulation therapy, vital signs, HRV, and GCS score should be monitored for patients with TBI as they contribute to neurological complications. Neurological symptoms which include vomiting, headaches and nausea may indicate cerebrovascular changes which include intracranial haemorrhage. Even in minor TBI cases, intracranial complications can be life-threatening and authors recommended that they should be treated with urgency.

CHAPTER 3

Research Methodology

3.1 Introduction

A research methodology is a systematic approach to solving a research problem which was discussed in section 1.3. Kothari (2004) described research methods as techniques that are used for the conduction of a particular research study. This chapter will describe the research design, the study setting, sampling methods, inclusion and exclusion criteria, data collection process and ethical considerations that were relevant to this research study.

3.2 Research Design

The research design employed was a retrospective cross sectional quantitative design using a documentary method of collecting data for patients who presented with TBI at the research site in Harare, Zimbabwe. As this was a retrospective study, patients' records of their clinical history and management remained the same over time, thus ensuring that the data were consistent and reliable. The aforementioned approach involves the selection and analysis of records which is based on low-cost, ease and accessibility (Sedgwick, 2014). The author also highlighted that a retrospective study enables collection of data in a short period as compared to a prospective study. Furthermore, a prospective study cannot predict how the patient will present by the time data is collected hence, the researcher adopted a retrospective approach. The research methodology involved collection of data and an analysis of CTB imaging reports for patients with TBI who had normal radiological findings after CTBI1. Thereafter, an assessment was made to establish whether the patient had developed any neurological complications and whether the performance of FCTBI was necessary.

3.3 Sample Population

The sample population comprised of all patients who presented with TBI treated at the neurosurgical ward at the research site within the study period mentioned earlier in section 1.2. The research site is the major referral centre for patients in Harare, Zimbabwe. Approximately 700 patients with TBI of which 70% are adults from the age of 18 and upwards, are treated annually at this hospital (Mapfumo 2017, personal communication,18 September).

3.4 Sampling Methods

A total sampling strategy was employed. The targeted sample population for this research study included all adult patients treated for TBI at the neurosurgical ward over the study period of two years (i.e. 01 June 2015 to 01 June 2017).

3.5. Inclusion and Exclusion criteria

The inclusion and exclusion criteria for this research study was considered.

3.5.1 Inclusion Criteria

The following were applied as the inclusion criteria for this research study:

1. Patient data from all male, female or intersex adults between the ages of 18 and 75 years treated for TBI within the specified study period at the research site were included;

2. Only data from patients with TBI who had a normal CTBI1 were included;

3. Only complete hospital records of patients (with variables as indicated in section 3.6) were included.

3.5.2 Exclusion Criteria

The following were applied as the exclusion criteria for this research study. Data from patients:

1. With existent intracranial injury observed during CTBI1 were excluded;

2. Who suffered further trauma to the brain on more than one occasion during the follow up period were excluded;

3. Under the age of 18 years or from patients older than 75 years were excluded as they were considered a vulnerable population for the purpose of this study;

4. With other non-relevant intracranial pathology were excluded.

3.6 Data Collection Process

Data collection occurred in the Diagnostic Radiography and patients' records departments of the research site within the research study period indicated in section 3.4. The researcher collected either electronic or hard copies (whichever was available, as both systems were used by the hospital), of radiology reports of all patients who had suffered TBI and had undergone CTB imaging. The CTB images were acquired as part of the routine hospital management of all

patients treated with TBI at the research site stated in section 1.2. As this was a retrospective study, CTB imaging for the purpose of data collection for this study was thus not required. The CT scanner used for the CTB imaging of patients was a 16 slice Toshiba Acquilon multi-slice CT scanner, manufactured by Toshiba in Japan, model number CEFT-006A. As referred to in the foregoing, the CTB imaging reports collected were only from those patients who had normal first CTB imaging results following traumatic injury. Patients' names and hospital numbers acquired from these reports were used to access electronic copies of the patient hospital folders from the neurosurgery ward and/or hospital records department. The researcher then assessed whether any neurological complications had occurred in the patients after acquisition of the CTBI1 and FCTBI scans.

A total of 85 patients qualified for inclusion based on the inclusion criteria. A unique numerical study number, between 1 and 85 was chronologically assigned to each patient's data. Data retrieved from patients' folders were used to ensure that the data collected were relevant to the objectives of the study. Data were recorded on a data collection sheet number 1 (Addendum A1). The variables recorded included: patient study number, gender, age, mechanisms of trauma, vital signs (i.e. heart rate, blood pressure, body temperature), GCS score, date and time of trauma injury, neurological status and symptoms, radiological findings and comments relevant to the CTBI1 as made by the attending neurosurgeon or radiologist, as well as a patient's anticoagulation status (either on medication or not). The date and time of the initial CTBI1 were also recorded. Time that elapsed between performing CTBI1 and the initial trauma event was noted. Breathing rate was excluded from the results as it was rarely recorded in patient's hospital records.

A maximum of three hospital observations of patients within 48 hours of the admission period was done by the neurosurgeons to check on patient progress. During these hospital observation periods, data that were recorded was entered into data collection sheet number 2 (Addendum A2), and included: changes that had occurred in the vital signs, neurological status and symptoms, the time FCTBI was performed, time that elapsed between that of the trauma occurrence and FCTBI, radiological findings and radiological comments on FCTBI results. The times of all hospital observations were recorded and added together to give the total time of observation with reference to the patient's initial admission. The patient's study number remained unchanged for the duration of the data collection period. Data were saved electronically on a personal computer with a password only known by the researcher.

For the purpose of this study, mechanisms of trauma which were responsible for the brain injury were categorised as RTAs, falls, struck on the head by an object (i.e. direct, or impulse as per section 2.4). The GCS score classification used to indicate the severity of TBI was determined at the time of injury as mild (13-15), moderate (9-12) or severe (8 or less) (Afzal *et al.,* (2013). Vital signs were measured by implementing the World Health Organisation WHO (2006) standards for

an average adult patient as: blood pressure was measured in mmHg according to the following categories: normal (110-119), low (<110), prehypertension (120-139), stage 1-hypertension (140-159) or stage 2-hypertension (>160). Body temperature was recorded as: normal (36.5-37.2 ^{o}C), low (<36.5 ^{o}C) or high (>37.2 ^{o}C). Heart rate was measured as pulse per second and was categorised as: normal (60-110), low (<60) or high (>110). The changes observed in the patient's neurological status during a 48 hour observation period in comparison to the initial status upon admission were noted as "improved", "worsened" or "unchanged" (Nasir *et al.,* 2011). (Table 3.1)

Table 3.1: Changes in neurological status of patients

Improved	Worsened	Unchanged
Mild to normal	Normal to mild	No changes in neurological status.
Moderate to normal	Normal to moderate	
Moderate to mild	Normal to severe	
Severe to normal	Mild to moderate	
Severe to mild	Mild to severe	
Severe to moderate	Moderate to severe	

(Nasir *et al.,* 2011).

Following on the radiological findings after FCTBI, comparative comments were made by neurosurgeon/radiologist when compared with the CTBI1. These were noted as either "positive" or "negative". If FCTBI comment was "negative", it implied that no changes in radiological findings were noticed when compared with the initial normal CTBI1. In other words, FCTBI results were normal. If FCTBI comment was "positive", it implied that additional radiological findings were observed when compared with the primary CTBI1. These radiological findings included: evolution of a lesion, mass effect, oedema, ventricular dilatation, intracranial pressure, compressed third ventricle or obliterated basal cistern as described by Lee *et al.* (1997). However, for the purposes of the current study FCTBI findings were categorised as; normal, SDH, SAH, EDH, ICH, and pneumocephalus. Compilation of this information assisted the neurosurgeons in determining any progress or regression with reference to the patient's status upon admission.

3.7 Ethical Considerations

This study was conducted in accordance with the guidelines of the Medical Research Council of South Africa (MRCSA) (2000), the Medical Research Council of Zimbabwe (MRCZ) (2004) and the Helsinki Principles of the World Medical Association (WMA) (2013) with respect to permission and ethical regulatory standards that are applicable for a research study such as the one presented here. The MRCZ (2004) states that,

> "*Medical records for research may be used without the consent of patients only if an ethical review committee have determined that the research poses minimal risk; rights or interests of patients are not violated; privacy, confidentiality or autonomy are assured and; the research answers important question/s*".

Therefore, following confirmation of the aforementioned, permission to conduct the research study was sought and granted by: research site authorities (Addenda B and C), the Research Ethics Committee, Faculty of Health and Wellness Sciences of the Cape Peninsula University of Technology effective from 2 August 2017 to 2 August 2018 approval reference *CPUT/HW-REC 2107/H21*) (Addendum D) and the MRCZ effective from 7 August 2017 to 8 August 2018, approval reference *MRCZ/B/1341* (Addendum E).

Principle 24 of the Helsinki declaration (WMA, 2013) stipulates the protection of research subjects and their personal information in all aspects. This was adhered to by upholding patients' privacy and confidentiality in such a way that a study number different from the patient's hospital number was assigned to each patient's clinical data. Patient names, date of birth, identification numbers, addresses as well as the name of the hospital where the study was conducted were not recorded during the data collection period. Data were recorded electronically on a personal computer with a password only known to the researcher. The research objectives of this study outweighed any risk that may be posed to participants as recommended by Helsinki Principle 16 (WMA, 2013). Furthermore, the study aimed to improve the management of TBI patients in agreement with the Helsinki Principle 6 (WMA, 2013). The research study also adhered to and was conducted in agreement with the guiding principle and values of the research site which are:

> "*We are committed to treating the information and circumstances of our patients, staff, clients and stakeholders with the utmost confidentiality, safety and trust they deserve"* (Zigora 2017,personal communication, 29 November).

3.8 Reliability and Validity

The validity and reliability of the data collection instruments should be an essential consideration when conducting a research study (Heffner, 2004). Validity refers to the extent to which a concept is accurately measured in a quantitative research study (Heale & Twycross, 2015). Reliability refers to the consistency of a research instrument used in the research study (Heale & Twycross, 2015). According to Heffner (2004), variable error depends on the size of the sample such that the larger the sample the lower the error. Therefore, in trying to increase the level of reliability in this research study, the researcher considered all adult patients with TBI treated at the research site during the period specified in section 1.2. The research design, which is a retrospective study, could improve the reliability of the study in that records of past events

remain the same over time promoting consistency in the research study findings. To add on, data from patients' records is used to determine the management of patients, hence this data is considered authentic and reliable. In an attempt to minimise error from the research findings, collected data were cleaned by means of excluding inaccurately or incompletely captured variables. In order to enhance a degree of consistency in the diagnostic value of CTBI findings, radiological reports were done by the radiologist and then analysed by the neurosurgeon to avoid missing pathology.

