DISCREPANCIES BETWEEN ANTEMORTEM COMPUTED TOMOGRAPHY SCAN AND AUTOPSY FINDINGS OF TRAUMATIC INTRACRANIAL HAEMORRHAGE AT PIETERSBURG HOSPITAL FORENSIC PATHOLOGY DEPARTMENT

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DEDICATION BY STUDENT

This work is dedicated to my wife and my daughter (Malerato)

Mmachuene I. Hlahla
October 2018

DECLARATION

I declare that **"DISCREPANCIES BETWEEN ANTEMORTEM COMPUTED TOMOGRAPHY SCAN AND AUTOPSY FINDINGS OF TRAUMATIC INTRACRANIAL HAEMORRHAGE AT PIETERSBURG HOSPITAL FORENSIC PATHOLOGY DEPARTMENT"** is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references and that this work has not been submitted before for any other degree at any other institution.

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Mmachuene I. Hlahla

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Date: 2018/10/05

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Author
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LIST OF ABBREVIATIONS

ACT	: Antemortem computed tomography
CT	: Computed Tomography
CSF	: Cerebrospinal fluid
EDH	: Epidural haemorrhage
GCS	: Glasgow Coma Scale
ICH	: Intracranial haemorrhage
LOC	: Level of consciousness
PMCT	: Postmortem Computed Tomography
SAH	: Subarachnoid haemorrhage
SDH	: Subdural haemorrhage
TBI	: Traumatic Brain Injury
TIH	: Traumatic intracranial haemorrhage

ABSTRACT

Background

Traumatic intracranial haemorrhages are common, carry a high mortality rate and are therefore commonly known in the practice of forensic pathology as unnatural deaths. Studies have demonstrated a significant decrease in mortality rate among patients who received surgical interventions compared to patients who were treated medically. Missed or mis-diagnoses, which may be apparent during an autopsy procedure, present possible missed treatment opportunities.

Aim/objective and methods

The study investigated the discrepancy rate and discrepancy pattern of diagnosis between antemortem brain computed tomography (CT) scan findings and autopsy findings in deceased patients with traumatic intracranial haemorrhage (TIH). A quantitative retrospective descriptive study was conducted based on bodies presented with TIH at Pietersburg Hospital Forensic Pathology Department. A total of consecutive 85 cases with antemortem CT (ACT) scan findings were compared to autopsy findings using percentage agreement and Cohen's kappa statistics.

Results and conclusion

There was a fair overall agreement (k=0.38) with overall discrepancy rate of 24.74%, ranging from 9.41% to 34.12% for individual TIH between ACT scan and autopsy findings. Subarachnoid haemorrhage had the lowest agreement between the ACT scan and autopsy findings for TIH. Patient and doctor factors associated with the discrepancies were assessed. Those associated factors, if addressed, may have a positive impact on patient outcome. As far as the debate on non-invasive autopsy procedure is concerned, as a result of existing discrepancy rate, we conclude that ACT should not be used alone in the determination of cause of death but may be used in conjunction with autopsy findings.

Keywords: *discrepancy rate, autopsy, antemortem computed tomography, traumatic intracranial haemorrhage*.

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CHAPTER 1

ORIENTATION TO THE STUDY

1.1. INTRODUCTION/BACKGROUND

Head injuries are common and important in forensic medicine practice, and usually carry high mortality rate. The overall incidence of traumatic brain injury (TBI) which results from head injuries in the United States (US) is 506.4 per 100 000 population and South Africa does not have such databank (Naidoo, 2013). However, population-based studies as reported by Naidoo (2013) in countries like South Africa suggest even higher rates of TBI accounted for primarily by road traffic accident. TBI includes intracranial haemorrhages, viz extradural, subdural, subarachnoid and intracerebral haemorrhages. CT scan is always performed on patients with TBI on arrival to the emergency medicine for the purpose of diagnosis and treatment. Deaths from head injuries are classified under death due to ‘unnatural cause’, as stipulated in the National Health Act no 61 of 2003, which means they will then be subjected to autopsy (South Africa, 2003).

Autopsy has been the reference standard in investigation of deceased trauma victims worldwide (Jalalzadeh et al., 2015; Yaniv et al., 2011). Missed or mis-diagnoses, which may be apparent at autopsy, may therefore mean possible missed treatment opportunities. Imaging techniques have also been considered as useful tools in medico-legal investigations (Filograna et al., 2010; Jalalzadeh et al., 2015; Kasahara et al., 2012) due to some advances made in the past decade. These “new emergent modalities are finding their way to augment, supplement and reduce the invasiveness of conventional autopsy” (Yaniv et al., 2011, p. 707). CT scan has been used as the preferred imaging modality in forensic imaging (Baglivo et al., 2013).

Studies have shown that postmortem computered tomography (PMCT) is useful in determining cause of death in case of traumatic intracranial haematoma while the use of antemortem computed tomography (ACT) scan findings remain unclear due to limited research in this regard (Bhat, Saraschandra & Neena-Priyadarshini, 2011; Kasahara et al., 2012; Liisanantt & Ala-Kokko, 2015). However, in some cases the lesion may be missed or misinterpreted by CT scan examination (Sharma & Murari, 2006). This means there are some discrepancies between CT scan findings and autopsy findings.

This research assessed the rate and pattern of discrepancies between the antemortem CT scan findings and conventional autopsy findings of traumatic intracranial haemorrhages in cases submitted for autopsy at Polokwane Forensic Medicine Department over a 3-year period. Some contributing factors responsible for the discrepancies were evaluated.

1.2. THE RESEARCH PROBLEM

People who sustained head injuries have a poor prognosis and in most instances die mainly due to pressure in the head. However, if surgical measures can be performed timeously, some individuals may survive this fatal condition. Studies demonstrated a significant decrease in mortality rate among patients who received surgical interventions compared to patients who were treated medically (Potts et al., 2012). In the field of forensic medicine, a large number fatal head injury cases are caused by accidents, suicides and homicides (Jacobsen & Lynnerup, 2010).There has been an alarming increase in crime (South Africa Stats Crime, [s.a.]) and road traffic accidents. In the light of these increasing crime and road traffic accidents, many may sustain head injuries and develop traumatic intracranial haemorrhage, which may need some surgical interventions. Diagnostic errors of haemorrhages associated with these injuries present missed treatment opportunities. These errors would then be apparent at autopsy. The author had personally observed discrepancies between antemortem CT scan findings and autopsy findings in his area of employment at the Department of Forensic Pathology (Polokwane).

Literature highlights discrepancies between the postmortem CT scan findings and autopsy findings and the possible usefulness of PMCT in the postmortem period (Gascho, Thali & Niemann, 2018; Graziani et al., 2018; Higginbotham-Jones & Ward, 2014; Panda et al., 2015); and says little about the antemortem CT scan findings and autopsy findings. The world is slowly considering moving away from conventional autopsy to imaging techniques for various reasons. In countries such as South Africa (SA), where there are financial constraints to acquiring imaging techniques in forensic pathology setting, a question then arises as to whether the use of antemortem CT can replace an autopsy procedure where applicable.

1.3. AIM OF THE STUDY

The study sought to investigate the rate and pattern of discrepancies between antemortem CT scan and autopsy findings in deceased patients with traumatic intracranial haemorrhage at Pietersburg Hospital Department of Forensic Pathology.

1.4. OBJECTIVES

To achieve its aim, the study had the following objectives

- To assess the agreement between antemortem CT scan and autopsy findings in the detection and diagnosis of traumatic intracranial haemorrhage.
- To determine the discrepancy pattern of diagnosis of the traumatic intracranial haemorrhage with low agreement.
- To evaluate factors which may contribute to the discrepancies.

1.5. RESEARCH QUESTIONS

The study sought to answer the following questions:

- What is the rate of discrepancies between antemortem CT scan and autopsy findings in diagnosis of traumatic intracranial haemorrhage at Pietersburg Hospital Forensic Pathology Department?
- What is the discrepancy pattern of diagnosis of the traumatic intracranial haemorrhage with low agreement?
- What are the factors that may be responsible for the discrepancies?

1.6. MOTIVATION/RATIONALE FOR THE STUDY

The researcher has observed some missed or misdiagnosed cases of traumatic intracranial haemorrhage (TIH) when comparing the antemortem computed tomography scan findings to autopsy findings. Some missed or misdiagnosed TIH may results in poor patient management while on the other hand if the correct diagnosis is made, patient care may improve and thus the mortality rate. This can be achieved by addressing factors associated with the discrepancies.

The use of body CT scan during postmortem examination is increasing in forensic setting in developed countries. In developing countries we are faced with financial constraints which make it difficult to acquire CT scan for the purpose of postmortem examination. In the light of this, can the antemortem CT scan findings be used in Forensic Medicine? Molina, Nichols and Dimaio (2007) acknowledged that there is little literature about the use of antemortem CT (ACT) scan findings during autopsy, though having consensus that there are discrepancies between the ACT findings and autopsy findings. Based on the practical observation and what the literature says, there is indeed a discrepancy, which in determining its rate and pattern of diagnosis for traumatic intracranial haemorrhage may add knowledge to this field.

1.7. SIGNIFICANCE OF THE PROPOSED RESEARCH

The research findings would make the Department of Radiology aware of the discrepancies and the factors responsible, so that they can address them, which will in turn hopefully improve reporting. Henceforth, an appropriate management of patient with the head injuries may ensue with possibility to improve the outcome of such cases.

The study exposed the actual rate of discrepancies between the antemortem CT scan findings and autopsy findings including the discrepancy pattern of diagnosis and attempted to establish factors that may be associated with the discrepancies. These may contribute to body of knowledge to the practice of forensic pathology concerning the issue of non-invasive autopsy against invasive autopsy and use of antemortem CT scan to determine cause of death.

1.8. DEFINITION OF CONCEPTS

Traumatic intracranial haemorrhage: may be "extradural (epidural), subdural, subarachnoid, or intracerebral in location following trauma" (Gurdjian & Thomas, 1974, p. 203). As used in this study this refers to haemorrhage into the potential spaces surrounding the brain namely epidural, subdural and subarachnoid.

Epidural haemorrhage: is the accumulation of blood in the potential space surrounding the brain, between the dura mater and the inner surface of the skull (Ferri, 2016).

Subdural haemorrhage: is a collection of blood or blood products between the arachnoidal (superficial) layer of the brain and the dura or meningeal layer of the brain (Ferri, 2016).

Subarachnoid haemorrhage: is defined as haemorrhage into the subarachnoid space (Ferri, 2016).

Road traffic accidents: according to arrive-alive [s.a.], this is defined as an accident, incident, event, collision or crash between two or more vehicles, a vehicle and a train, a vehicle and a cyclist, a vehicle and a pedestrian, a vehicle and an animal, a vehicle and a fixed object, such as a bridge, building, tree, post, etc., or a single vehicle that overturned on or near a public road.

Autopsy: is a highly specialized surgical procedure that consists of a thorough examination and 'dissection' of a corpse to determine the cause and manner of death and to evaluate any disease or injury that may be present (Tejaswi & Aarte-Hari-Periya, 2013).

Antemortem: performed or occurring before death (Keane, 1997)

Postmortem: performed or occurring after death (Keane, 1997)

Imaging techniques: These are techniques used in radiological sciences for visualization of anatomical structures (modalities include x-ray radiography, x-ray mammography, x-ray Computed Tomography, ultrasound and Magnetic Resonance Imaging) and metabolic information (modalities include positron emission tomography, fluorescence imaging and etc.) of the human body (Dhawan, 2003). As used in this study this refers to the use of computed tomography.