Two types of validity which are external and internal validity were considered by the researcher in this study. External validity refers to the extent to which results of the study are generalizable to the whole population (Ferguson 2004). Internal validity takes into consideration the study design and reasons for any causal relationships between the independent and dependent variables (Heale &Twycross, 2015). As such, the researcher considered the context of the research study and also, consulted a statistician regarding the statistical tests which were adopted. The retrospective design (mentioned earlier in section 3.2) could also promote internal validity in that the research findings could be a true reflection of the role FCTBI has played at the research site during the study period stated in section 1.2. A review of literature that defined local and external standards adopted in treatment of patients with TBI and the role of FCTBI revealed research designs which were carried out by other researchers. Previous studies allowed the researcher to identify knowledge gaps in the usefulness of FCTBI in patients with TBI (Babbie & Mouton, 2001). Document review of all identifiable patients' records for the research site was conducted using a predefined set of rules which ensured that the research study was carried out in a systematic and logical manner (Neuman, 2007). The research site favoured external validity as TBI patients treated at this hospital are typical of those in the rest of the country and thus the results of this study may have meaning for other patients treated at other hospitals in Zimbabwe (Ferguson, 2004).

3.9 Chapter Summary

The research methodology described in this chapter emphasized the procedures taken to investigate the research question, the rationale for the application of specific procedures and the appropriate study design used to elucidate the research objectives. The data that were collected during the current study are presented in the Chapter 4.

CHAPTER 4

Research Results

4.1 Introduction

This chapter commences with a discussion of the manner in which data were analysed. Research results are then presented. For the purposes of this study, appropriate medical records of 85 patients were analysed for brain pathology following TBI.

4.2 Data Analysis

Data were entered into Microsoft Excel and imported into the Software Package for Social Sciences (SPSS 24) for statistical analysis by the researcher together with the assistance of a statistician from the Cape Peninsula University of Technology. Descriptive and inferential statistical tools were applied for the analysis of data. Variables that were analysed from collected data (refer 3.6) were grouped into continuous, categorical and dichotomous as shown in Table 4.1. The dates of: injury occurrence, the patient's admission to hospital, performance of CTBI1 and FCTBI and the patient study number were not analysed. The date indicated the time period the events took place. The patient number was used to cross reference data that were collected with patient information as recorded in the relevant hospital folder.

Table 4.1 Grouping of variables

Continuous Data	**Categorical Data**	**Dichotomous Data**
Age	GCS score	Gender
Time that elapsed between that of trauma occurrence and performing of CTBI1	Neurological status	Anticoagulation status
Time that elapsed between that of trauma occurrence and performing of FCTBI	Blood pressure	FCTBI comments
Time of hospital observation period	Body temperature	
Neurological symptoms	Heart rate	
	FCTBI findings	
	Mechanisms of trauma	

4.2.1 Descriptive Analysis

Descriptive analysis refers to attributes of the study population and provides a means by which further analysis and interpretation of results can be executed (Tuuli & Odibo, 2011). Descriptive analysis was done on the following variables**:** FCTBI findings, neurological symptoms, gender,

age, mechanisms of injury and neurological status. Descriptive analysis involved reporting variables as numbers with proportions in percentages, and central tendency measures in the form of mean, median and mode. The median was defined as the middle value where the measured objects were placed in order commencing with the lowest value. The mean was obtained from dividing the summation of the measurements by the total number of measurements (formulae in Addendum F) (Hildebrand *et al.,* 2005). Measures of dispersion in the form of standard deviation, range and percentiles were also used. Kurtosis was used as a preliminary indicator for peakedness of the age distribution (Decoursey, 2003). Sheskin (2011) described kurtosis as follows: Positive Kurtosis demonstrates a leptokurtic distribution in which the peak is sharper than in a normal distribution with a distribution tail that is thicker than for a normal distribution. Negative Kurtosis demonstrates a platykurtic distribution with a flatter distribution and a wider peak than a normal distribution whilst, Kurtosis = 0 is characterized by a mesokurtic distribution in which data are normally distributed (Sheskin, 2011).

4.2.2 Inferential Analysis

Inferential statistics aid in reaching conclusions beyond the sample that is being directly studied (Tuuli & Odibo, 2011). Cross tabulations were performed to develop percentage comparisons and determine the relationship between two variables (Ott & Longnecker, 2010). The cross tabulations were run for FCTBI findings and: mechanisms of injury, anticoagulant status, neurological status, heart rate, body temperature, blood pressure and GCS score. The Fishers' exact test performed at a 95% level of significance and was introduced for analysing cross tabulations in which the expected counts were less than 5 (Ott & Longnecker, 2010). Correlation analysis was done to determine the strength of relationships between the variables (Heffner, 2004). The Pearson's correlation coefficient was used and the formula is stated in Addendum F.

The logistic regression model (Addendum F) was used to predict the linear relationship between the log odds ratio of an outcome variable and a set of independent variables (i.e. categorical and/or continuous) (Tuuli & Odibo, 2011). To facilitate the application of this model, all dichotomous variables (as seen in Table 4.1) were labelled. In this study, FCTBI comments were labelled as "negative" or "positive" as discussed in section 3.6. Regarding gender, male was labelled "1" and female "0". In the case of anticoagulation, patients on therapy was labelled "1", and those not on therapy "0". Predictor variables included the time of hospital observation, time elapsed between CTBI1 and FCTBI, neurological status, age, gender, vital signs and anticoagulation status**.** Forward stepwise regression was employed to identify variables to be used in the logistic regression model. This method involves fitting regression models by adding each variable, noting that which has the most statistically significant improvement of the fit, and repeating the process until there is no variable that improves the model (Harrell, 2001). In this study, independent predictors of outcome, identified by a p-value ≤ 0.05 were considered

significant following a forward stepwise logistic regression. The corresponding log-odds units of these predictor values were used in the logistic regression equation (Addendum F) to determine their relationship to FCTBI comments. The Omnibus Tests of Model Coefficients indicated the statistical significance of logistic regression model, i.e. goodness of fit test, ($p<0.05$) to predict the outcome variable. Logistic regression was based on the following assumptions that were observed in this study: that data should form a random sample of the population and the existence of a linear relationship between the dependent and independent variables (Tuuli & Odibo, 2011).

4.3 Research Results

The results obtained from analysed data in this research are presented as follows:

4.3.1 Types of Neurological Complications in Patients with TBI

Radiological findings that were reported after FCTBI indicated the neurological complications which were experienced by patients with TBI. In this study, radiological findings which were noted from FCTBI were grouped as negative and positive. As discussed (refer section 3.6), negative FCTBI findings implied that the images showed normal radiological results whereas positive FCTBI findings showed abnormal pathology when compared with the CTBI1. Overall, 64% (n = 54/85) and 36% (n = 31/85) had negative and positive radiological findings based on FCTBI–respectively. The SDH was reported as the most common intracranial pathology with 19% (n = 16/85) among the abnormally diagnosed pathology after FCTBI (Fig 4.1). Other pathologies diagnosed were as follows: ICH 8% (n = 7/85), SAH 6% (n = 5/85), pneumocephalus 2% (n = 2/85) and EDH which was observed least at 1% (n = 1/85). Thus, for the sample population under review for the current study, SDH was the most common radiological finding reported for abnormal FCTBI in patients with TBI.

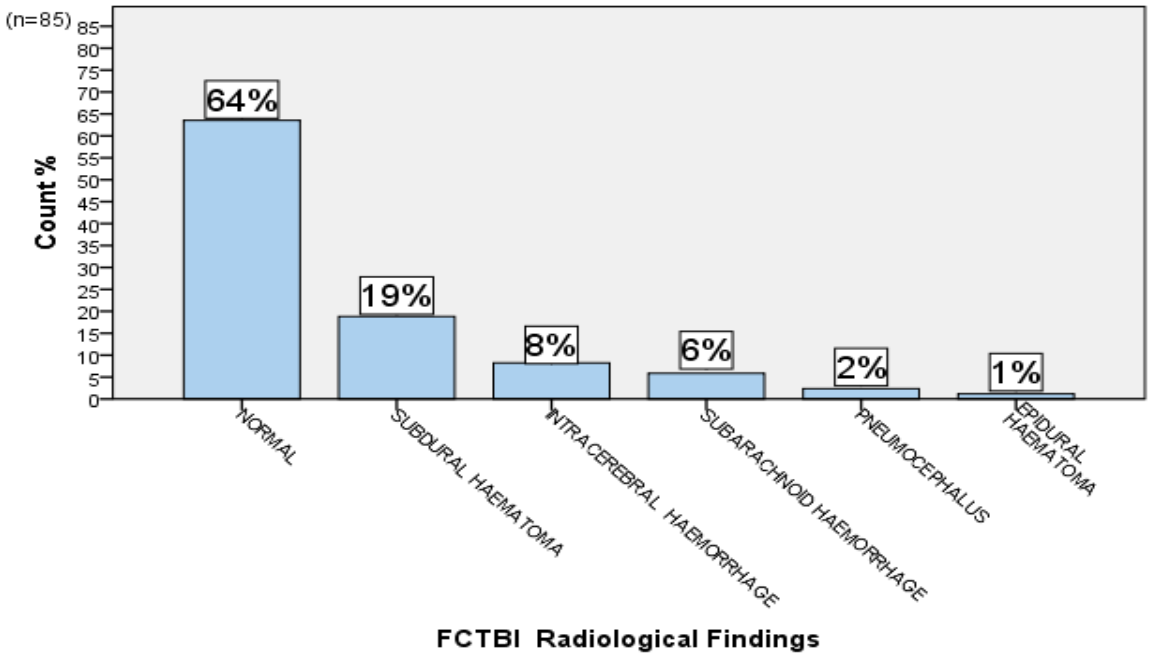

Figure 4.1 Distribution of FCTBI findings

4.3.2 Distribution of Neurological Symptoms in Patients with TBI

The neurological symptoms that were experienced by patients with TBI in this study were noted during patients' observational period. Each patient had one or several of these symptoms. Post-traumatic headaches occurred most frequently, recording 87% (n = 74/85), followed by confusion 61% (n = 52/85), dizziness 51% (n = 43/85), episodes of vomiting 39% (n =33/85), post traumatic seizures 38% (n =32/85) and loss of consciousness 27% (n =23/85). This result indicated that the aforementioned neurological symptoms were most common in patients with TBI (Refer Table 4.2).