1.9. CONCLUSION

This chapter explained the problem, rationale and importance of the study. The aim and objectives of the study were outlined in order to answer the research questions. The next chapter will deal with the literature review.

CHAPTER 2

LITERATURE REVIEW

2.1. INTRODUCTION

Intracranial haemorrhage (traumatic or non-traumatic) is a serious disorder that has poor outcomes and majority of those who sustained intracranial haemorrhage may die as a result of its consequences. Hence, it requires rapid diagnosis and management (Evans et al., 2017; Kidwell & Wintermark, 2008). In the current practice, the modality of choice for evaluation of head trauma is the computed tomography (CT) scan (Hijaz, Cento & Walker, 2011). CT scan assists in assessing the location, extent and type of intracranial lesions caused by head injury (Nixon, 2014). The findings still need to be interpreted after imaging. According to Bruno, Walker and Abujudeh (2015), radiologic interpretation cannot be programmed and as such its interpretation is subject to a variety of mistakes because is based on complex psychophysiological and cognitive processes. These error types may result in discrepancies.

In radiology, a discrepancy occurs when the original radiology report differs from the opinion of another reporter (Owens, Taylor & Howlett, 2016). Brady (2017) stated that in some circumstances, surgical examination and autopsy examination may show evidence of the pathologic diagnosis, though this is not a common basis for proving whether error has occurred.

2.2. THE RATE OF DISCREPANCIES BETWEEN CT SCAN AND AUTOPSY FINDINGS

A search of academic literature locally and internationally showed limited information about the rate of discrepancies between the antemortem CT scan and autopsy findings. However, Brady (2017) argues that errors and discrepancies in radiology practice are uncomfortably common, with an estimated day-to-day rate of 3-5% of studies reported, and much higher rates reported in many targeted studies among the radiologist.

The international studies conducted in different countries with different objectives by Bhat et al. (2011) and Molina et al. (2007) demonstrated that antemortem CT scan have a low rate of accuracy and sensitivity compared to autopsy findings of in the diagnosis traumatic intracranial haemorrhage. In the later study, the discrepancies occurred despite the fact that CT scans were performed within 24hrs before death. In the former study, there was no mention of when the CT scans were performed. Their findings are summarised below in a table format. Table 2.1 shows an antemortem CT scan detection rate for intracranial haemorrhage. Recent study by Panzer et al. (2017) reported a high specificity (≥80%) for autopsy when comparing traumatic head injury between autopsy and antemortem computed tomography. This means that autopsy has more chances of accurately excluding the pathology in the head from all bodies without the pathology.

Table 2.1: Antemortem CT scan detection rate for traumatic intracranial haemorrhage

	Extradural haemorrhage (EDH)	*Subdural haemorrhage (SDH)*	*Subarachnoid haemorrhage (SAH)*
Molina et al., 2007	33.3%	65.8%	44.4%
Bhat et al., 2011	35.7%	41.86%	44.4%

Source: Adapted from Bhat et al., 2011; Molina et al., 2007

Studies by Tejerina et al. (2012) and Frohlich et al. (2014) reported discrepancy rate of 30% to 50% between the antemortem CT scan findings and autopsy findings. A similar study was conducted by Liisanantt and Ala-Kokko (2015) and results were found to be similar to the aforementioned study. As much as antemortem CT scan findings can prompt someone to look for certain findings in the brain during autopsy, one must still be vigilant enough and not rely solely on those findings as the above studies confirm the presence of discrepancies between antemortem CT scan and autopsy findings. Many international centres which use postmortem computed tomography (PMCT) have evaluated relationships between PMCT and autopsy findings in trauma facilities and found that discrepancies do exist in cases of traumatic intracranial haemorrhages (Leth & Thomsen, 2013).

Yen et al. (2007) evaluated postmortem brains with traumatic injuries (cited in Smith et al., 2012) and found that PMCT had a sensitivity of 73% for the detection of subdural haemorrhage. This means approximately 1/3 of cases with subdural haemorrhage may be missed using the imaging techniques. Despite the fact that some discrepancies have been identified, Pohlenz et al. (2008) highlighted the point that PMCT techniques still benefit forensic science and thus the reason there have been great advances in postmortem computered tomography investigations in the past years.

2.3. REASONS FOR THE DISCREPANCIES

There are several factors which may be responsible for the discrepancies which may be seen on comparing radiologic findings to autopsy findings. These include patient factors, radiology practitioner factors, forensic practitioner factors and unexplained factors.

2.3.1. Patient factors

A quick, reliable and the most commonly used method of assessing level of consciousness in patients with traumatic brain injury (TBI) or who sustained head trauma, is the use of Glasgow coma scale (Barlow, 2012). These patients with TBI will then be graded as mild, moderate, and severe based on the same scale.

Mild, moderate and severe TBI are defined as GCS score between 13 and 15, between 12 and 9 and below 9 respectively (Knopman & Hartl, 2017). As soon as patient with head trauma arrives in the hospital, depending on the level of consciousness, a CT scan is performed. They are then placed in a specific position for the purpose of scanning.

Barret and Keat (2004) explained a specific positioning method to be followed when a radiologist has to achieve a very good quality of CT scan image. The standard protocol is to put the patient in supine position with the head in the head-holder. Bontrager (2001) further emphasised that for all cranial CT scan "no rotation" and "no tilt" of the head are important features so that any bilateral asymmetry due to pathologic processes can be determined. This means failure to place the patient in a described position, which may take place in some patient with decreased level of consciousness (especially involuntary movements) may result in motion on the cranial CT scan image and hence failure to recognize certain findings in the head.

Carlton and Alder (2001) and Barrett and Keat (2004) agree that motion is a problem in CT scan because it produces streak artefact through the image or obscure information. Although some CT scan units are capable of analysing a motion image – deleting the portion of the data that made up the motion and reconstructing a stationary image from the remaining data, these images do not contain as much information as originally planned. On comparing the antemortem CT scan findings and postmortem examination findings Lisanantt and Ala-kokko (2015) showed that dealing with critically ill patients is challenging and this may result in some missed diagnosis especially in patient hospitalized for trauma or with neurologic disorders.

Since patients with altered level of consciousness may unintentionally move their head during performance of CT scan, this may results in misinterpreting or missing some intracranial haemorrhage, which in turn when examined during autopsy the discrepancies may ensue.

2.3.2. Radiology practitioner factors

Pinto et al. (2012) said that errors are an inevitable part of human life and every health professional has made mistakes. The same sentiments were shared by Brady et al. (2012, p. 3), who maintained that “in all branches of medicine, there is inevitable element of patient exposure to problems arising from human error”. Radiology practitioners are no exception.

The aetiology of radiological errors are multifactorial (Pinto et al., 2012). Higginbotham-Jones and Ward (2014) concluded that the cross-sectional forensic investigations outcomes are affected by general technical limitation. Though these limitations were derived from the postmortem CT scan, the same factors may still apply to the antemortem CT scan. The inference can be drawn since there is “virtually no difference in imaging intracranial haemorrhage between the living and the dead” (Christe et al., 2010, p. 216) with the exclusion of decomposed body.

Some radiological literature states different classification system used to categorise radiological error (Pinto & Brunese, 2010; Brook et al., 2010). According to Bruno et al. (2015), the most recent and comprehensive model was developed by Kim and Mansfield and is illustrated in the table below. Table 2.2 classify errors found in diagnostic radiology. This classification was adapted after two radiologists (Kim & Mansfield, 2014) reviewed the cases. Though the discrepancies were found between two radiologists, autopsy studies have identified major discrepancies, implying that the working or final clinical diagnosis may be wrong (Bruno et al., 2015).

Table 2.2: Classification of Errors in Diagnostic Radiology

Type	**Cause of Error Explanation**
Complacency	Error of over reading and misinterpretation, in which a finding is appreciated, but is attributed to the wrong cause.
Faulty reasoning	Error of over reading and misinterpretation, in which a finding is appreciated and interpreted as abnormal but is attributed to the wrong cause. Misleading information and a limited differential diagnosis are included in this category.
Lack of knowledge	The finding is seen but is attributed to the wrong cause because of a lack of knowledge on the part of the viewer or interpreter.
Under-reading	The finding is missed.
Poor communication	The lesion is identified and interpreted correctly, but the message fails to reach the clinician.
Technique	The finding is missed because of the limitations of examination or technique.
Prior examination	The finding is missed because of failure to consult prior radiologic studies or reports.
History	The finding is missed because of acquisition of inaccurate or incomplete clinical history.
Location	The finding is missed because of the location of a lesion outside the area of interest on an image, such as in the corner of an image.
Satisfaction of search	The finding is missed because of failure to continue to search for additional abnormalities after the first abnormality was found.
Complication	Complication from a procedure.
Satisfaction of report	The finding was missed because of complacency of report, and overreliance of the radiology report of the previous examinations.

Source: Kim and Mansfield, 2014

There are three major categories of error described in radiology literature which can ultimately lead to discrepancies that may be found on accompanying the CT scan report. These include: perceptual error, in which when an abnormality, through present, is not reported or when an abnormality, through absent is reported; cognitive error, where a radiographic finding is seen but the radiologist attaches the wrong significance; and system errors, which are organizational issues in the institution (Filograna et al., 2010, and Berlin, 2008). The above-mentioned factors were also found by Smith et al. (2012) in their study, where after the review of autopsy findings and careful correlations with the images, there was an agreement about two missed cases of subarachnoid haemorrhage. In addition to these errors, level of experience of the practitioners also plays a role.

Perceptual errors

According to Berlin (2008), perceptual errors are far more common, accounting for 70% of the diagnostic radiographic errors. In general, to be considered a perceptual error, the findings would need to be deemed satisfactorily noticeable and detectable when reviewed by the interpreting radiologist or a pathologist during autopsy (Bruno et al., 2015).

There are two types of perceptual error based on the anticipated aetiology of the error. These are identification and non-identification errors (Filograna et al., 2010, p. 14). Identification error is “a false-positive error that occurs when a radiologist reports a finding that is not present in the image”. Non-identification is “a false-negative error that occurs when image features, although recorded, are not appreciated by the radiologist”. The underlying aetiology of perceptual error remain poorly understood, however there may be attributable to specific risk factors (Bruno et al., 2015). These include: poor conspicuity of the target lesion on the image; reader fatigue; an overly rapid pace of performing interpretations; distractions, such as phone calls, e-mails, and other internet-based distractions or interruptions; and a phenomenon known as satisfaction of search (described in table 2.2 above).

Cognitive error

According to Filograna et al. (2010), cognitive error has been defined as incorrect interpretation of findings and this occur when image features, through reported correctly, lead to incorrect conclusions. Waite et al. (2017, p. 743) mentioned that "radiologists use visual detection, pattern recognition, memory, and cognitive reasoning to synthesize final interpretations of radiologic studies". He further added that this synthesis is performed in an environment in which there are numerous extrinsic distractors, increasing workloads and fatigue. This implies that eventually some degree of inaccuracies may occur even in the hands of expert observers. This type of error may be secondary to a "lack of knowledge, a cognitive bias on the part of the radiologist interpreting the study, or misleading clinical information distorting the apparent pre-test probability of disease" (Bruno et al., 2015, p. 1670).

System error

System errors are caused by poor planning and organization of the radiology department (Filograna et al., 2010). In their study, Brady et al. (2012) summarised system contributors to discrepancies and errors in radiology as staff shortage, inexperience of staff, inadequate equipment, inadequacy of clinical information available to the reporting radiologist and inappropriate expectations. These contributing factors may lead to what has been referred as burnout or professional fatigue syndrome which is a 'concern for radiologists' (Harolds et al., 2016) and is associated with deleterious effects on their work (Chew et al., 2017).