Table 4.2 Distribution of neurological symptoms that presented in patients with TBI

Symptoms	n = 85	Percentage %
Post traumatic headache	74	87
Confusion	52	61
Dizziness	43	51
Episodes of vomiting	33	39
Post traumatic seizures	32	38
Loss of consciousness	23	27
Decrease in sensation	15	18
Stroke	8	9
Behavioural changes	7	8
Difficulty with speech	6	7
Loss of vision	4	5
Meningitis	3	4
Other	9	11

4.3.3 Distribution of Neurological Status in Patients with TBI

The study also assessed the neurological status of patients whilst undergoing treatment in the hospital. The neurological status in this study was defined as an overall condition of the function of the nervous system. It was determined at the final observation period of the patient and was categorised as improved, worsened or unchanged as discussed in section 3.6. The neurological status of the patient following FCTBI findings was used to decide on appropriate patient care. However, some of the patients were deceased before appropriate treatment could commence. The majority of the patients, 66% (n = 56/85) showed improved neurological status, whereas 25% (n = 21/85) and 9% (n = 8/85) recorded worsened and unchanged neurological status respectively. The proportion of patients discharged was 46% (n = 39/85) whilst 45% (n = 38/85) underwent hospital treatment, and 9% (n = 8/85) were deceased. Of the deceased, 76% (n = 6/8) had presented with SDH, whereas 12% (n = 1/ 8) showed EDH and (n = 1/8) showed pneumocephalus. Thus most patients who died following TBI sustained SDH. (Table 4.3 and Table 4.4)

Table 4.3 Distribution of neurological status in patients with TBI

	Patient Care			
Neurological status comments	**Hospital treatment**	**Discharged**	**Deceased**	**Total**
Improved	17 (20%)	37 (44%)	2 (2%)	56 (66%)
Worsened	15 (18%)	0 (0%)	6(7%)	21 (25%)
Unchanged	6 (7%)	2 (2%)	0 (0%)	8 (9%)
Total	38 (45%)	39(46%)	8 (9%)	85 (100%)

Table 4.4 Distribution of types of injuries amongst the deceased

Type	n = 8	percentage %
SDH	6	76
EDH	1	12
Pneumocephalus	1	12

4.3.4 Distribution of Mechanisms of Trauma Sustained by Patients with TBI

Mechanisms of injury pertaining to this research were defined as the casual methods by which trauma to the brain occurred. The mechanisms of injury sustained by patients with TBI were classified as RTA, assault, fall or struck on the head by an object. The most common mechanism of trauma recorded was RTA which recorded 58% (n = 49/85), followed by assault 22% (n = 19/85), falls 12% (n = 10/85) and struck on the head by an object, at 8% (n = 7/85), (Figure 4.2). Thus for the population sampled for the current study, most common mechanisms of injury were RTA and assault.

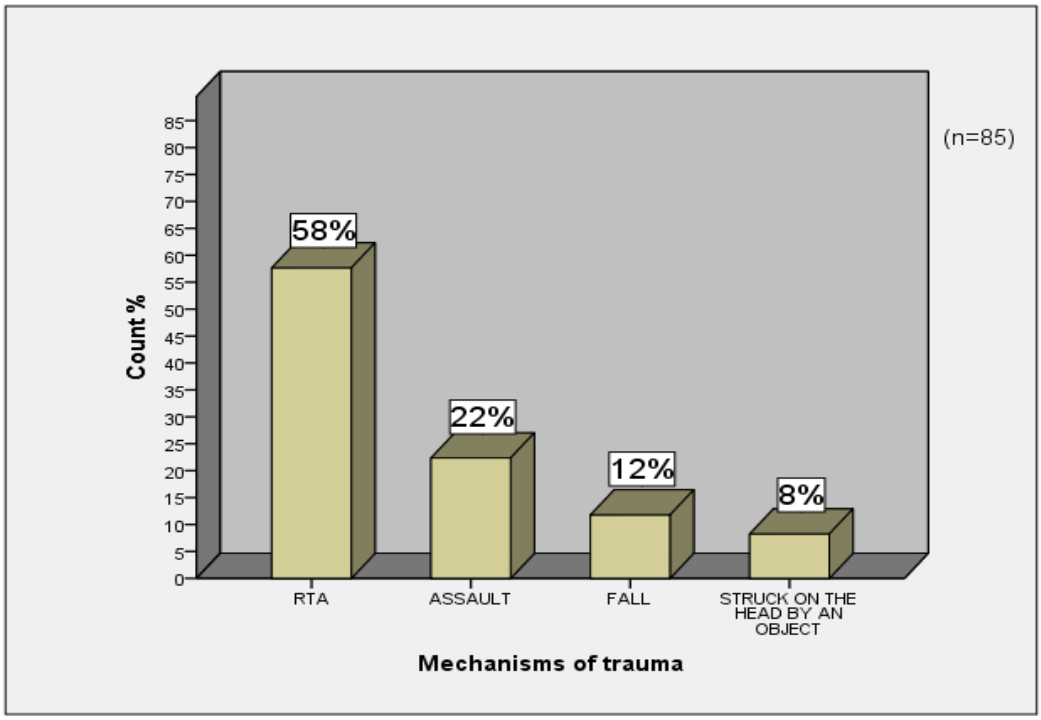

Figure 4.2 Mechanisms of trauma sustained by patients with TBI

4.3.5 Factors Contributing to Mechanisms of Trauma

There are several factors which contributed to the mechanisms of trauma. These causes can be due to one or a combination of the following: human error or behaviour, hazards in work places and from the environment. Table 4.5 shows the distribution of these factors with alcohol and drug abuse recording 30% (n = 26/85), domestic violence 21% (n = 18/85) and disputes 15% (n = 13/85). Driver-related factors included excessive speeding and sleeping whilst driving, and recorded 12% (n = 10/85). Occupational hazards e.g. slips and trips, were noted in 10% (n =9/85). Other factors included adverse climatic conditions, and dangerous road networks which recorded 10% (n = 9/85).

Table 4.5 Factors contributing to mechanisms of trauma

Factors	n = 85	Percentage%
Alcohol and drug abuse	26	30
Domestic violence	18	21
Disputes	13	15
Driver related	10	12
Occupational hazards	9	10
Others	9	10

4.3.6 Factors Associated with TBI

Several factors associated with TBI in this research study were analysed and showed the following results:

4.3.6.1 Gender Distribution of Sample Population

Proportions of gender of patients with TBI were analysed by means of graphs and percentages. No intersex persons were noted in the sample population. Males and females recorded 53% (n = 45/85) and 47% (n = 40/85) respectively. Thus there were more males who presented with TBI than females. (Refer to Figure 4.3)

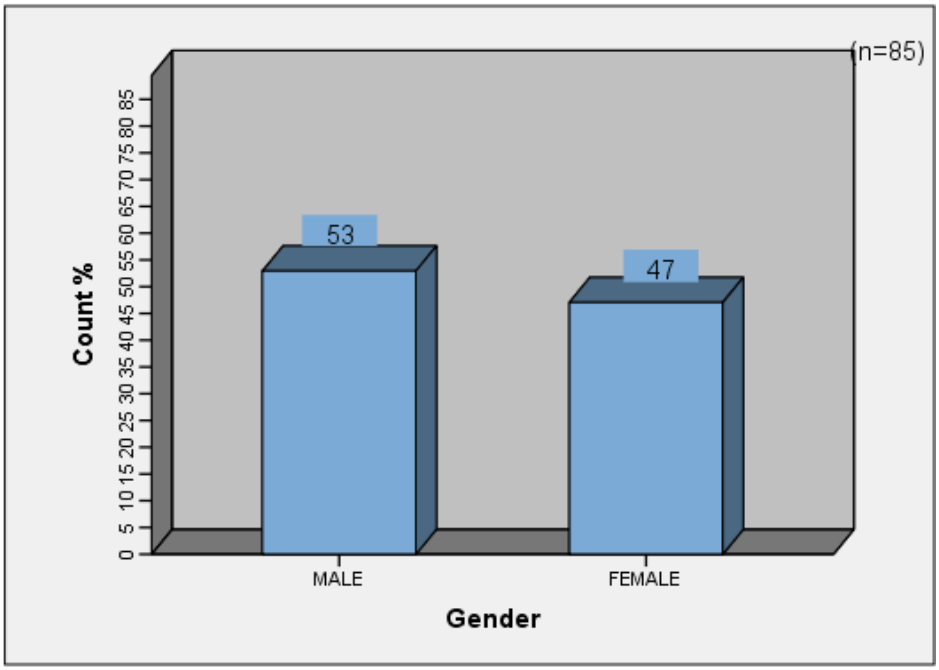

Figure 4.3 Distribution of Gender

4.3.6.2 Age Distribution of Sample Population

Figure 4.4 and Table 4.6 provides an analysis of the age distribution of the sample population. The analysis showed that the mean age of patients was 34.0 years (indicated by the red dashed reference line on the graph) with an age range between 18 and 74 years with a standard deviation of 14.307. The mode and median age for this sample was 30.0 years respectively. Thus, the distribution curve shows a positive kurtosis for the age distribution. The age group of 26-30 years was most frequent (n = 23/85), followed by the age group of 31-35 years (n = 17/85). The age groups recording least frequency were 51-55, 61-65, and 71-75 years which all had n = 2/85. Thus more young adults presented with TBI than older adults. The 25th percentile

age was 24 and the 75th percentile age was 35.50 which was almost equal to the mean.

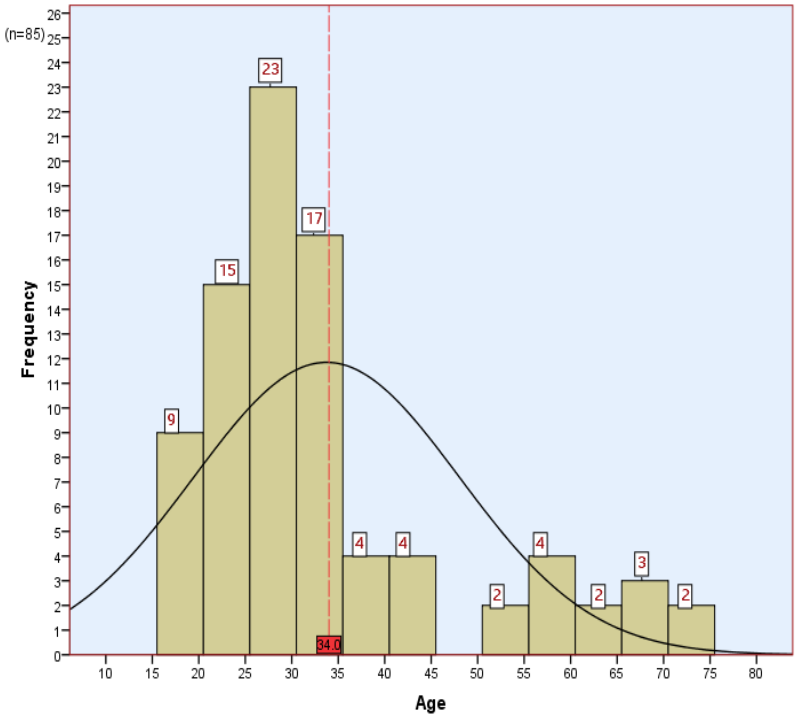

Figure 4.4 Age distribution of the sample population

Table 4.6 Age range (years)

Measures		Values
Median		30.00
Mode		30.00
Std. Deviation		14.307
Percentiles	25th percentile	24.00
	50th percentile	30.00
	75th percentile	35.50

4.3.7 Cross Tabulations

This section provides an analysis of the variables in cross tabulation form. The Fisher's exact test was used at 95% confidence interval to find the association of variables with FCTBI findings in patients with TBI. The following cross tabulations were carried out for the sample population:

4.3.7.1 FCBI Findings and Neurological Status

A cross tabulation was performed to determine the relationship between FCTBI findings and neurological status. Out of the 62 cases with mild neurological status, 77% (n = 48/62) and 23% (n = 14/62) showed normal and abnormal FCTBI findings respectively. The distribution of the abnormal radiological findings was as follows: 8% (n = 5/62) had ICH, 7% (n = 4/62) was recorded for both SDH and SAH; and 1% (n = 1/62) showed pneumocephalus.

Out of 18 who presented with a moderate neurological status, 33% (n = 6/18) and 67% (n = 12/18) showed normal and abnormal FCTBI findings respectively. The distribution of the abnormal FCTBI findings was as follows: 44% (n = 8/18) had SDH, 11% (n = 2/18) showed ICH; and 6% (n = 1/18) was recorded for both pneumocephalus and SAH. For those patients with a severe neurological status, 100% recorded abnormal FCTBI findings characterised by 80% with SDH (n = 4/5) and 20% (n = 1/5) with EDH. As noted, in the majority of cases with mild neurological status, the majority recorded normal FCTBI findings. However, as the neurological status worsened from moderate to severe, most of FCTBI findings were recorded as abnormal. The SDH was the most common FCTBI finding for this sample population.

The Fisher's exact value was 35.176 with p = 0.000 ($p<0.05$); hence there was a strong evidence of a significant relationship between neurological status of a patient and the FCTBI results (Table 4.7).

Table 4.7 FCBI findings and neurological status cross tabulation

FCTBI Findings	Neurological Status			
	Mild	Moderate	Severe	Total
Epidural Haematoma	0 (0%)	0 (0%)	1 (20%)	1 (1%)
Intracerebral Haemorrhage	5 (8%)	2 (11%)	0 (0%)	7 (8%)
Normal	48 (77%)	6 (33%)	0 (0%)	54 (63%)
Pneumocephalus	1 (1%)	1 (6%)	0 (0%)	2 (2%)
Subarachnoid Haemorrhage	4 (7%)	1 (6%)	0 (0%)	5 (6%)
Subdural Haematoma	4 (7%)	8 (44%)	4(80%)	16 (19%)
Total	62 (100%)	18 (100%)	5 (100%)	85 (100%)

4.3.7.2 FCTBI Findings and Mechanisms of Trauma

A cross tabulation was carried out to establish the relationship between FCTBI findings and the mechanisms of trauma. Among the 49 patients with TBI who were involved in RTA, 63% (n = 31/49) showed a normal FCTBI. Those with abnormal radiological results showed the following distribution: 27% (n = 13/49) with SDH, 4% (n = 2/49) with ICH and 2% (n = 1/49) presented with SAH, EDH and pneumocephalus respectively. For assault cases 80% (n = 15/19) showed normal FCTBI whereas 5% (n = 1/19) each recorded SDH, ICH, SAH and pneumocephalus. In the sample where the trauma mechanism was fall, 40% (n = 4/10) of the patients recorded normal FCTBI and 30% (n = 3/10) showed ICH and SAH respectively. In patients who were struck on the head by an object, 57% (n = 4/7) showed normal FCTBI, whilst 29% (n = 2/7) and 14% (n = 1/7) developed SDH and intracerebral haemorrhage respectively. Thus SDH was the most common radiological finding for patients involved in RTA, assault or for those struck on the head by an object. Different results were recorded from patients who sustained TBI due to a fall where ICH and SAH were the most common radiological findings. The Fisher's exact value was 23.365 and p = 0.014 ($p<0.05$). Hence there was evidence of a significant relationship between FCTBI findings and the mechanisms of injury for the sample population screened (Table 4.8).

Table 4.8 FCTBI findings and mechanisms of trauma

FCTBI Findings	Mechanism of trauma				
	Assault	Fall	Struck on the head by an Object	RTA	Total
Epidural Haematoma	0 (0%)	0 (0%)	0 (0%)	1 (2%)	1 (1%)
Intracerebral Haemorrhage	1 (5%)	3 (30%)	1 (14%)	2 (4%)	7 (8%)
Normal	15 (80%)	4 (40%)	4 (57%)	31 (63%)	54 (63%)
Pneumocephalus	1 (5%)	0 (0%)	0 (0%)	1 (2%)	2 (2%)
Subarachnoid Haemorrhage	1 (5%)	3 (30%)	0 (0%)	1 (2%)	5 (6%)
Subdural Haematoma	1 (5%)	0 (0%)	2 (29%)	13 (27%)	16 (19%)
Total	19 (100%)	10 (100%)	7 (100%)	49 (100%)	85 (100%)

4.3.7.3 FCTBI Findings and Anticoagulation Medication

From Table 4.9, it is observed that 9% (n = 8/85) of the patients who had FCTBI were on anticoagulation therapy. Only 25% (n = 2/8) of these patients had an abnormal FCTBI presenting with SAH. Overall, most of the patients, 75% (n =6/8) with TBI who were on anticoagulation treatment showed a normal FCTBI. The Fisher's exact value was 7.00 with p = 0.178 (p>0.05). Hence there was no evidence of a significant relationship between patients on anticoagulants and FCTBI findings for this sample population.

Table 4.9 FCTBI findings and anticoagulants cross tabulation

FCTBI findings	On Anticoagulants		Total
	No	Yes	
Epidural Haematoma	1 (100%)	0 (0%)	1 (100%)
Intracerebral Haemorrhage	7 (9%)	0 (0%)	7 (8%)
Normal	48 (62%)	6 (75%)	54 (63%)
Pneumocephalus	2 (3%)	0 (0%)	2 (2%)
Subarachnoid Haemorrhage	3 (4%)	2 (25%)	5 (6%)
Subdural Haematoma	16 (21%)	0 (0%)	16 (19%)
Total	77 (100%)	8 (100%)	85 (100%)

4.3.7.4 FCTBI Findings and GCS Scores

The cross tabulation between FCTBI findings and GCS score was carried out to determine the relationship between the two variables. The GCS score was classified into mild, moderate and severe as discussed in section 3.6. Out of the 68 patients who showed a mild GCS score, 72% (n =49/68) showed normal FCTBI results and in 28% (n =19/68) abnormal FCTBI findings were recorded. The latter were distributed as follows: 13% (n = 9/68) SDH, 7% (n = 5/68) ICH, 6% (n = 4/68) SAH and 2% (n = 1/68) with pneumocephalus.

In patients who had a moderate GCS score, 38% (n =5/13) showed a normal FCTBI whilst 62% (n = 8/13) recorded abnormal FCTBI findings. The latter had the following distribution: 31% (n = 4/13) SDH, 15% (n = 2/13) ICH, and 8% (n = 1/13) was recorded for both SAH and pneumocephalus.

In patients who presented with a severe GCS score, 100% (n = 4/4) showed abnormal FCTBI findings with the following distribution: 75 % (n = 3/4) SDH and 25% (n = 1/4) EDH. As noted, in the majority of cases with a mild GCS score, most FCTBI findings were normal. However, as the GCS score worsened from moderate to severe, the majority of FCTBI findings were recorded as abnormal. A SDH was the common FCTBI finding for this sample population.

The Fisher's exact value was 24.004 with p = 0.002 (p< 0.05). Hence there was marked evidence of a significant relationship between GCS outcome and FCTBI findings. (Table 4.10).

Table 4.10 FCTBI findings and GCS score cross tabulation

FCTBI Findings	GCS Score			
	Mild	Moderate	Severe	Total
Epidural Haematoma	0 (0%)	0 (0%)	1 (25%)	1 (1%)
Intracerebral Haemorrhage	5 (7%)	2 (15%)	0 (0%)	7 (8%)
Normal	49 (72%)	5 (38%)	0 (0%)	5 (63%)
Pneumocephalus	1 (2%)	1 (8%)	0 (0%)	2 (2%)
Subarachnoid Haemorrhage	4 (6%)	1 (8%)	0 (0%)	5 (6%)
Subdural Haematoma	9 (13%)	4 (31%)	3 (75%)	16 (19%)
Total	68 (100%)	13 (100%)	4 (100%)	85 (100)

4.4 Logistic Regression for Factors Determining Positive or Negative FCTBI Comments

Logistic regression was used to determine variables that were significantly related to dichotomised FCTBI comments i.e. positive or negative (as discussed in section 4.2.2). In this study, a negative FCTBI comment by an attending neurosurgeon/radiologist indicated that radiological findings were normal. On the other hand, a positive FCTBI comment indicated that there was pathology detected without necessarily specifying the exact type of the radiological finding. The Omnibus Tests of Model Coefficients (Table 4.11) shows that the Chi-squared value was $\chi 2 = 46.595$ and $p = 0.000$ ($p<0.05$). Thus, the logistic regression model indicated a statistical significance to predicting the outcome variables.

Table 4.11 Omnibus Tests of Model Coefficients

		Chi-square	Df	Sig.
Step 3	Step	8.673	4	0.070
	Block	46.595	6	0.000
	Model	46.595	6	0.000

Following a forward stepwise regression, the variables that had a p value of less than 0.05 were: male gender with p = 0.011, the time of observation, p = 0.000, and stage 2-hypertension, p =0.025. Thus the final logistic regression model expression using the significant variables as referred to in section 4.2.2 (Addendum F) was:

ln(p) = 0.341+1.753Gender (1) -0.003observation times + 3.807Blood pressure (4)+0.942Blood pressure(3) + 2.039Blood pressure (2) + 2.304Blood pressure (1) + e

This implied that when all other variables were controlled, there was marked relationship between FCTBI comments and male gender, time of observation, and stage 2-hypertension. The likelihood of a male recording a positive FCTBI comment was 5.77 times higher than that of a female – all other factors being equal. The likelihood of a patient with stage 2-hypertension (as defined in section 3.6) to record a positive FCTBI comment was 45 times higher than for other classes of hypertension.

4.5 Times Observed During CT Brain Imaging

This section provides an analysis of various time intervals that were recorded prior to performing CTBI1 and FCTBI.

4.5.1 Correlation Between the Time of Hospital Observation and the Time that Lapsed Before CTBI1 and FCTBI were Performed

The correlation to indicate the strength of the relationship between the time of hospital observation and the time that lapsed before CTBI1 and FCTBI were performed following TBI occurrence was carried out. Results recorded in Table 4.12 show that the Pearson correlation value was +0.226 which indicated a weak positive relationship between the times the patient was under hospital observation and that which lapsed before CTBI1 was performed. Thus these two variables were not strongly correlated. However, the p value was 0.037 ($p<0.05$); therefore,

there was a statistically significant correlation between these two variables. The relationship between the time of hospital observation and performing FCTBI recorded a Pearson correlation value of +0.005 which indicated a very weak positive correlation between the two variables. Furthermore, there was no statistically significant correlation between time of hospital observation and the period of time that lapsed before FCTBI was performed as indicated by the p = 0.966 (p>0.05). There was a moderate positive correlation between the time of performing CTBI1 and that of FCTBI as indicated by a Pearson value of +0.56. However the relationship between the two variables was not statistically significant i.e. p = 0.608 (p> 0.005).