Fatigue is classified under system-related error in radiology because of the demand placed on health care providers to deliver quality patient care to their patients despite the stress of disrupted circadian rhythms (Lee et al., 2013). It has both physical and mental components. Although many other system issues coexist, we selected burnout and visual fatigue as they are well studied in radiologist.

- Burnout in radiologist

According to Mesters et al. (2017), burnout occur because of exposure to a situation in which the strategies of the subject who are supposed to manage the stresses of the environment become outdated and inoperative. Chew et al. (2017), Kurzthaler, Kemmler and Fleischhacker (2017), Romani and Ashkar (2014) defined burnout as a syndrome characterized by emotional exhaustion, depersonalization and low personal accomplishment. According to Harolds et al. (2016), diagnostic radiologists have a high burnout rate when compared to other physicians. Burnout can result in unprofessional behaviour, thoughts of suicide, premature retirement, and in particular relating to our study, errors in patient care (Harolds et al., 2016). This can result in one missing or misinterpreting the diagnosis and furthermore implies that subsequent discrepancies between the antemortem CT image findings and autopsies findings may be identified.

In the study looking in the incidence of professional burnout syndrome among radiologists, Czekajska-Chehab et al. (2003) found the level of burnout to be moderate. The individual elements of the burnout syndrome include reduced emotional control, loss of the subject's commitment, reduced effectiveness of action, limited interpersonal contacts and physical fatigue. This lack of motivation may manifests through the loss of enthusiasm for work, feeling helpless, trapped, and defeated (Romani and Ashkar, 2014). Therefore, risk of errors among radiologist may increase and result in reduced diagnostic accuracy and subsequent discrepancies when compared to autopsy findings.

- Visual fatigue

Visual fatigue is of “particular interest in radiologist” because the interpretation of images are highly dependent on what one sees (Waite et al., 2017, p. 192). They further stated that most investigations regarding the quantification of visual fatigue focused on its oculomotor related symptoms. In another study Waite et al. (2017) mentioned that these symptoms reflect changes in the accommodation and vergence responses of the eye.

Barry and Denniston (2017) defined accommodation as a process by which the eye changes focus from distant to near objects through conformational changes in the ciliary muscle and crystalline lens; while vergence as a binocular disconjugate eye movements, i.e. when the eye move in the opposite direction. Accommodation and vergence drop when one get exhausted resulting in diminished ability to sustain focus. Krupinski and Berbaum (2009), when testing this hypothesis found that the current practice of radiology produces oculomotor fatigue, which result in difficulties to maintain focus on an image also previously confirmed this.

The difficulty on focusing can make it harder to detect abnormalities, by either reducing diagnostic or detection accuracy or requiring more interpretation time if accuracy is preserved (Krupinski et al., 2010; Krupinski & Berbaum, 2009; Waite et al., 2017).

Level of radiology practitioners' experience

Another factor which should not be ignored is experience. Does experience or working in radiology department for some time help to reduce errors? In this case, the retrospective and prospective evaluations may be considered as examples. The following are the examples of discrepancies found in the radiology trainee (residents/registrars), and the neuroradiologist served as gold standard.

First example, out of 153,420 cases interpreted by the radiology registrars, 2169 showed discrepancies which gave an overall discrepancy rate of 1.4%. Discrepancy rates for postgraduate year (PGY) -2, PGY-3 and PGY-4 were 1.31%, 1.65%, and 1.88%, respectively (Mellnick et al., 2016). Bruni, Bartlett and Yu (2012) observed less discrepancies in senior registrars than in junior registrars. Their findings confirmed previous study by Wechsler (1996) that experience appears to decrease discrepancy rates, and registrars are more likely to miss findings, than to read normal scans as abnormal. Nonetheless, Mellnick et al. (2016) and Bruni et al. (2012) exceptionally showed that discrepancy rate varies with patient status, study indication, and hour of call.

Second example, a prospective evaluation was performed for 419 consecutive emergency posttraumatic cranial CT scan studies that had been interpreted by radiology registrar on call (Wysoki, 1998). The discrepancy rates for PGY-2 = 2.4%, PGY-3 = 0% PGY-4 = 4%. Major and minor discrepancies were 1.7% and 2.6%, respectively, among interpretations made by registrar and those by radiologists. Among the major discrepancies, there were four subdural hematomas and one subarachnoid haemorrhage (Wysoki, 1998).

In the two above-mentioned examples, false negative detection errors occurred more in lower level postgraduate registrars/trainee than false positive in advanced postgraduate trainee – i.e. it is more common for the lower postgraduate trainee to miss a finding than to misinterpret one. This could be due to lack of knowledge by the lower postgraduate trainee (Brady et al., 2012). These two scenarios also indicate that there are complex and multifactorial factors which can results in discrepancies, but at the same time the more one gains experience the less likely to miss a lesion. Limitations to their studies were imperfect gold standard of the neuroradiologists though the best available when the patient is still alive.

Most registrars and medical officers in radiology department if not all, work after working-hours (overtime) often overnight and without adequate sleep. Lee et al. (2013) indicated that visual fatigue was seen more in registrars than in (specialist) radiologist. He further stated that this was due to subjective ratings of physical discomfort, eye strain, and lack of motivation which also deepen by the end of the workday. As discussed above, visual fatigue may result in reduced diagnostic accuracy. This may imply that a significant reduction in diagnostic accuracy may be seen in registrars than the specialists and hence the discrepancies.

2.3.3. Pathology practitioner factors

Brady et al. (2012, p. 3) said: “In order for a report to be erroneous, it follows that the correct report must also be possible”. Radiologic studies lack the natural full-colour 3D of autopsies, suggesting that autopsies might be able to serve as reference point for produced radiology report (Murken et al., 2012). Though autopsy are used as a gold standard, the assumption might not be valid because Roberts et al. (2012) demonstrated that some intracranial pathologies could better be detected by imaging techniques than autopsy. The reason why conclusion of a second autopsy is often dissimilar to those of the first shows that autopsy cannot be assumed better than imaging. Pathologists are not immune to human errors and as a result postmortem findings can be misinterpreted. This implies that discrepancies between the ACT scan findings and autopsy findings can occur.

There is no empirical research dealing with perceptual, cognitive and system errors including level of pathology experience as in radiology department. In order to present pathology practitioner factors, a concept called postmorterm artefacts was considered. This concept was well explained in one article written by Mirza and Makhdoom in 1998. Mirza and Makhdoom (1998) highlighted the importance of differentiating between antemortem injuries and postmortem artefacts as failure to do so may result is misleading findings. They defined postmortem artefacts as “any change caused or a feature introduced into a body after death, which is likely to lead to misinterpretation of medically significant antemortem findings”. They further defined these artefacts in the context of Forensic Pathology as a “spurious postmortem presentation which simulates a finding which would be significant in the course of antemortem events”.

Artefacts can be introduced in the period between death and postmortem examination and/or during postmortem examination (Mirza & Makhdoom, 1998). Under artefacts introduced during period of death and autopsy we discussed only those related to the study i.e. agonal artefacts, artefacts related to postmortem lividity and artefacts of decomposition. On the other hand, artefacts introduced during autopsy included artefacts introduced during opening of the skull cap. These are most likely to mislead pathologist with insufficient forensic experience (Saukko & Knight, 2016)

Postmortem lividity and decomposition artefacts

Postmortem lividity is also called livor mortis or postmortem hypostasis. This refers to purplish-blue discolouration due to settling of blood by gravitational forces within dilated, toneless small vessels and capillaries of the deceased's skin (Dimaio & Dimaio, 2001; Spitz, 2006). A similar process to the gravitational movement of blood in capillaries as seen in livor discolouration of the skin occurs in the internal organs (Spitz, 2006). This is known as postmortem internal hypostasis. This discolouration of the organs may be misinterpreted as subarachnoid haemorrhage in the brain.

In a decomposing body, which can occur if the body has been stored in a defective fridge, postmortem lividity may cause head injury interpretations challenging. For example, if a body is found lying on its back, blood accumulate in the dependent half due to gravity. Dimaio and Dimaio (2001) stated that this accumulated blood might cause rupture of the small vessels and result in a very thin localized film of blood in the subarachnoid or subdural spaces coating the dependent part of the brain.

Resuscitation artefact

Usually the neck is extended to pass an endotracheal tube and if can be forced in a hyperextension, this can tear the vertebral arteries and result in subarachnoid haemorrhage (Saukko & Knight, 2016). Additionally, they have seen subarachnoid haemorrhage after external cardiac massage.

Agonal artefact

Agonal rupture of the congested vessels leads to thin grossly visible films of subdural and subarachnoid blood (Saukko & Knight, 2016). This type of artefact and the aforementioned types of artefacts can erroneously be identified as discrepancies especially if the antemortem CT scan did not show that type of intracranial haemorrhage.

Artefact during removal of skull cap

Ludwig (2002) and Waters (2009) described steps to be followed during removal of the cranium. Ideally, sawing should be stopped just short of cutting through the inner table of the cranium. This will leave the dura and underlying leptomeninges intact which allows viewing the brain with the overlying cerebrospinal fluid (CSF) still in the subarachnoid space. Unfortunately, in some cases the dura and the underlying leptomeninges are cut which in few cases subarachnoid haemorrhage make leak through the defect if not visualised quickly (Ludwig, 2002).

2.3.4. Type of traumatic intracranial haemorrhage (TIH)

Intracranial haemorrhage have been classified into 4 major types: intracerebral haemorrhage (excluded in this study), subarachnoid haemorrhage, subdural haemorrhage, and epidural haemorrhage (Kidwell & Wintermark, 2008). The CT scan imaging characteristic of ICH are determined by the degree that the X-ray are attenuated by the blood products.

Subarachnoid haemorrhage

Subarachnoid haemorrhage is defined as haemorrhage into the subarachnoid space (Ferri, 2016). Overall, the most common cause of SAH is trauma (Hijaz et al., 2011). In a recent study, Modisett, Koyfman and Runyon (2014) came to the conclusion that the sensitivity of head CT scan in SAH diagnosis is more greater early in clinical setting and the haemorrhage degrades rapidly the further away from its onset. They further found factors that can affect diagnostic accuracy which include the patient’s haematocrit, the time from the onset of symptoms to acquisition of the CT scan image, the technical specification of the scanner and the skill of the person interpreting the scan. The former two factors were not considered in the current study.

Intracranial haemorrhages are typically divided into five distinct stages on the basis of blood breakdown products: hyperacute (<12 h); acute (12 h to 2 days); early subacute (2–7 days); late subacute (8 days to 1 month); and chronic (>1 month to years) (Kidwell and Wintermark, 2008). The major diagnostic challenge with subacute SAH which may be encountered is the isodensity of the SAH to CSF on CT scan (Hijaz et al., 2011). Moreover, SAH may not be visualised in autopsy especially in patient who died after some weeks post head trauma. Jones Jr et al. (2012) reported that approximately 50% of SAHs could still be seen 1 week after the ictus, and only one third after 2 weeks. This will be because the erythrocytes which were in the subarachnoid space, are progressively washed off (Kidwell & Wintermark, 2008). A forensic pathologist should bear this in mind before label this as a diagnostic error.

Traumatic head injury may results in cerebral oedema (Ryu et al., 2013). According to Kim and Eom (2016, p. 1), brain oedema may compress the dural sinuses and compromise venous drainage from the brain to result in "engorgement of the superficial veins, which stand out against the oedematous slow-attenuated brain parenchyma, mimicking an SAH". This has been referred as a pseudosubarachnoid sign which can be seen in the basal cistern.