Table 4.12 Correlation between the time of hospital observation and the time that lapsed before CTBI1 and FCTBI were performed

		Hospital Observation (minutes)	Time FCTBI performed (minutes)	Time lapsed before CTBI1 (minutes)
Hospital Observation (minutes)	Pearson Correlation	1	0.005	0.226*
	Sig. (2-tailed)		0.966	0.037
	N	85	85	85
Time FCTBI performed (minutes)	Pearson Correlation	0.005	1	0.056
	Sig. (2-tailed)	0.966		0.608
	N	85	85	85
Time lapsed before CTBI1 (minutes)	Pearson Correlation	0.226*	0.056	1
	Sig. (2-tailed)	0.037	0.608	
	N	85	85	85

4.5.2 Time of Hospital Observation Period, CTBI1 and FCTBI Performance Following the Time of Trauma Occurrence

The distribution of the time of the observation period, performing the CTBI1 and FCTBI following the time the trauma occurred was done. The mean time (the calculation discussed in section 4.2.1) recorded for each patient under hospital observation was 1 223 minutes (approx. 20 hours), with the median and mode each having an identical time of 1 080 minutes (18 hours) which was less than the mean time. The standard deviation (SD) was 530 minutes (approx. 9 hours). The mean time that elapsed between carrying out a CTBI1, and the time the trauma occurred was 471 minutes (approx. 8 hours) with a mode of 187 minutes (approx. 3 hours), a

median of 430 minutes (approx. 7 hours) and SD of 251 minutes (approx. 4 hours). The mean for the time that elapsed between doing FCTBI and the time the trauma occurred was 1 063 minutes (approx.18 hours) with a mode of 821 minutes (approx. 14 hours), a median of 1 039 minutes (approx.18 hours) and SD of 386 minutes (approx.6 hours). This shows that most of the CTBI1 and FCTBI scans were performed within the patients' hospital observation period as discussed in section 3.6.

Table 4.13 Distribution of the time of hospital observation period, CTBI1 and FCTBI performance following the time the trauma occurred

	Hospital Observation (in minutes)	Time elapsed CTBI1 (in minutes)	Time elapsed FCTBI (in minutes)
Mean	1 223 (20 hours)	471 (8 hours)	1 063 (18 hours)
Median	1 080 (18 hours)	430 (7 hours)	1 039 (18 hours)
Mode	1 080 (18 hours)	187 (3 hours)	821(14 hours)
Std. Deviation	530 (9 hours)	251 (4 hours)	386 (6 hours)

4.6 Chapter Summary

Follow up Computed Tomography Brain Imaging findings, neurological symptoms, age, GCS score, gender, neurological status, anticoagulation status, blood pressure, FCTBI comments, length of hospital observation period, body temperature, heart rate, mechanisms of trauma, the time interval between that of trauma occurrence and carrying out CTBI1 and FCTBI were investigated. This was done to answer the research question and objectives (Refer to section 1.4), to determine the relevant conclusions of the study. In the next chapter, the results will be discussed within the study context and compared to the relevant literature reviewed. The discussion, limitations of the study, recommendations and conclusion will also be presented.

CHAPTER 5

Discussion, Recommendations and Conclusion

5.1 Introduction

This chapter presents a discussion of the results of this study, refers to the limitations of the study, and makes recommendations and conclusions. Results are linked to the research questions and objectives (as outlined in section 1.4), and illustrate the extent to which these have been addressed within the study context and compared to the relevant reviewed literature. This study was successful in various ways. The next section describes how this study contributed to the body of knowledge and explained the role FCTBI played in patients with TBI.

5:2 Discussion of Research Findings

The findings from this research study that are presented in the previous chapter, are discussed in the subsequent sections of this chapter.

5.2.1 Factors Related to FCTBI Findings

The study showed that in patients with TBI, 36% (Figure 4.1) presented with abnormal FCTBI findings. This proportion is considered sufficient to justify the usefulness of FCTBI in such patients at the research site. Follow up CTB imaging within the context of this study has thus shown that significant neurological findings were found amongst 36% of patients. Therefore, FCTBI findings assist in relevant decision-making concerning patient hospital treatment. This is supported by results obtained for this study which showed that patients who could be discharged from the hospital and those who remained admitted for hospital treatment were 46% and 45% respectively (Table 4.3). Computed Tomography, which was the available imaging modality of choice at the research site for diagnosis of patients with TBI, identified intracranial pathology which resulted in determining the care needed for various patients (Joseph *et al.,* 2014).

The distribution of intracranial lesions in patients with TBI recorded on FCTBI during this study was as follows: 19% had SDH, 8% had ICH, 6% had SAH, 2% had pneumocephalus and 1% had EDH (Figure 4.1). As noted, SDH was the most common abnormal radiological finding recorded from FCTBI. The trend of SDH being a common radiological finding was similar in mechanisms of trauma which showed evidence of a significant relationship with FCTBI findings ($p = 0.014$). This could be attributed to sudden impact to the head after various types of trauma, which rupture blood vessels on the surface of the brain. In older people, brain atrophy leads to

enlargement of subdural space which then further expands the bridging veins, making SDH common following TBI (Anzai & Minoshima, 2011; Feinberg *et al.,* 2015). Furthermore, SDH can be considered as an indicator of death as it recorded the highest intracranial pathology in 76% cases of the deceased in this study (Table 4.4).

Abnormal FCTBI findings referred to in the foregoing may be associated with various neurological symptoms that were exhibited by patients with TBI. This study found the common neurological symptoms in patients with TBI to be: post traumatic headache (87%), confusion (61%), dizziness (51%), episodes of vomiting (39%) post traumatic seizures (38%) and loss of consciousness (27%) (Table 4.2). These neurological symptoms have various characteristics which may warrant a FCTBI in such patients. Post traumatic headaches can be due to swelling or invasion of the brain parenchyma by haematomas. Dizziness may be linked to psychological distress after head injury (Riggio & Jagoda, 2016). Episodes of vomiting may indicate the stimulation of vomiting centres by a chemoreceptor trigger zone, which is an area situated at the base of the fourth ventricle of the brain (Horn *et al.,* 2014). This could warrant the need for FCTBI to assess for abnormalities in this region of the brain. Post traumatic seizures arise from a selective hyper nonoxidative glucose metabolism, glutamate, potassium and a slight reduction in cerebral blood flow (Vespa & Nuwer, 2000). Webster *et al*. (2017) added that neuroinflammation, which is a secondary brain injury process, contribute to onset of post-traumatic seizures. Furthermore, post traumatic seizures result in progressive neurodegeneration and poor psychosocial outcomes for patients with TBI. Thus, post traumatic seizures can be treated as a serious sign of neurological deterioration (Webster *et al.,* 2017).

The incidence of bowel incontinence which was recorded under “other” signs of neurological complications (11%) (Table 4.2) may be associated with frontal contusions (Foxx-Orenstein *et al.,* 2003). Meningitis was noted in 4% of the patients (Table 4.2) and may be due to cerebrospinal fluid leakage following TBI (Bernal-Sprekelsen *et al.,* 2000). In general, neurological symptoms may also determine the neurological status of the patient as discussed in section 3.6. Thus neurological symptoms may indicate whether the patient is regressing or improving; hence the need for FCTBI.

This study showed a marked significant relationship between the neurological status of a patient and FCTBI findings ($p = 0.000$). In patients presenting with a mild neurological status, 23% showed abnormal radiological findings on the FCTBI scan whilst those who had moderate or severe neurological statuses recorded 67% and 100% abnormal radiological findings respectively (Table 4.7). This implies that the severity of the neurological status of patients is associated with an increased likelihood of the detection of intracranial pathology on FCTBI. This result is similar to that reported by Stippler *et al.* (2012) who showed that patients who declined neurologically (67%) recorded serious radiological findings on FCTBI.

A similar trend of increasingly adverse radiological findings was also associated with the severity of the GCS score which showed a statistically significant relationship (p = 0.002) with FCTBI findings (Table 4.10). Subdural haematoma and epidural haematoma were the only intracranial lesions associated with a severe GCS score, recording a frequency of 75% and 25% on FCTBI respectively. A moderate or severe GCS score and neurological status may indicate clinical deterioration in patients with TBI. This was indicated by 25% (Table 4.3) of the relevant patients whose neurological status deteriorated as defined in section 3.6.

Therefore, when patients present with persistent neurological symptoms e.g. post traumatic headaches or seizures, it is likely that their neurological status is deteriorating and could even result in death (Ritter *et al*., 2016). In this current study, 7% cases of death had worsened neurological status (Table 4.3). Furthermore, GCS score cannot solely be used to determine the severity of TBI. In this research study, one of the patients who died was involved in a RTA but had recorded a mild GCS score of 15, with a neurological status which declined from mild to moderate. The patient died approximately five hours after FCTBI which diagnosed SDH. Thus, it can be argued that a mild GCS score does not negate the evolution of new lesions detected by FCTBI in patients with TBI. In this study, a significant proportion of patients with TBI presented with a mild neurological status (23%) (Table 4.7) and mild GCS score (28%) (Table 4.10) yet in those patients abnormal radiological findings were also recorded. It should be noted that it is possible that patients may regress or die after what presents as clinically mild TBI. Hence, they may be considered as suitable candidates to undergo a period of hospital observation before being discharged (Refer to section 5.4). This finding underscore the importance of FCTBI in patients with TBI especially with an altered or abnormal GCS score.

5.2.1.2 Gender

This study showed a statistically significant relationship between male patients with TBI and the comments of relevance to FCTBI made by the attending neurosurgeon/radiologist, p = 0.011 ($p<0.05$), (section 3.6). The study also showed that the likelihood of positive FCTBI (i.e. abnormal radiological findings) for males was 5.77 times greater than that recorded for females, when all other variables were equal. Male patients had a probability of 0.84 of showing positive FCTBI findings whilst females showed a probability of 0.48. Thus, males with TBI had a higher risk of presenting with abnormal radiological findings on FCTBI which may be attributed to differential sensitivity. Male neurons are more prone to pharmacological insults that trigger brain injury (e.g., glutamate). Hence male cells are unable to retain intracellular glutathione levels post-TBI causing the evolution of brain pathology (Vagnerova *et al.,* 2008). The proportions of male and female patients with TBI recorded during this study were 53% and 47% respectively (Figure 4.3). However, these values may indicate that generally, there is an increased number

within the population who experiences brain trauma. This could be attributed to the economic and social environments of Zimbabwe in that today both males and females require more mobility to reach the workplace. Associated with this would be an increased likelihood in the number of RTAs. This differs from the past where males were perceived to comprise the dominant work force as principal breadwinners. Statistics have shown that there has been an increase (69%) in the number of females in the employment sector in Zimbabwe (ZIMSTAT, 2013). Promotion of gender equality policies which were implemented by the government of Zimbabwe saw increasing numbers of females involved in activities and roles on an equal footing with male counterparts e.g. working with heavy duty machinery in industries. Thus it is quite likely that today, both males and females are more prone to occupational accidents which cause TBI.

5.2.1.3 Age

In previous studies done elsewhere, the impact of age on patients with TBI indicated that young persons were at higher risk (Lannsjö *et al.,* 2012). In this research study the highest number of patients with TBI was observed in the age groups 26-30 and 31-35 years (27% and 20% respectively) (Figure 4.4). Thus TBI in the age group 26-35 years was 47%. The mean age of this at-risk group, as shown by the positive kurtosis, was 33.7 at which age, it was considered that there was a high probability of sustaining TBI (MedCalc, 2012). As this age group is very active and economically productive they may be more commonly exposed to occupational and social risks than are the other age groups screened. Risk-taking and lack of driving skills on the roads could be highlighted as a primary problem within the young 26-35 year-old group. Thus this particular age cohort of the sample is possibly increasingly vulnerable to RTAs and violent disputes. Furthermore, it is possible that younger participants fall more during running and sporting activities thus increasing TBI risk (Talbot *et al.,* 2005). In this study also, the older age group of 60-75 years comprised only 12% of the patients with TBI (Figure 4.4). In the older age group within the patient sample, TBI was caused mainly by fall. This was most likely due to changes in balance, proprioception, muscle tone, attention and impaired vision which make judgement of environmental hazards difficult (Talbot *et al.,* 2005). Literature reviewed by the researcher showed that different age groups experience different factors which expose them to undergoing TBI (as discussed in section 2.5.2). However, despite the trauma mechanism of a given TBI, radiological findings in patients were similar.

5.2.1.4 Blood Pressure

In the current study, patients with stage 2 hypertension (SBP >160mmHg) showed a probability of 1 of recording a positive FCTBI comment. This was also indicated by a statistically significant relationship, ($p = 0.025$), between FCTBI comments by neurosurgeon/radiologist and stage 2 hypertension. Thus, patients with stage 2 hypertension, can show abnormal radiological findings

on FCTBI. This may be due to excess pressure in intracranial vessels which cause bursting, accompanied by intracranial bleeding. However, these findings are contrary to the set cut off SBP of < 90 mmHg, which has been stated to show severe negative effects on TBI outcome (Chi *et al.,* 2003).

5.3 Prevalence of Mechanisms of Trauma

In this research study, the most common mechanism of trauma was RTAs which were responsible for 58% of the TBI cases (Figure 4.2). This could be due to a rapid increase in the population number in Zimbabwe from an estimate of 14.09 million in 2013 to 16.91 million in 2017 (Countries Data, 2017). This could enhance the number of vulnerable road users. There has been a marked increase in the number of light duty vehicles by approximately 100% (from 509 764 in 2005 to 1 037 643 in 2016) on road infrastructure in Zimbabwe (Zanamwe, 2017). The roads are in a dilapidated state and potholes on roads as well as road traffic lights malfunctioning are frequently observed. Both the increase in population and number of vehicles on the road are responsible for a massive traffic mix of motorists, pedestrians, and cyclists. In addition, communities living within the vicinity of roads have increased. Studies have shown that an increase in traffic by 100% causes an increase in the number of RTAs and fatal accidents by approximately 80% and 25% respectively (Elvik & Vaa, 2004). The poor performance of drivers which was recorded at 12% (Table 4.5) in this study, was another factor contributing to RTAs in Zimbabwe. Other mechanisms of trauma such as assaults, falls and being struck on the head by an object all can contribute to TBI and need to be further investigated. Assault was responsible for 22% of the TBI reported on in this study (Figure 4.2). Domestic violence was responsible for 21% of the TBI (Table 4.5). Furthermore, alcohol consumption and drug abuse was a factor that influenced mechanisms of injury and was responsible for 30% of the TBI recorded from patients (Table 4.5). Alcohol intake causes severely impaired judgement when driving, as well as aggressive behaviour and reduced self-control. Thus, those imbibing alcohol are likely to resort to violence in confrontations or disputes which recorded 15% in this research study (Table 4.5) (Benyera, 2017). Occupational hazards responsible for 10% of the TBI in the current study were comprised of slips and trips, cables across walkways, wet surfaces, slippery footwear and random objects on a surface. Patients who were struck on the head by an object recorded a frequency of 8% in this study. These incidents were either accidental at work, or intentional during fighting.

5.4 Time of Observation and CT Brain imaging

The mean time of hospital observation for patients with TBI was 20 hours after the incident, where the majority of patients were observed for at least 18 hours (Table 4.13). The CTBI1 and FCTBI were performed after 8 and 18 hours respectively on average after the trauma incident.

The research site, as a major referral hospital in Zimbabwe has an increased throughput of patients with TBI. Thus, a standardised observational period of 20 hours could see more patients being discharged early, creating room for new admissions. In this study, a patient who had been involved in a RTA showed a mild neurological status, a GCS score of 14, and had CTBI1 performed 4 hours post-trauma occurrence which recorded normal radiological findings. The patient was discharged after 9 hours of hospital observation. However, the patient revisited the hospital approximately 10 hours after being discharged presenting with a persistent headache and two episodes of vomiting. Follow up CTBI was performed 22 hours post trauma occurrence and this showed a left temporo-parietal EDH which had evolved between the time of the CTBI1 and FCTBI. Thus, an observational period of 20 hours, would have provided timeous detection of neurological symptoms which indicated a clinical deterioration, and appropriate medical treatment could have been employed. Furthermore, performance of CTBI1 at 8 hours post-trauma, within an observation period of 20 hours, may give enough time for lesions to evolve and hence determine appropriate care (section 4.3.3) for patients with TBI under treatment in Zimbabwe. This was supported by the Pearson correlation value of +0.226 and a statistically significant correlation $p = 0.037$ between the time of patient hospital observation and the time that lapsed before CTBI1 was performed (Table 4.12). Similarly, elsewhere, it was found that EDHs increased in volume size when detected within 6 hours post-TBI occurrence (Wu & Jallo, 2011). Thus, the latter authors recommended that a CTBI1 should be performed between 6-12 hours after initial trauma to detect any developing haematoma regardless of the patient's clinical examination.

5.5 Variables with an Insignificant Relationship with Radiological FCTBI Findings

Variables that showed an insignificant relationship with radiological FCTBI findings were also noted in this study. Even though literature may support and show the significance of anticoagulants on patients with TBI, the current study showed that 75% of the patients with TBI who were taking anticoagulants did not show abnormal radiological findings after FCTBI (Table 4.9). Furthermore, there was no evidence of a significant relationship between patients on anticoagulants and the radiological FCTBI results ($p = 0.178$). Hence, discharging patients on anticoagulant treatment from the hospital after a normal CTBI1 radiological result is acceptable although delayed traumatic ICH may occur.

A proportion of 36% ($n = 31/85$) of patients with TBI who had normal heart rate exhibited an abnormal radiological result in this study. Noted also, 9% ($n = 8/85$) with an abnormal body temperature demonstrated abnormal radiological findings. Furthermore, heart rate and body temperature of patients showed no significant relationship with radiological FCTBI findings; $p = 1.000$ and $p = 0.161$ respectively.

This study also showed that the time of FCTBI performance was not correlated to the time period of observation of patients in hospital; ($p = 0.966$) (Table 4.12). This indicated that FCTBI can be performed at any time during or after the observation period.

Overall, in patients with TBI, the anticoagulation status, heart rate and body temperature should not be considered as indicators for FCTBI. Patients with instability in these aforementioned variables and showing a normal CTBI1, can be admitted for hospital observation without performing a FCTBI.

5.6 Limitations of the Research Study

During the time period covered by the current study, 149 adult patients were referred for a FCTBI following a normal CTBI1. However, data originating from only 85 patients was suitable for use in the study. A number of patient files had to be excluded for various reasons. Patient files in the Records department at the research site were digitised onto the computers for storage purposes. During the process of scanning, some of the patients' files or pages with relevant information were lost, whilst others were illegible. Some information pertaining to studied variables was not recorded for all patients. An example of this was the breathing rate which was not regularly recorded in patient files. Thus study variables were limited to those which were recorded for all patients to provide a more conclusive study. The picture archiving and communication system (PACS) at the research site did not function between August-October 2016; hence radiological reports of some of the patients were lost. Patients were required to pay for CT scanning services at the hospital. Though a payment plan was arranged by the hospital, not all patients were willing to commit to this which resulted in some not having the CTB imaging performed at all. This led to probability of sampling error and it is not known how many more of these patients would have been included in this research study.

The research site has one CT scanner which malfunctioned on three occasions within the period of patients' records included in this research study (June 2015 to June 2017). Therefore patients had to access CT services from other private hospitals which reduced the sample size. Furthermore, this may have also compromised the type of cases admitted at the research site and may have skewed findings of this study. The relative small sample size negated generalisation of these findings to the larger population.

5.7 Recommendations

The above limitations were identified and the recommendations intended for the health care professionals (such as neurosurgeons, radiologists, radiographers) who diagnose and manage

neurological cases in patients with TBI, were outlined. Included also are recommendations for further research.

There is rational evidence that clinical factors can be used for predicting brain pathology in adult patients with TBI (Borg *et al.,* 2004). The intracranial lesions considered in this research study were: SDH, EDH, SAH, ICH and pneumocephalus. However, further studies may look broadly at other types of neurological complications (e.g. oedema, ventricular dilatation, and intracranial pressure) in determining the role of FCTBI and the management of these patients. The current study shows that young adult age group (26-53 years) and male gender patients with TBI may be considered high risk for developing late neurological complications. However, according to a report by ZIMSTAT, (2013), there is an increase in female dominance (52%) over males (48%) in the Zimbabwean population. Therefore, future research studies should be carried out to validate gender affected by TBI. Stage 2 hypertension (systolic >160mmHg) is a risk factor for a positive FCTBI outcome. Hence, as suggested by Fuller *et al.* (2014), there is also a need to reconsider the current standard cut-off threshold of 90 mmHg for SBP that is associated with a poor outcome in patients with TBI. One may argue that the set cut off needs to be revised. Therefore, further studies should be done to redefine and reconsider the threshold of 90mmHg for SBP that is associated with abnormal radiological findings on FCBTI in patients with TBI in Zimbabwe.