Subdural Haematoma

Subdural haematoma is a collection of blood or blood products between the arachnoidal (superficial) layer of the brain and the dura or meningeal layer of the brain (Ferri, 2016). This can occur after head trauma, coagulopathy, antithrombotic therapy or spontaneously (Kidwell & Wintermark, 2008). There is usually an associated scalp haematoma or bone fracture in cases caused by trauma.

A basic knowledge of the appearance of subdural haemorrhage on CT scan is crucial to appreciate why certain lesions may be misdiagnosed or missed. Its appearance depend on the stage and location. In acute stage, subacute stage and chronic stage, the subdural haematoma typically appear hyerdense, isodense and hypodense, respectively (Hijaz et al., 2011; Kidwell & Wintermark, 2008). They further emphasized that it can be difficult to recognise a subdural haematoma on CT in subacute stage because they become isodense to grey matter.

A mass with a high and low attenuation coefficient may resemble an acute blood clot and a liquefied clot, respectively (Catana et al., 2016). In their systematic review, they identified the common mimickers such as: lymphoma (29%), followed by metastasis (21%), sarcoma (15%), infectious disease (8%) and autoimmune disorder (8%) (Catana et al., 2016). These mimickers can be visualised in someone who has been scanned after sustaining head injury and may be mistakenly misinterpreted as SDH.

An acute subdural haematoma on CT scan assume a crescent shape lesion along the cortical convexity, a linear shaped lesion between the hemispheres or a thin-layered shaped lesion along the tentorium cerebelli (Catana et al., 2016; Su et al., 2010; Kidwell & Wintermark, 2008). Not all cases of acute SDH will show the classic crescent shape. Su et al. (2010) found that approximately 8-14% of atypical SDH have biconvex margins, which will appear like typical EDH. This has been referred as lentiform subdural haematoma and its cause remains unclear but may result from blockage of the subdural space by adhesions (Prasad & Menon, 2017). Misinterpretation is thus possible if diagnosis is based merely on the shape and extent of the haematoma shown on the CT scans (Su et al., 2010). Therefore, if one does not have adequate knowledge may end-up attributing certain findings to the wrong cause.

Epidural haematoma

Epidural haematoma is the accumulation of blood in the potential space surrounding the brain, between the dura mater and the inner surface of the skull (Ferri, 2016). This usually occur after acute head trauma (Kidwell & Wintermark, 2008). Hijaz et al. (2011) said that these haemorrhages often have a lentiform, biconvex appearance. Although lentiform appearance is a typical finding of epidural haematoma, Gu, Lee and Park (2016) reported a case whereby CT scan revealed lentiform haematoma and only to find out during surgery that it did not represent epidural haematoma but rather the subdural haematoma. It has also been documented in the literature that delayed EDH may be missed during initial CT scan and the same apply with delayed SDH (Hijaz et al., 2011).

2.3.5. Location of misidentified/missed intracranial haemorrhage

Typical locations for SAH after head trauma are the interpeduncular cistern, Sylvian fissure or over the cerebral convexity; while SDH can be seen along cerebral convexities, the falx cerebelli and tentorium cerebelli (Kidwell & Wintermark, 2008). Strub et al. (2007) reported in their study whereby it was aimed at determining the patterns of error in the detection of ICH on the head CT scan examined, and it was found that the most common type of ICH that were missed were subdural and subarachnoid haemorrhage. Subdural haemorrhage was commonly missed in either parafalcine or frontal regions while subarachnoid haemorrhage was in the interpeduncular cistern (Strub et al., 2007). There was no precise clarification for why they were missed in those locations. It is also worth mentioning that the neuroradiologist was used as quality control, however, this was a times an unsatisfactory reference.

Nevertheless, Strub et al. (2007) tried to come with an explanation why subdural haematoma was most commonly missed in the midline along the tentorium, while a diffused pattern of the subarachnoid haemorrhage was commonly misidentified. It was explained that the normal attenuated appearance of the falx and tentorium make it harder to distinguish haemorrhage in these areas. Furthermore, a diffused pattern of the subarachnoid haemorrhage was commonly misidentified, likely because it was symmetric and more challenging to perceive than an asymmetric pattern.

2.3.6. Unexplained factors

In some cases, the reasons for the discrepancies remain unexplained. This was confirmed by Smith et al. (2012) that a true discrepancy (which was 12%) concerning detection of intracranial surface haemorrhages can occur between the radiologist and pathologist.

The unexplained factors may be due to the fact that autopsy is not a definitive gold standard of postmortem examination process. Rutty et al. (2017) recommended that the gold standard of postmortem investigations should include both imaging techniques and invasive autopsy. Once an autopsy has been performed, it may be difficult to audit its procedure adequacy than the postmortem report (Robert et al., 2012). The difficulty in auditing might be caused by failure to retain photographic records of the macroscopic pathologies. This implies that failure to retrieve the photographic records, the unknowns will remain unexplained. Hence, the reasons for the discrepancies remains unexplained in certain cases.

2.4. CONCLUSION

This chapter examined and scrutinised the literature. The next chapter deals with the research methodology.

CHAPTER 3

RESEARCH METHODOLOGY

3.1. INTRODUCTION

Methodology is the rationale and the philosophical assumptions underlying a particular study rather than a collection of methods, though the methodology leads to and informs the methods (Wisker, 2008). The purpose of this study was to investigate the rate and pattern of discrepancies between antemortem CT scan and autopsy findings in deceased patients with traumatic intracranial haemorrhages as well as to examine factors that may result in those discrepancies. Since the task of the methodology is to explain and justify the particular methods, the research method described below were designed to answer these problems (Clough & Nutbrown, 2012).

This chapter is divided into several sections addressing the research design, study area and population, sampling, sample size and sampling technique, data collection process and study tool (instrument), reliability and validity, data analysis and ethical considerations.

3.2. CHOICE AND RATIONALE OF RESEARCH DESIGN

The choice of the study design is determined largely by the research question being posed and a researcher has to follow a particular structure to answer that particular question (Joubert & Ehrlich, 2007). This has also been referred as the ‘architecture’ of the study.

A retrospective quantitative descriptive research was employed for this study. The quantitative study “tries to measure variables in some numerical way” with the intention of validating or establishing relationships (Leedy & Ormrod, 2014, p. 97). The study gave numerical values by assessing agreement between antemortem CT scan and autopsy findings and determining discrepancy pattern of traumatic intracranial haemorrhage (TIH). In return, this gave us the rate of discrepancy between them.

The retrospective outlook was utilized using the records presented with traumatic intracranial haemorrhage at Pietersburg Hospital Forensic Pathology Department unit from 01 January 2014 to 31 December 2016.

3.3. STUDY AREA

The study was conducted at Polokwane Department of Forensic Medicine. Department of Forensic Medicine is situated in Pietersburg Hospital, which is situated in Limpopo Province, in the Northern part of South Africa. This hospital is the main referral in the province and performs autopsies of individuals who die from unnatural causes including traumatic intracranial haemorrhage cases.

3.4. STUDY POPULATION

Study population refers to the entire group of people or an object that is of interest to the researcher, or, in other words, that meets the criteria the researcher is interested in studying (Brink, Van der Walt & Van Rensburg, 2006). The researcher considered all autopsy case reports of bodies presented at Forensic Medicine Department from 01 January 2014 to 31 December 2016, which were diagnosed with traumatic head injuries based on CT scan findings. Cases comprised of admitted patients referred from peripheral hospitals in Limpopo Province and direct admission at Pietersburg hospital.

Inclusion criteria:

- Traumatic head injury cases in which antemortem CT scan was done and later subjected to autopsy. No surgical intervention was performed in this cases.

Exclusion criteria:

- Files with missing CT scan reports.
- Files of patients who died of head injury but the CT scan not performed.
- Files of cases were surgical interventions were done.

3.5. ETHICAL CONSIDERATIONS

The word ‘Ethics’ has been defined variously as “system of moral values” … or “the rules or standards governing the conduct of a person or the members of a profession” (Joubert & Ehrlich, 2007, p. 30). Below are ethical considerations to which the researcher paid attention to:

Permissions to conduct study

Permission was obtained from the Limpopo Provincial Department of Health while ethical clearance was secured from Turfloop Research and Ethics Committee and Pietersburg Research Ethics Committee to conduct the study before the commencement of research (Appendix 2 to 5)
Permission was also sourced from the hospital management to use the medical records and postmortem reports.

Right to privacy/confidentiality

Any research study involving human beings must respect participants’ right of privacy (Leedy, 2014). The researcher maintained personal identity privacy of the deceased during and after the study therefore protecting right to dignity of the deceased and the family ensuring anonymity. The data was coded with numbers. The collected information was stored in a locked cabinet and computer; and the computer was protected with password to ensure privacy and confidentiality (security of collected information). The information could only be accessed by the researcher and supervisor.

3.6. SAMPLING, SAMPLE SIZE AND SAMPLING TECHNIQUE

Sampling refers to the process of selecting the sample from a population whereas sample refers to a fraction of a whole, or a subset of a larger set, selected by the researcher to participate in a research project (Brink et al., 2006; Cormark, 2000). In this study, a consecutive sample of bodies diagnosed with traumatic head injuries based on CT scan findings during the period of the study was selected. This offered an opportunity that all traumatic intracranial haemorrhage (EDH, SDH, and SAH) cases meeting the inclusion criteria be used for this specific purpose. These consecutive cases had to be included in a sample until a calculated minimum sample size has been studied (Joubert & Ehrlich, 2007).

A minimum sample size of 86 CT scanned and autopsy cases was calculated based on the 95% confidence level, 5% sampling error, 80% power to detect a difference of 15% with a CT scan detection rate (subdural haemorrhage) of 42% (Bhat et al., 2011). The 15% difference has been chosen as the cut-off value for the difference between autopsy detection rate and CT detection rate with the extrapolation of p1 at 57%. Any value below this cut-off level would fail to detect the significant difference while the converse would be true. The sample size was calculated using the formula below:

$$n = \frac{\left[Z_{\frac{\alpha}{2}} \sqrt{p_0(1-p_0)} + Z_{\beta} \sqrt{p_1(1-p_1)} \right]^2}{(p_1 - p_0)^2}$$

Where

$Z_{\frac{\alpha}{2}}$ is the 95% confidence level (1.96)

Z_{β} is the 80% power (0.84)

p_0 is the CT scan detection rate (0.42)

p_1 is the autopsy detection rate (0.57)

A total of 85 traumatic head injury cases were obtained (one less than the minimum calculated sample size) which met the inclusion criteria and used for the purpose of this research.

3.7. DATA COLLECTION PROCESS AND STUDY TOOL

A ‘Computed Tomography scan and autopsy data tool form’ has been devised to collect data (Appendix 1). This was devised and revised to ensure reliability. Seaman (1987) and Joubert and Ehrlich (2007) have said a stable instrument remains consistent on repeated applications. Data details of all bodies presented at the Department of Forensic Medicine with traumatic head injury underwent CT scan and autopsy examination included: Age, gender, race, manner of injury (traffic accident, fall, assaults, and unspecified), length of admission, type of intracranial haemorrhage (EDH, SDH and SAH). Patient and practitioner factors, level of practitioner’s experience (e.g. medical officer, registrar or specialist) and number of years in Radiology and Forensic Pathology were also included in the data collection form. Practitioner’s information was acquired from the respective disciplines mentioned above. Personal identity and death register number were recorded on a separate sheet, not on the data collection form to ensure anonymity.