Road traffic accidents, among other mechanisms of trauma, are a risk factor for evolution of different types of late neurological complications. Neurological status decline is a predictor for intracranial lesions on FCTBI. This is usually noted by an aggravation of the following neurological symptoms: post traumatic headaches, loss of consciousness, dizziness, episodes of vomiting, loss of vision, confusion, post traumatic seizures, meningitis, behavioural changes, stroke, decrease in sensation and difficulty with speech. It is recommended, from this study, that CTBI1 should be performed at 8 hours after the trauma occurrence to give time for brain pathology to evolve. However, FCTBI should be performed when necessary and should be guided by a decline in either GCS score or neurological status, rather than as routine imaging. It was found reasonable, with regard to findings from this research study, to recommend 20 hours as the minimal observation time for hospitalized trauma patients. That is, in patients with TBI presenting with a mild GCS score, mild neurological status, normal CTBI1, observed for at least 20 hours and with no other risk factors or injuries which may warrant hospital admission, can then be discharged home without performing FCTBI. There is also need to carry out research studies to determine the role of FCTBI in patients who re-visit the hospital outside the observation period of 20 hours as suggested in this research study. In order to enhance the diagnosis of TBI, it is recommended that a minimum set of data should be recorded for all patients with TBI. This includes: gender, age, mechanisms of trauma, exhibited neurological

symptoms, GCS score, blood pressure, time of trauma occurrence, length of hospital observation and time of CTB imaging.

In a rare case that was encountered in this study where 18% of patients recorded decreased sensation following brain injury, one patient had a brainstem haemorrhage which is an unusual radiological finding that was later detected by Magnetic Resonance Imaging (MRI) (Newman & Prabhu, 2014). Traumatic brainstem haemorrhage may cause a disruption of axonal tracts in the brainstem which typically results in nervous system dysfunction (Se *et al.,* 2009). The aforementioned authors therefore reiterated that if the supratentorial lesion cannot explain observed neurological deficits, the possibility of brainstem haemorrhage should be considered using MRI. As such, further studies could be done to determine other life-threatening neurological complications (if any) that may be missed by CTB imaging, but are detected by other neuroimaging modalities.

5.8 Conclusion

The internal validity of this research study is important. Despite the limitations that were encountered, the results presented here most likely represent the true state of TBI trends at the research site in Zimbabwe. Albeit the results cannot be generalized, there is value in exploring them in high and low income countries elsewhere. This research study managed to answer the research question (in section 1.4) appropriately in the sense that, FCTBI was found to be of value in detecting the evolution of intracranial lesions leading to a change in hospital treatment in a significant proportion of patients. The identified problem (in section 1.3) was also addressed in this research study as mentioned in the subsequent statements. A FCTBI in patients with TBI is highly recommended for male patients and younger age group of 26-35 years, who show a decline in both GCS score and neurological status, as well as stage 2 hypertension and who were involved in RTA as these were identified as risk factors associated with the evolution of intracranial lesions. The care of patients with TBI in Zimbabwe may also be improved by performing CTBI1 and FCTBI at 8 and 18 hours respectively post trauma occurrence, and a hospital observation for a minimum time period of 20 hours.

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ADDENDA

ADDENDUM A1: DATA COLLECTION SHEET 1 USED FOR ALL PATIENTS WITH A NORMAL CTB IMAGING.

Study number:	001	002	003	004	005	006	n = Unknown
Gender							
Age							
Date & Time of injury occurrence							
MECHANISMS OF TRAUMA e.g.							
RTA							
Assault							
Fall							
Struck on the head by an object							
OTHER							
VITAL SIGNS							
Blood pressure							
Body temp							
Breathing rate							
Heart rate							
GLASGOW COMA SCORE(out of 15)							
NEUROLOGICAL SYMPTOMS e.g.							
Post traumatic headache							
Loss of consciousness							
Loss of vision							
Episodes of vomiting							
Confusion							
Dizziness							
Decrease in sensation							
Difficulty with speech							
Post traumatic seizures							
Hydrocephalus							
Sensory problems							

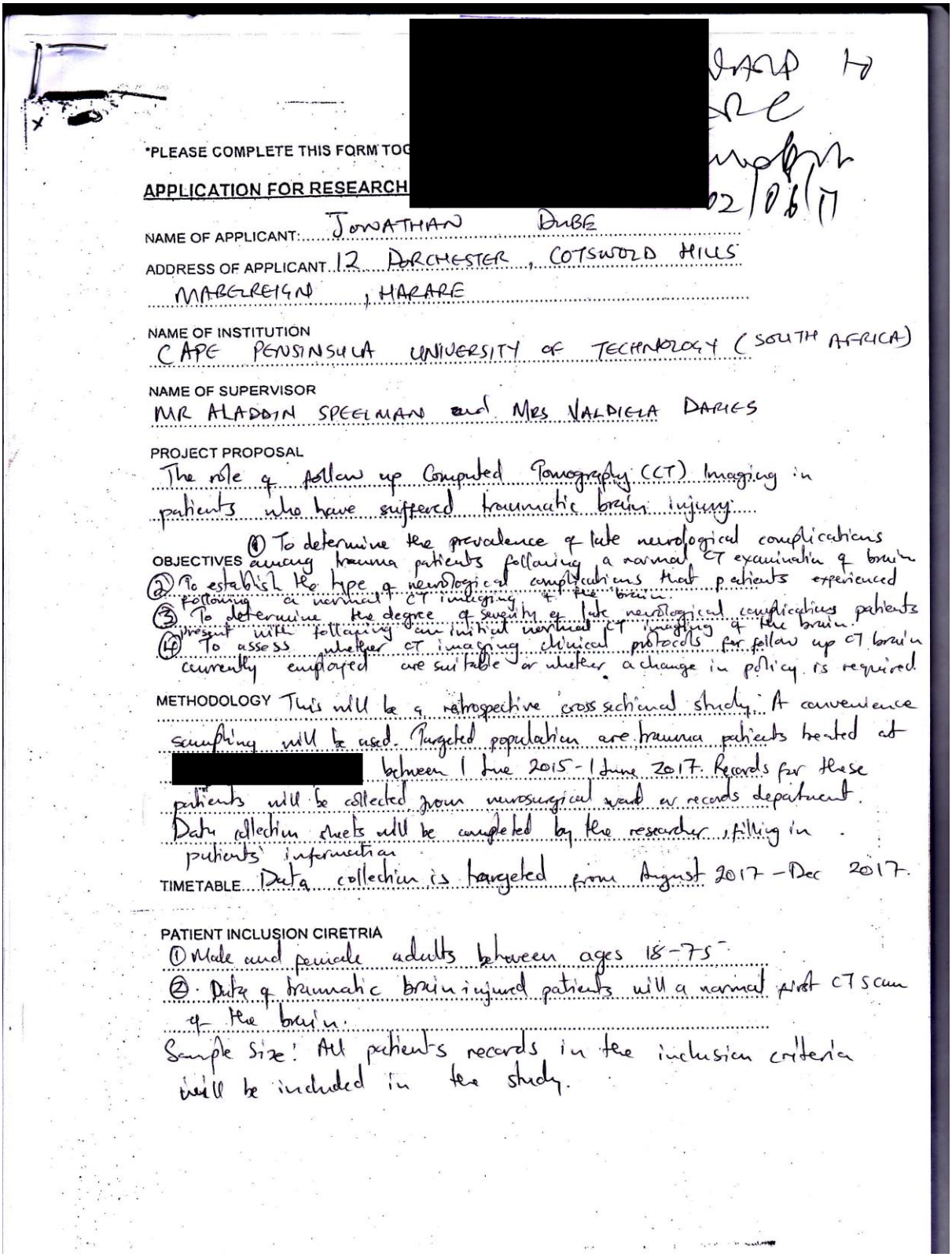
Meningitis							
Behavioural changes							
Stroke							
Intellectual problems							
Emotional changes							
Urinary incontinence							
OTHER							
SEVERITY OF NEUROLOGICAL STATUS							
Mild							
Moderate							
Severe							
Date & Time first CT scan was performed							
Time that lapsed between trauma occurrence and performing first scan (hours)							
CTBI1 RADIOLOGICAL FINDINGS							
CTBI1 COMMENTS							

ADDENDUM A2: DATA COLLECTION SHEET 2 FOR PATIENTS' HOSPITAL OBSERVATION DURING ADMISSION PERIOD

Study number:	001			002			n = unknown		
Observation (O)	Ob1	Ob2	Ob3	Ob1	Ob2	Ob3	Ob1	Ob2	Ob3
Observation time (hours)									
VITAL SIGNS									
Blood pressure									
Body temp									
Breathing rate									
Heart rate									
GLASGOW COMA SCORE (out of 15)									
NEUROLOGICAL SYMPTOMS e.g.									
Post traumatic headache									
Loss of consciousness									
Loss of vision									
Episodes of vomiting									
Confusion									
Dizziness									
Decrease in sensation									
Difficulty with speech									
Post traumatic seizures									
Hydrocephalus									
Sensory problems									
Meningitis									
Behavioural changes									
Stroke									
Intellectual problems									
Emotional changes									
Urinary incontinence									
OTHER									
SEVERITY OF NEUROLOGICAL STATUS									

Mild									
Moderate									
Severe									
Comments:									
Improved									
Worsened									
Unchanged									
FCTBI requested:									
Yes (Y)									
No (N)									
Time FCTBI scan performed									
Time that elapsed between trauma occurrence and performing FCTBI scan (hours)									
FCTBI Findings									
Subdural Haematoma/haemorrhage									
Epidural Haematoma/haemorrhage									
Subarachnoid haemorrhage									
Pneumocephalus									
Intracranial Haemorrhage									
None									
FCTBI Comments:									
Worsened									
Unchanged									
FCTBI requested but not performed, **REASON**									

ADDENDUM B: APPROVAL FROM THE CLINICAL DIRECTOR- RESEARCH SITE



*PLEASE COMPLETE THIS FORM TOC

APPLICATION FOR RESEARCH

02/06/17

NAME OF APPLICANT: JONATHAN DUBE

ADDRESS OF APPLICANT 12 DORCHESTER, COTSWOLD HILLS MABELREIGN, HARARE

NAME OF INSTITUTION
CAPE PENINSULA UNIVERSITY OF TECHNOLOGY (SOUTH AFRICA)

NAME OF SUPERVISOR
MR ALADDIN SPEELMAN and MRS VALDIEZA DAVIES

PROJECT PROPOSAL
The role of follow up Computed Tomography (CT) Imaging in patients who have suffered traumatic brain injury.