Reliability refers to the degree of similarity of the results obtained when the measurement is repeated on the same subject or the same group (Joubert & Ehrlich, 2007). To achieve this, data collection tool was piloted before the actual data collection. This pilot-study was conducted by selecting 20 cases outside the year range of the study with consideration put on answering the aim and objectives of the study. The inter-rater reliability of the data collection tool was established by giving the tool to experts in Forensic Pathology and that in Radiology as well as to the statistician for review before the actual data collection. Observations from the pilot and comments received were used to change the tools accordingly.

Validity refers to the extent to which a measurement actually measures what it is meant to measure (Joubert & Ehrlich, 2007). The CT scans have been performed from the same manufacture/generation using 640 slice multi-slice 3D Scanner Toshiba Aquilion one T5X-301A from 2014 to 2016. The use of the same version during the study period controlled bias. Parameters used during scanning detector collimation – 0.4 to 0.6 mm slice thickness with one (1) second reconstruction time. Maintenance of CT scan machine was adhered to and calibrated 6 monthly. The radiographers pass a quality assurance test by warming the scan up to a minimum of 20% tube (OLP) before it can be used.

Postmortem examinations were conducted according to the standards of the National code in South Africa. Brain sections were cut into 5 mm slices during autopsy. Thereafter all registrars who performed an autopsy consulted with the specialist (pathologist) immediately after postmortem as per Pietersburg Forensic pathology department standard operating procedure. Autopsy reports were reported by different practitioners with different levels of experience.

"No type of project is done in a vacuum, not even a pure work of art" (Walliman, 2011, p. 177). Hence, secondary data was used. In our study, CT scan reports were collected from Records and Radiology Department at Pietersburg hospital while autopsy reports were retrieved from the Department of Forensic Pathology records by the principal researcher. A total of 203 cases with head injury being the cause of death were requested for the purpose of the project. Eighty-five (85) cases which met the inclusion criteria were obtained and included in the study. The remainders of either missing files, incomplete files without CT scan reports, surgical intervention performed or CT scan not performed were excluded from the study.

The CT scan reports and autopsy reports were retrieved and being compared to each other. Autopsy reports served as a gold standard because most studies demonstrated that it remains superior to CT scan (all be it PMCT) for the detection of brain injuries (Jalazadeh et al., 2015; Leth et al., 2013; Panda et al., 2015).

The following traumatic intracranial haemorrhages were assessed from these reports: epidural, subdural and subarachnoid haemorrhages.

3.8. DATA ANALYSIS

Data was captured and analysed using excel and SPSS statistical software 23 running under Microsoft windows. Details were summarised descriptively by frequency tables, pie charts and bar charts. Cross-tabulations were used to establish the percentage agreement between CT scan findings and autopsy reports. Measures of agreement were assessed using Cohen's kappa statistics.

To obtain percentage agreement, findings of individual cases on the study were tabulated, comparing their similarities. If CT scan findings were similar to autopsy findings, that individual case was recorded as 1 (in agreement). If CT scan findings varied from autopsy findings, the case was recorded as 0 (in disagreement). After all cases were recorded into the matrix cells, the total number of cases which were recorded as 1 under the agreement column were divided by total number of cases in the research project. This gave the percentage agreement of the study.

"The kappa coefficient is a popular descriptive statistic for summarizing an agreement table" (Warrens, 2011, p. 473). Landis and Kohn (1977) categorised the standard for the strength of agreement for the kappa coefficient into six groups: ≤0=poor, 0.01–0.20=slight, 0.21–0.40=fair, 0.41–0.60=moderate, 0.61–0.80=substantial and 0.81–1=almost perfect.

3.9. CONCLUSION

This chapter deliberated on the rationale for this study research methodology as well as how data were collected, captured and analysed. The following chapter will cover the interpretation of the results and thereafter discuss the findings.

CHAPTER 4

DATA ANALYSIS AND DISCUSSION OF FINDINGS

4.1. INTRODUCTION

In this chapter, the results are presented and interpreted. The study investigated the discrepancy rate and associated factors for the discrepancies between the antemortem CT findings and autopsy findings. The discussion will answer the research questions by looking at the objectives of this study.

4.2. DATA ANALYSIS AND FINDINGS

4.2.1. Demographic characteristics of the deceased

A total of 85 intracranial haemorrhage autopsies were performed at Pietersburg Hospital Forensic Pathology during the study period.

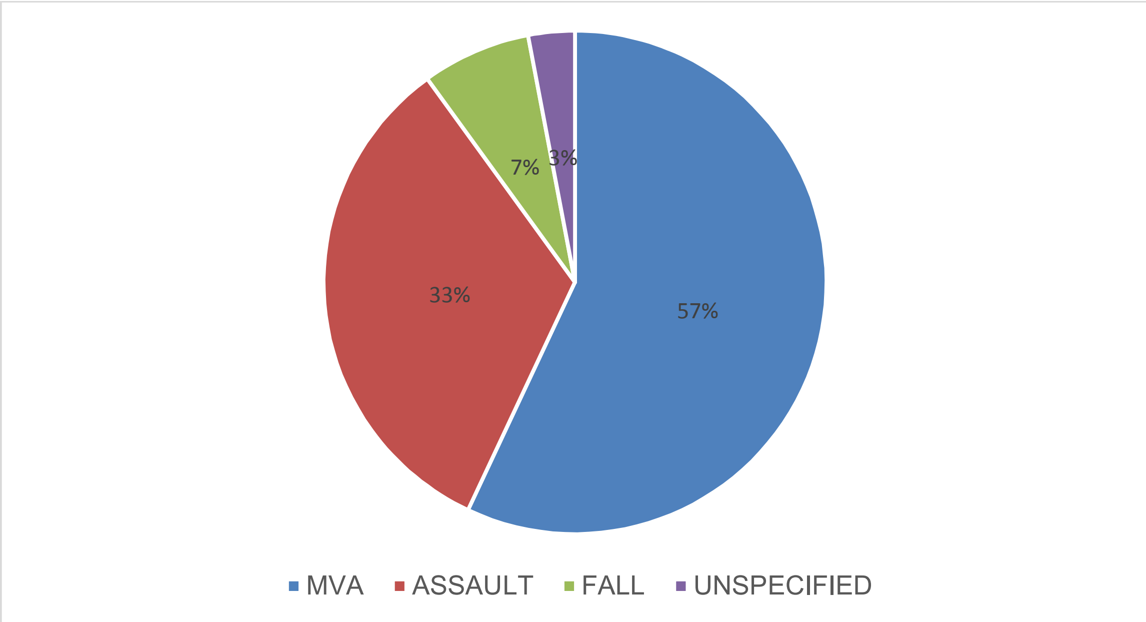
The majority (89%) were males and slightly more than half (52%) were in the age group 20-39 years. The mean age of the deceased was 35.5 years with a standard deviation of 18.3 (Table 4.1).

Table 4.1: Age and Gender of the deceased, n=85

	No	%
Age (years)		
<15	5	6
15-19	7	8
20-29	24	28
30-39	20	24
40-49	10	12
50-59	8	9
>=60	11	13
Gender		
Male	76	89
Female	9	11

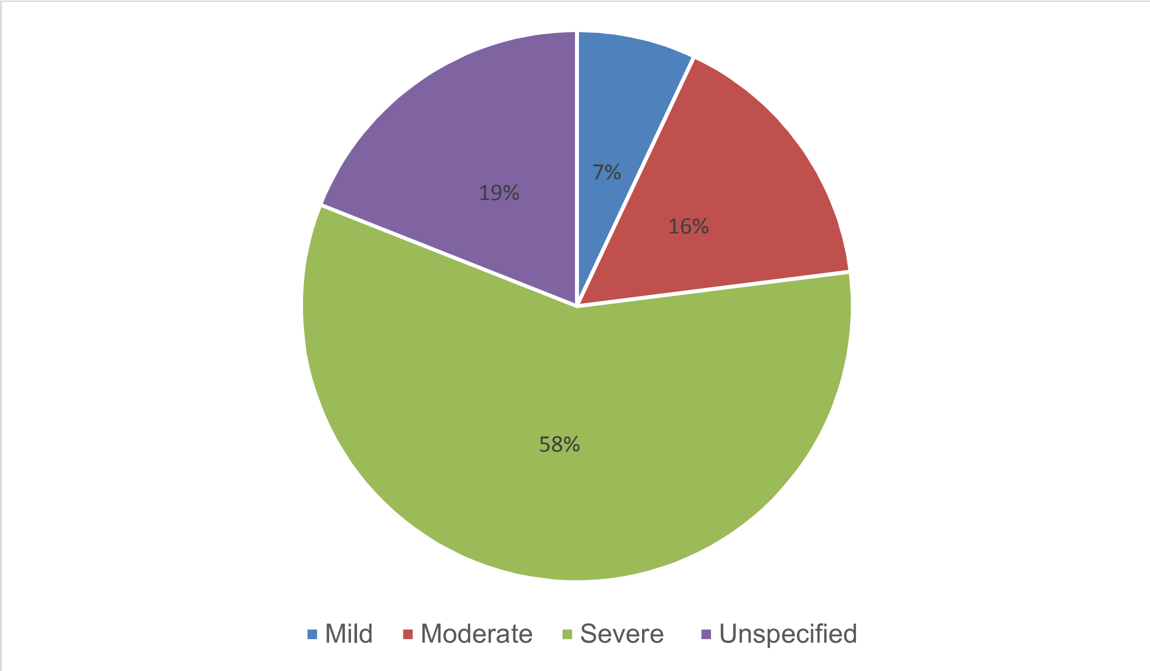
Source: Author

Figure 4.1, 4.2 and 4.3 present manner of injury, severity of head injury and length of hospital stay distributions, respectively. The most common manner of injuries were motor vehicle accidents (57%) and assault (33%). There were few (3%) cases with unspecified manner of injury. Most (48%) of the deceased spent a week on average before death and majority (58%) had severe traumatic head injury.



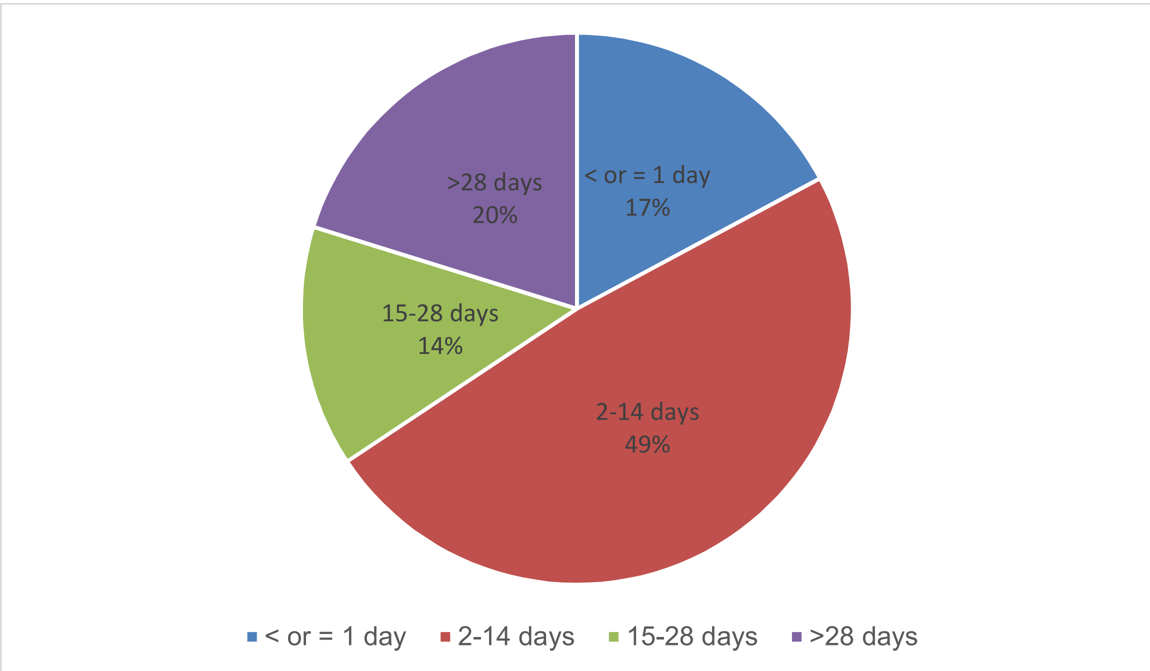
Source: Author

Figure 4.1 Distribution of manner of injury



Source: Author

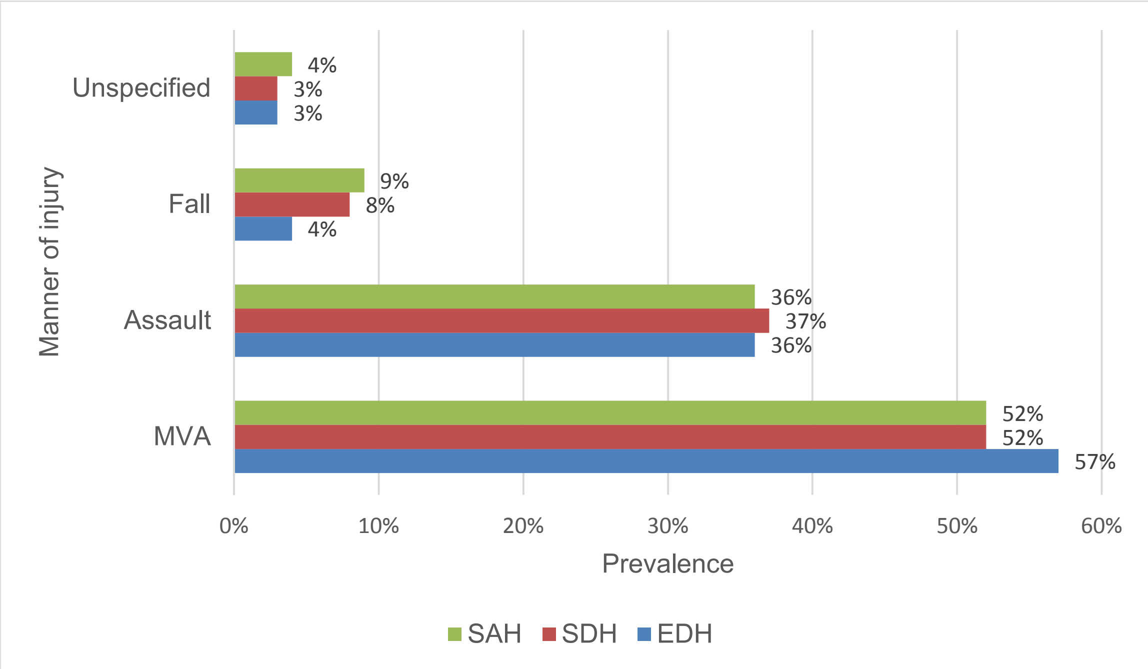
Figure 4.2 Distribution of severity of head injury



Source: Author

Figure 4.3 Distribution of length of hospital stay

It can be seen in the below figure that most people who died due to MVA showed high prevalence of EDH (57%), SDH (52%) and SAH (52%). The prevalence of traumatic intracranial haemorrhages among individuals died due to assault was second to those died from MVA. Most deaths from falling showed to have high prevalence of SAH (Figure 4.4).



Source: Author. TIH = traumatic intracranial haemorrhage, MVA = motor vehicle accident

Figure 4.4 Prevalence of TIH according to manner of injury

From the below figure, it can be seen in our data set that most cases involved in MVA (53%) and assault (43%) spend two days to two weeks in the hospital. Half of the cases due to fall, spend a day or less in the hospital, while of the 3% of unspecified cases (refer to figure 4.1) spend two days to four weeks (two week on average) before death (Figure 4.5).

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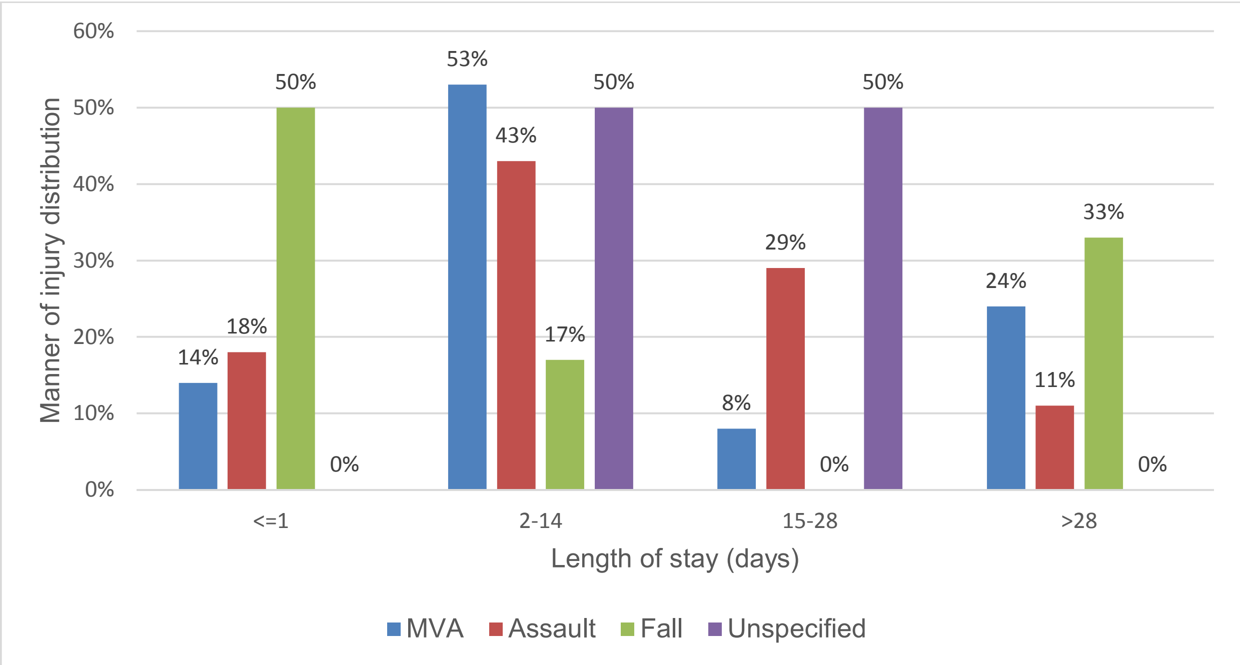


Source: Author. MVA = motor vehicle accident.

Figure 4.5 Manner of injury and length of admission (in days)

4.2.2 CT scan and autopsy findings in detection and diagnosis of TIH

Measures of agreement were assessed using Cohen's kappa statistics. The CT-scan and autopsy identified the same category (in agreement) in 75.26% (64/85) cases with a Kappa coefficient of 0.3834 (Table 4.2). The remaining 24.74% represents the overall discrepancy rate between antemortem CT scan and autopsy findings in diagnosis of traumatic intracranial haemorrhages (EDH, SDH and SAH).

Table 4.2: Overall agreement between CT scan and autopsy findings

		Autopsy findings	
		Present	Absent
Antemortem CT scan findings	Present	51	12
	Absent	9	13

Source: Author. Kappa = 0.3834, Agreement = 75.29%, p<0.001

The CT scan and autopsy identified the same category in 90.59% (77/85) cases with a Kappa coefficient of 0.5823 (Table 4.3) and a discrepancy rate of 9.41% for EDH.

Table 4.3: Agreement between CT scan and autopsy findings in diagnosis of EDH

		Autopsy findings	
		Present	Absent
Antemortem CT scan findings	Present	7	4
	Absent	4	70

Source: Author. Kappa = 0.5823, Agreement = 90.59%, p<0.001

With regard to SDH, agreement was recorded in 74.12% (63/85) with Kappa coefficient of 0.4857 (Table 4.4) and a discrepancy rate of 25.88%.

Table 4.4: Agreement between CT scan and autopsy findings in diagnosis of SDH

		Autopsy findings		
		Present	Absent	Misinterpreted
Antemortem CT scan findings	Present	26	6	1
	Absent	15	37	0

Source: Author. Kappa = 0.4857, Agreement = 74.12%, p<0.001

The CT scan and autopsy identified the same category in 65.88% (56/85) cases with a Kappa coefficient of 0.32.19 (Table 4.5) and a discrepancy rate of 34.12% for SAH.

Table 4.5: Agreement between CT scan and autopsy findings in diagnosis of SAH

		Autopsy findings	
		Present	Absent
Antemortem CT scan findings	Present	31	19
	Absent	10	25

Source: Author. Kappa = 0.3219 Agreement = 65.88%, p=0.012

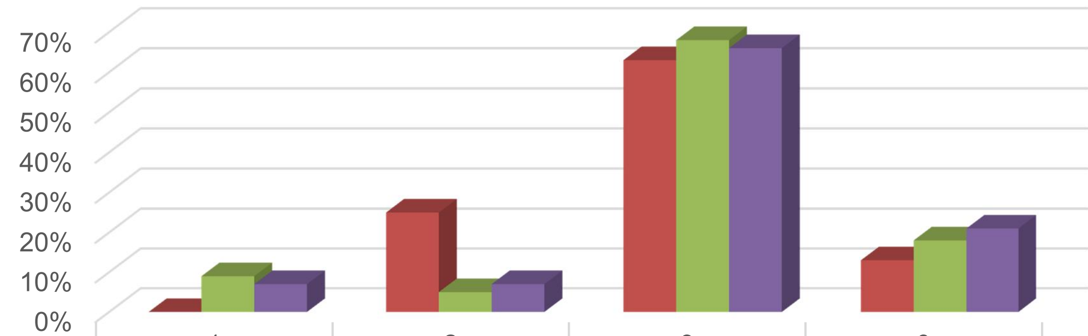
The table below showed the misclassification of the overall type of intracranial haemorrhages (Table 4.6). SAH has been found to have higher discrepancies or lower agreements between the radiologists and pathologist. Of the 11 deaths ascribed to SAH on the autopsy finding, CT scan agreed in only 7 cases, 4 cases were re-classified to other causes. In 23 deaths certified as due to SDH/SAH on the autopsy finding, 11 were classified as such by CT scan, the remaining twelve (12) were assigned to other causes.

Table 4.6: Discrepancies Observed between CT scan and Autopsy findings

		Autopsy finding							
		EDH	**EDH/SAH**	**EDH/SDH**	**EDH/SDH/SAH**	**SAH**	**SDH**	**SDH/SAH**	**Absent**
Radiology finding	**EDH**	2							
	EDH/SAH	1	1						2
	EDH/SDH	1	1		1				
	EDH/SDH/SAH		1		1				
	SAH		2			7	3	5	7
	SDH						3	3	2
	SDH/SAH			1		3	4	11	1
	Absent	1				1	3	4	13
	Total	4	5	1	2	11	13	23	25

Source: Author

Figure 4.6 demonstrates discrepant traumatic intracranial haemorrhage cases and their association to level of consciousness. The analysis revealed that most discrepancies were seen in patients with severe traumatic head injury.