OBJECTIVES
① To determine the prevalence of late neurological complications among trauma patients following a normal CT examination of brain
② To establish the type of neurological complications that patients experienced following a normal CT imaging of the brain.
③ To determine the degree of severity of late neurological complications patients present with following an initial normal CT imaging of the brain.
④ To assess whether CT imaging clinical protocols for follow up CT brain currently employed are suitable or whether a change in policy is required

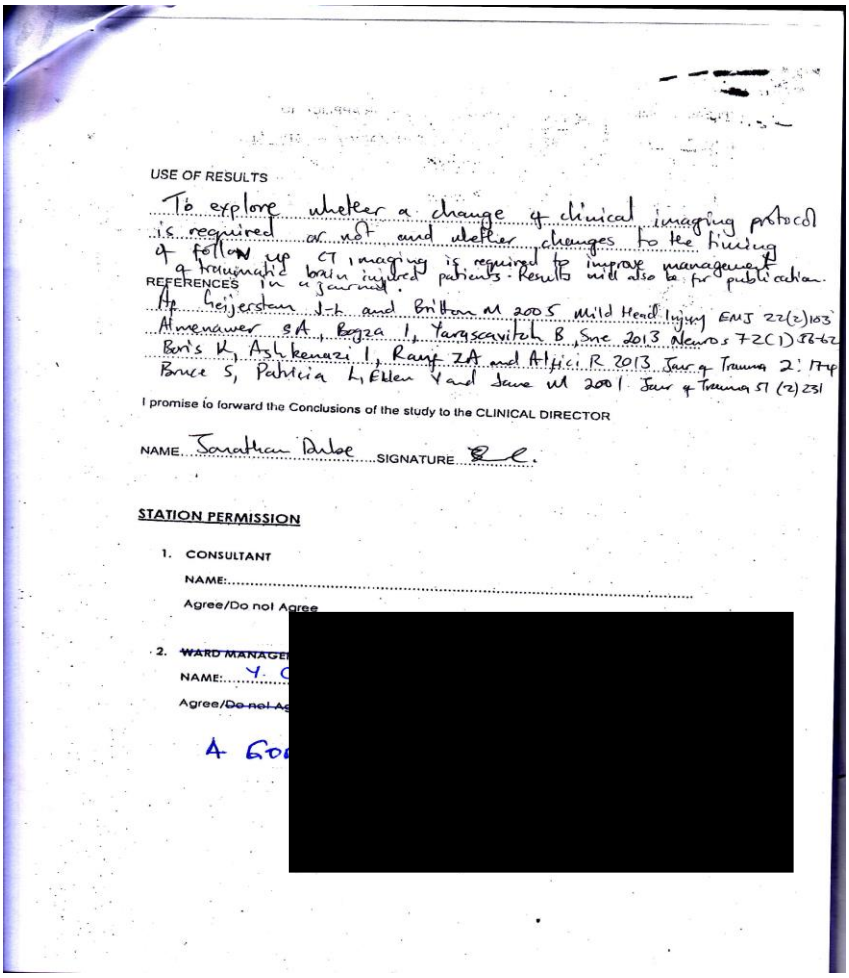
METHODOLOGY This will be a retrospective cross sectional study. A convenience sampling will be used. Targeted population are trauma patients treated at [redacted] between 1 June 2015 - 1 June 2017. Records for these patients will be collected from neurosurgical ward or records department. Data collection sheets will be completed by the researcher, filling in patients' information

TIMETABLE Data collection is targeted from August 2017 - Dec 2017.

PATIENT INCLUSION CIRETRIA
① Male and female adults between ages 18-75
② Data of traumatic brain injured patients with a normal first CT scan of the brain.

Sample Size: All patients records in the inclusion criteria will be included in the study.

ADDENDUM C: APPROVAL FORM THE CHIEF RADIOGRAPHER AND HEAD OF RECORDS DEPARTMENT-RESEARCH SITE



USE OF RESULTS

To explore whether a change of clinical imaging protocol is required or not and whether changes to the timing of follow up CT imaging is required to improve management of traumatic brain injured patients. Results will also be for publication in a journal.

REFERENCES

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Almenawer SA, Bogza I, Yarascavitch B, Sne 2013 Neuros 72(1) 8262
Ben's K, Ashkenazi I, Rang ZA and Alfici R 2013 Jour of Trauma 2: 174
Bruce S, Patricia L, Ellen Y and Jane M 2001 Jour of Trauma 51 (2) 231

I promise to forward the Conclusions of the study to the CLINICAL DIRECTOR

NAME Jonathan Dube SIGNATURE

STATION PERMISSION

1. CONSULTANT

NAME:

Agree/Do not Agree

2. ~~WARD MANAGER~~

NAME: Y.

Agree/~~Do not Ag~~

A Go

[redacted]

ADDENDUM D: ETHICS APPROVAL FROM FACULTY OF HEALTH AND WELLNESS SCIENCES-CPUT

Cape Peninsula
University of Technology

HEALTH AND WELLNESS SCIENCES RESEARCH ETHICS COMMITTEE (HW-REC)
Registration Number NHREC: REC- 230408-014

P.O. Box 1906 • Bellville 7535 South Africa
Symphony Road Bellville 7535
Tel: +27 21 959 6917
Email: sethn@cput.ac.za

2 August 2017
REC Approval Reference No:
CPUT/HW-REC 2017/H21

Dear Mr Jonathan Dube

Re: APPLICATION TO THE HW-REC FOR ETHICS CLEARANCE

Approval was granted by the Health and Wellness Sciences-REC on 15 June 2017 to Mr Dube for ethical clearance. This approval is for research activities related to student research in the Department of Medical Imaging & Therapeutic at this Institution.

TITLE: The role of follow up Computed Tomography (CT) imaging in patients who have suffered traumatic brain injury

Supervisor: Mr A Speelman and Ms V Daries

Comment:

Approval will not extend beyond 3 August 2018. An extension should be applied for 6 weeks before this expiry date should data collection and use/analysis of data, information and/or samples for this study continue beyond this date.

The investigator(s) should understand the ethical conditions under which they are authorized to carry out this study and they should be compliant to these conditions. It is required that the investigator(s) complete an **annual progress report** that should be submitted to the HWS-REC in December of that particular year, for the HWS-REC to be kept informed of the progress and of any problems you may have encountered.

Kind Regards

Mr. Navindhra Naidoo
Chairperson – Research Ethics Committee
Faculty of Health and Wellness Sciences

ADDENDUM E: ETHICS APPROVAL FROM MEDICAL RESEARCH COUNCIL OF ZIMBABWE

Telephone: 791792/791193
Telefax: (263) - 4 - 790715
E-mail: mrcz@mrcz.org.zw
Website: http://www.mrcz.org.zw

Medical Research Council of Zimbabwe
Josiah Tongogara / Mazoe Street
P. O. Box CY 573
Causeway
Harare

APPROVAL LETTER

Ref: MRCZ/B/1341 **7 August, 2017**

Jonathan Dube
Faculty of Health and Wellness
Cape Peninsula University of Technology
Cape Town
South Africa

RE: - The Role of Follow up Computed Tomography (CT) imaging in patients who have suffered traumatic brain injury .

Thank you for the above titled proposal that you submitted to the Medical Research Council of Zimbabwe (MRCZ) for review. Please be advised that the Medical Research Council of Zimbabwe has **reviewed** and **approved** your application to conduct the above titled study. This is based on the following documents (among others) that were submitted to the MRCZ for review:

a) Research Protocol

- **APPROVAL NUMBER : MRCZ/B/1341**

This number should be used on all correspondence, consent forms and documents as appropriate.

- **TYPE OF REVIEW : EXPEDITED**
- **EFFECTIVE APPROVAL DATE : 7 August, 2017**
- **EXPIRATION DATE : 8 August, 2018**

After this date, this project may only continue upon renewal. For purposes of renewal, a progress report on a standard form obtainable from the MRCZ Website should be submitted three months before the expiration date for continuing review.

- **SERIOUS ADVERSE EVENT REPORTING**: All serious problems having to do with subject safety must be reported to the Institutional Ethical Review Committee (IERC) as well as the MRCZ within 3 working days using standard forms obtainable from the MRCZ Website.
- **MODIFICATIONS**: Prior MRCZ and IERC approval using standard forms obtainable from the MRCZ Website is required before implementing any changes in the Protocol (including changes in the consent documents).
- **TERMINATION OF STUDY**: On termination of a study, a report has to be submitted to the MRCZ using standard forms obtainable from the MRCZ Website.
- **QUESTIONS**: Please contact the MRCZ on Telephone No. (04) 791792, 791193 or by e-mail on mrcz@mrcz.org.zw
- **Other**
- Please be reminded to send in copies of your research results for our records as well as for Health Research Database.
- You're also encouraged to submit electronic copies of your publications in peer-reviewed journals that may emanate from this study.

Yours Faithfully

.....

MRCZ SECRETARIAT
FOR CHAIRPERSON
MEDICAL RESEARCH COUNCIL OF ZIMBABWE

MEDICAL RESEARCH COUNCIL OF ZIMBABWE
2017 -08- 07
APPROVED
P.O. BOX CY 573 CAUSEWAY, HARARE

PROMOTING THE ETHICAL CONDUCT OF HEALTH RESEARCH

ADDENDUM F: LIST OF FORMULAE

Arithmetic mean:

Ungrouped data

$$A = \frac{1}{n} * \sum_{i=1}^{n} x_i$$

A = average (or arithmetic mean)
n = the number of terms (e.g., the number of items or numbers being averaged) x_1 = the value of each individual item in the list of numbers being averaged

Grouped data

Arithmetic Mean = ΣfX/Σf where
X = Individual score f = Frequency

Standard deviation

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \mu)^2}{n}}$$

$\sigma = Standard\ Deviation$

$\mu = Mean$

$n = Number\ of\ Elements\ in\ Set$

Mode

$M_0 = O_{mo} + c(f_m - f_{m-1})/2f_m - f_{m-1} - f_{m+1}$

Median

$M_e = O_{me} + c[n/2 - f(<)]/f_{me}$

Range

Range = Maximum value – Minimum value

= X_{max} - X_{min}

Pearson's coefficient of skewness

Sk_p = 3(mean-median)/standard deviation

Pearson's Correlation Coefficient

$$r = \frac{\sum_{i=1}^{n}(X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{\sum_{i=1}^{n}(X_i - \bar{X})^2}\sqrt{\sum_{i=1}^{n}(Y_i - \bar{Y})^2}}.$$

Where: X represents the independent variables Y represents the dependent variables
N is the number of the independent and dependent variables $\dot{X}$ is the mean of the independent variables
$\bar{Y}$ is the mean of the dependent variables.

Logistic regression model:

(For log odds of an outcome variable (Y))

ln[P/(1 – P)] = β0 + β1X1 + β2X2 + β2X2 + β3X3 + . . . + βnXn + e,

where: ln is the natural logarithm (loge);
P is the probability that the outcome Y occurs;
P/ (1 – P) is the odds of the outcome;
ln [P/(1 – P)] is the log odds or "logit," of the outcome;
e is the residual error.
X1, X2, X3 . . . X are categorical and/or continuous independent variables

Chi square test

$$\mathrm{X}^2 = \sum_{i=1}^{n} \frac{(O_i - E_i)^2}{E_i}$$

Where

X^2 = Pearson's cumulative test statistic, which asymptotically approaches
O_i = an observed frequency;
E_i = an expected (theoretical)
frequency; n = the number of cells
in the table.

Formulae adapted from Hilderbrand D., Ott, R.L. & Gray J.B., (2005), Tuuli & Odibo 2011