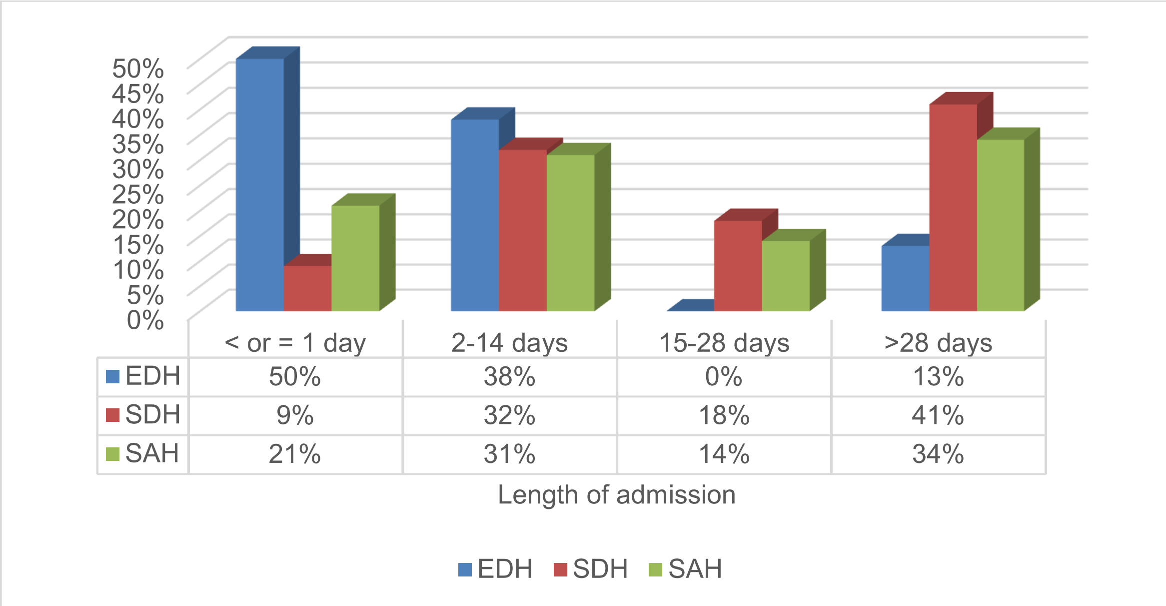
	1	2	3	0
EDH	0%	25%	63%	13%
SDH	9%	5%	68%	18%
SAH	7%	7%	66%	21%

Level of consciousness

Source: Author. LOC= Level of consciousness; TIH= traumatic intracranial haemorrhage. 1= mild, 2 = moderate, 3 = severe, 0 = unspecified

Figure 4.6 Discrepancy correlation between LOC and TIH

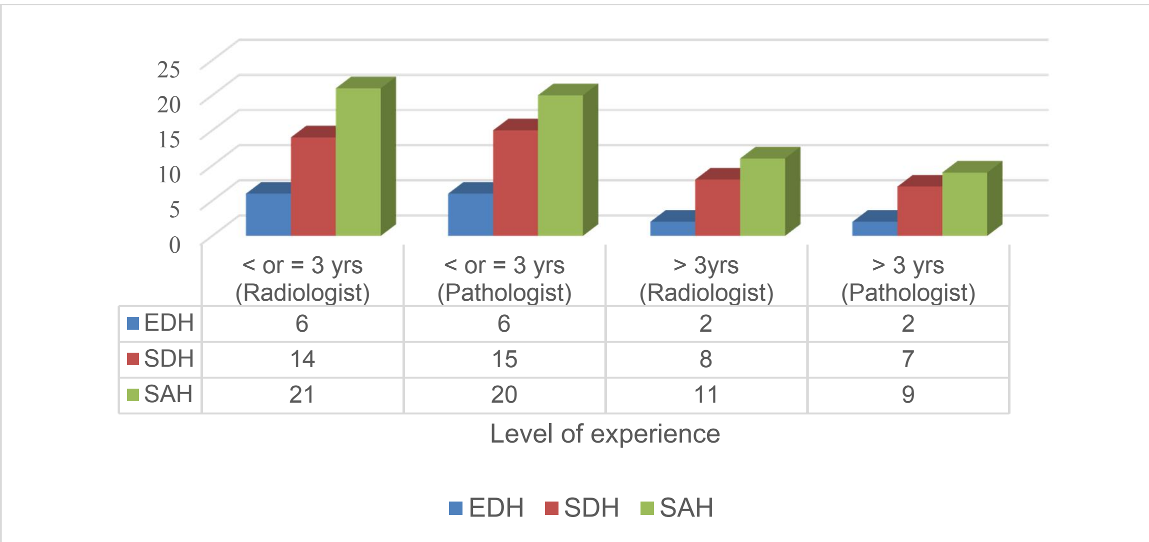
Figure below demonstrates the relationship between length of hospital stay and TIH in cases which showed discrepancies between radiology findings and autopsy findings (Figure 4.7). Half of the discrepant cases for EDH were found to been admitted on average a day or less. On the other hand, most discrepancies for SAH were seen in patients who were admitted for 3 weeks on average; and for SDH, majority of them stayed in the hospital for more than a month.



Source: Author. TIH = traumatic intracranial haemorrhage

Figure 4.7 Discrepancy correlation between length of admission and TIH

Figure 4.8 shows that most discrepancy is seen on doctors with less than three years of working experience.



Source: Author. TIH = traumatic intracranial haemorrhage

Figure 4.8 Discrepancy correlation between level of experience (in years) and TIH

Most discrepancies were seen on registrars in both departments, followed by medical officer (Table 4.7). Registrars, in Radiology tend to miss or misinterpret more of SDH (82%), while in Forensic is more of SAH (76%).

Table 4.7: Discrepancy correlation between doctor ranks and TIH

		Radiologist	Forensic Pathologist
EDH	**Medical officer**	2 (25%)	0 (0%)
	Registrar	6 (75%)	6 (75%)
	Specialist	0 (0%)	2 (25%)
	Unspecified	0 (0%)	0 (0%)
SDH	**Medical officer**	4 (18%)	3 (14%)
	Registrar	18 (82%)	15 (64%)
	Specialist	0 (0%)	4 (18%)
	Unspecified	0 (0%)	0 (0%)
SAH	**Medical officer**	9 (31%)	0 (0%)
	Registrar	17 (59%)	22 (76%)
	Specialist	0 (0%)	7 (24%)
	Unspecified	3 (10%)	0 (0%)

Source: Author. TIH= traumatic intracranial haemorrhage

Table below shows a high agreement (96.47%) for epidural haemorrhage with a Kappa coefficient of 0.64 as per site of haemorrhage on the frontal lobe. On the other hand, its agreement in the occipital, cerebellum, parafalcine and interpeduncular fossa had a kappa coefficient of zero (k=0) (Table 4.10). This implies that this might have occurred by chance. Most discrepancies were seen on the parietal and occipital lobes for all TIH, with no scientific explanation.

Table 4.8: Agreement per site of haemorrhage

	Site	Agreement	Kappa	p-values
Epidural haemorrhage	Frontal lobe	96.47	0.6516	<0.0001
	Parietal lobe	89.41	0.2558	0.0055
	Temporal lobe	91.76	0.3262	0.0004
	Occipital lobe	97.65	0.0000	<0.0001
	Parafalcine	98.61	0.0000	-
	Interpeduncular fossa	98.61	0.0000	-
	Cerebellum	98.61	0.0000	-
Subdural haemorrhage	Frontal lobe	65.28	0.3253	<0.0001
	Parietal lobe	61.97	0.3146	<0.0001
	Temporal lobe	69.44	0.3729	<0.0001
	Occipital lobe	63.89	0.3135	<0.0001
	Parafalcine	77.78	0.2596	<0.0001
	Interpeduncular fossa	84.72	0.2296	<0.0001
	Cerebellum	84.51	0.2305	<0.0001
Subarachnoid haemorrhage	Frontal lobe	62.50	0.2795	0.0007
	Parietal lobe	55.56	0.2237	0.0048
	Temporal lobe	66.20	0.3310	<0.0001
	Occipital lobe	54.17	0.1902	0.0144
	Parafalcine	62.50	0.2800	0.0003
	Interpeduncular fossa	73.61	0.2525	0.0057
	Cerebellum	69.44	0.2000	0.0191

Source: Author

4.2.3. Demographic characteristics of the medical practitioners

From Table 4.9 and 4.10 it can be seen that most medical officers have less than 3 years' experience in both groups, radiology and forensic departments. Most cases were performed by registrars in both departments. Comparing registrars' experience, it can be seen that registrars in radiology department have more experience compared to those ones in forensic department. The data shows that there was no case reported by the radiology specialist from the selected cases. Few cases (7%) were not assigned to any practitioner in radiology due to unrecognized signatures on their reports.

Table 4.9: Medical doctor ranks and years of experience distribution

	Radiologist n(%)	Forensic Pathologist n(%)	p-value
Rank			
Medical officer	19(24)	5(7)	<0.001
Registrar	59(69)	61(72)	0.561
Specialist	-	19(21)	<0.001
Unspecified	7(7)	0(0)	<0.001
Years of experience			
1	9(10)	28(33)	<0.001
2	21(25)	23(27)	0.861
3	23(27)	11(13)	0.034
≥4	32(38)	23(27)	0.189

Source: Author.

Table 4.10: Level of experience comparison amongst practitioners

	Radiologist		Forensic Pathologist	
Rank	**≤3 years**	**>3 years**	**≤3 years**	**>3 years**
MO	19 (100%)	0 (0%)	5 (100%)	0 (0%)
Registrar	34 (58%)	25 (42%)	57 (93%)	4 (7%)
Specialist	0 (0%)	0 (0%)	1 (5%)	18 (95%)
Unspecified	0 (0%)	7 (100%)	0 (0%)	0 (0%)

Source: Author. MO = Medical Officer

4.3. DISCUSSION OF RESEARCH FINDINGS

A search of literature on the subject yielded few results for comparing antemortem CT scan and autopsy findings, on the other hand, more literature was found comparing postmortem CT scan findings and autopsy findings. The later results can still be used to certain extend to compare the antemortem CT scan findings to autopsy findings as there is “virtually no difference in imaging the intracranial haemorrhage between the living and the dead” (Christe et al., 2010, p. 216).

4.3.1. Rate of discrepancies between the antemortem CT scan and autopsy findings in detection and diagnosis of TIH

Surgically treatable intracranial haemorrhage (be it traumatic or non-traumatic), like subdural haemorrhage and epidural haemorrhage need to be correctly diagnosed without any delay due to catastrophic consequences (Molina et al., 2007). The modality of choice which is often used in the diagnosis of above-mentioned haemorrhages is CT scan (Coley, 2013). Jalalzadeh et al. (2015) looked at eight studies investigating ICH and found that postmortem CT scan tends to miss more of smaller haemorrhages which were considered clinically less significance. The present study, albeit involving antemortem CT scan, contributes to show that the discrepancies exist between the antemortem CT scan and autopsy findings for traumatic intracranial haemorrhages.

The current study has found that the overall significant discrepancy rate to be 24.74% and ranges from 9.41% to 34.12% for individual traumatic intracranial haemorrhages. This is consistent with what has been reported by number of previous studies (Jacobesen & Lynnerup, 2010; Leth et al., 2012; Liisanantt & Ala-kokko, 2015). They collectively revealed discrepancy rate ranging from 9% to 39%. This implies that some TIH can be missed or misinterpreted during CT scan interpretation or during autopsy examination. Higher sample sizes are still needed to determine the discrepancy rate.

4.3.2. The overall agreement and associated factors between antemortem CT scan and autopsy findings in diagnosis and detection of TIH

Based on the above strength of agreement categories, the current study showed a fair overall kappa agreement (k = 0.3834) between the antemortem CT scan findings and autopsy findings, with 75.29% of percentage agreement. This is similar to previous studies in percentage agreement (Jacobsen & Lynnerup, 2010; Liisanantti & Ala-Kokko, 2015) though vary in terms of kappa agreement. This low kappa with a higher percentage agreement could be due to multiple combinations of different variables (Warren, 2010). The study revealed two major factors which may be responsible for the overall discrepancies (24.74%), viz patient factor and level of experience factor (discussed below).

Patient factor

The Glasgow Coma Scale is used as a primary method of assessing level of consciousness after TBI. A score less than 15 is an indicator of neurologic deficit (Yue et al., 2017). In the current study, cases with severe TBI (low level of consciousness) had high discrepancies for TIH (SAH, SDH and EDH). Previous study by Lisanantt and Ala-kokko (2015) showed similar findings whereby they concluded that dealing with critically ill patient (with neurologic disorders) might result in some missed diagnoses.

Level of Experience factor

The current study showed that most discrepancies were seen in practitioners with less experience. Though most studies support that experience appears to decrease the discrepancies (Bruni et al., 2012; Mellnick et al., 2016; Wechelsler, 1996), they also agree that there are multifactorial and complex factors which can results in those discrepancies. The main reason for the discrepancies in lower postgraduate trainees has been identified as lack of knowledge (Brady et al., 2012; Filograna et al., 2010).

In both Radiology and Forensic Medicine departments, most of the discrepancies were seen in registrars followed by medical officers. This could be explained in part to be due to the fact that most of the work was performed by registrars (approximately 2/3 of the work in each department). Similar findings were reported by Lee et al. (2013) that discrepancies tend to be higher among registrars, owing to “physical discomfort, eye strain and lack of motivation” which intensify by the end of workday. Moreover, registrars and medical officers do overtime, in which they have to work overnight. This may result in difficulty in focusing and hence reduced diagnostic or detection accuracy seen in them (Krupinski et al., 2010; Waite et al., 2017).

4.3.3. Discrepancy pattern of TIH with low agreement and associated factors (subarachnoid haemorrhage)

Amongst the types of TIH in the current study, SAH was found to have the lowest agreement (65.88%). There are varying findings with regard to percentage agreement for SAH (Graziani et al., 2018; Panzer et al., 2017; Sharma & Murari, 2006). In majority of previous studies, SAH has had the lowest agreement.

The current study highlighted reasons for the low agreement or high discrepancy. Firstly, the presence of too many combinations i.e. SAH/SDH; SAH/EDH and SAH/SDH/EDH while on the other hand some SAH diagnosis were missed or misdiagnosed. Seven reports for missed or misdiagnosed SAH were reviewed.

One case whereby SAH was diagnosed in radiology department, it was revised by the author and found to be intense cerebral vascular congestion. This is similar to what was found by Kim and Eom (2016). Other revised cases (5) which were radiologically diagnosed as SAH, they were reported by the pathologists as brain contusions. One case of diffused SAH was interpreted as normal by CT scan. It is certainly more challenging to make a diagnosis of diffused SAH by CT scan as the pathological lesion is symmetrical (Strub et al., 2007)

Secondly, the current study showed that most people with subarachnoid haemorrhage stayed in the hospital for approximately 3 weeks on average. It can only be postulated that this could form part of the major reason why SAH had the lowest agreement i.e. high discrepancy between radiologists and pathologist in this type of haemorrhage, though the study did not determine the time interval between the CT scan and death. According to Jones Jr (2012) and Kidwell and Wintermark (2008), a progressive clearance of red blood cells in the cerebrospinal fluid results in approximately 50% of SAH are not visualized after 1 week of ictus, which is even worse (30%) after two weeks (Adams et al., 2013). This process can be shorter or longer (Daroff et al., 2016). This implies that the majority of the previously diagnosed SAH under CT scan, may after approximately three weeks not be seen in autopsy if patient demises. This is dependent on the amount of SAH in the leptomemeninges. This was clearly evident from the current study whereby autopsy was superseded by CT scan in diagnosis of SAH. This is consistent with previous studies (Deshmukh & Yafai, 2008; Kidwell & Wintermark, 2008; Panzer et al., 2017).

Lastly, the level of experience played a role in low agreement for SAH diagnosis. Most of the discrepant SAH diagnosis was observed in registrars with less than three years of working experience in both groups, radiology and forensic departments. It was assumed that this was going to be inevitable since most of the cases were reported by the registrars (radiology – 69 % and forensic – 72%). Arguments put in the aforementioned subheading with regard to level of experience still apply to low agreement for SAH diagnosis. There was no relationship established between the level of consciousness and low agreement for SAH diagnosis.

4.3.4. The agreement between antemortem CT scan and autopsy findings in diagnosis and detection of EDH, and it associated factors

The present study demonstrated a moderate inter-observer kappa agreement for epidural haemorrhage (k = 0.5823) with high percentage agreement (90.59%).

This is similar to the study performed by Panzer (2017) when comparison was done between antemortem CT scan and autopsy. Furthermore, the same results were found when postmortem computed tomography diagnoses were compared to autopsy results (Jacobsen & Lynnerup, 2010).

Eight reports for discrepant EDH cases were reviewed. One case was diagnosed by antemortem CT scan as EDH and on the contrary autopsy reported a bulged out brain tissue through the skull defect without EDH. This was incorrectly diagnosed as EDH because it gave a lentiform appearance which is usually seen in cases of EDH (Hijaz et al., 2011). There were also two cases in which CT scan findings were reported as 'no surface collection' and on the other hand autopsy findings were reported as thin film of EDH. It has been previously reported that thin film of EDH can be missed on CT scan due to limited resolution (Graziani et al., 2018; Jacobsen & Lynnerup, 2010; Jalalzadeh et al., 2015). Nonetheless, it should be remembered that these small haemorrhage have implications forensically. The other 5 discrepant cases remained unexplained after the review.

4.3.5. The agreement between antemortem CT scan and autopsy findings in diagnosis and detection of SDH, and its associated factors

The current study demonstrated a moderate inter-observer kappa agreement (k = 0.48) for subdural haemorrhage with approximately two-third (74.12%) of cases diagnosed and detected by both antemortem CT scan and autopsy. Panzer (2017) found similar finding to these; whereas Graziani et al. (2018) and Bhat et al. (2011) found a lower agreement between CT image and autopsy. The reason for the lower agreement may be because their studies focused specifically on the true positive findings only (present – present) rather than the true positive and true negative findings (present – present and absent – absent) for SDH.

Nonetheless, one-third (24.69%) of the SDH cases were diagnosed by CT scan (6 of 85 cases) or autopsy (15 of 85 cases) alone. The current study showed that majority of discrepant cases were seen in patients who were admitted for more than a month on average. Possible reason that may explain the discrepancies after a month of hospitalization could be the effects of healing process which may be overlooked during postmortem examination. This can happen in thinner blood collection cases which after a month may be enclosed or may be completely absorbed (Itabshi et al., 2007; Saukko & Knight, 2016).

One case of misinterpreted SDH as reported in the CT scan was found in autopsy as subarachnoid haemorrhage. Similar to EDH, some cases of missed SDH under CT image findings were described under autopsy findings as thin film of blood.

4.3.6. Unspecified factors for the discrepancies

In certain instances factors responsible for the discrepancies remained unexplained as seen in the current study. In this study there were cases diagnosed either by autopsy or by computed tomography scan alone. This is consistent with what has been found by previous study (Graziani et al., 2018). This reiterate what other studies have highlighted before about autopsy not being a true gold standard. (Graziani et al., 2018; Poulsen & Simonsen, 2007; Smith et al., 2012). In the absence of a true gold standard, some associated factors responsible for the discrepancies may remain unidentifiable.

4.4. CONCLUSION

Of the 85 cases reported, majority (57%) of head injuries were due to motor vehicle accident. The objectives of the study have been achieved by determining the agreement between the antemortem CT scan and autopsy findings for traumatic intracranial haemorrhage. There was a fair overall agreement (k = 0.38) with overall discrepancy rate of 24.74% ranging from 9.41% to 34.12%.

SAH had the lowest agreement for TIH owing to too many combinations of haemorrhages and missed or misdiagnosis of this haemorrhage. In addition, length of stay in the hospital and level of experience contributed to this finding, while there was no relationship demonstrated regarding level of consciousness.

The following factors associated with the discrepancies have been assessed: 1) Type of haemorrhage - subarachnoid haemorrhage was found to have the highest discrepancies, 2) Level of consciousness – more discrepancies were seen in patient with severe head injuries, 3) Length of stay – majority of cases with high discrepancy were admitted for approximately two weeks, 4) Level of experience – most discrepancies were seen on practitioners with equal or less than 3 year experience, 5) Site of haemorrhage – parietal and occipital lobes showed high discrepancies as per site and 6) amount of traumatic intracranial haemorrhage – small amount tend to be missed during antemortem CT scan interpretations.

The following chapter summarises the report, gives recommendations and concluding remarks.

CHAPTER 5

SUMMARY, RECOMMENDATIONS AND CONCLUSION

5.1. SUMMARY OF THE STUDY

Head injuries are common and important in Forensic practice, and usually carry high mortality rate. Studies have demonstrated a significant decrease in mortality rate among patients who received surgical interventions compared to patients who were treated medically. The problem which exists is that some cases of traumatic intracranial haemorrhage were missed during CT scan interpretations. Currently there is little literature highlighting the discrepancies between antemortem CT scan and autopsy findings. This research may add knowledge to the practice of forensic pathology concerning the use of antemortem scans to determine cause of death, it also contributes to the notion that autopsy alone may not be a gold standard as previously known. Secondly, this may assist the Department of Radiology to better improve the manner in which they read and interpret the CT scan

In order to answer the research questions, the study looked at the rate and pattern of discrepancies between antemortem CT scan and autopsy findings in deceased patients with traumatic intracranial haemorrhage at Pietersburg Hospital Department of Forensic Pathology. A retrospective descriptive study was conducted based on bodies presented with intracranial haemorrhage at the aforementioned department. There was a fair overall agreement with overall discrepancy rate of 24.74%, ranging from 9.41% to 34.12% for individual traumatic intracranial haemorrhages between antemortem CT-scan and autopsy findings. These findings support previous studies. SAH had the lowest agreement for TIH diagnosis. Factors like severity of traumatic brain injury, level of experience and length of stay since admission to death have been established to be associated with discrepancies.

The presence of discrepancies between CT scan and autopsy findings has implications for both radiology and forensic medicine departments in terms of establishment of interdepartmental interaction and improving the quality of postmortem examination. Antemortem CT scan findings should not be used alone in determination of cause of death but rather be used in conjunction with autopsy findings.

5.2. RECOMMENDATIONS

5.2.1. Learning platform

“Learning is not achieved if errors are not achieved” (Prowse, Pinkey & Etherington, 2014, p. 19). Since the discrepancies exist between the two raters, clinically significant discrepancies should be reported to radiology department for learning purpose which ultimately may reduce mortality rate due to head injury through appropriate management. This can be achieved by creating a learning platform between the two departments. The interdepartmental interaction can be done on regular basis which can be determined by both parties involved.

However, caution should be exercised during the interdepartmental interaction as in the current study there were cases diagnosed either by autopsy alone or antemortem computed tomography scan alone, implying that autopsy cannot serve as perfect gold standard for antemortem CT scan findings. Furthermore, radiology or autopsy cases should be reviewed by the specialists before they can be finalised.

5.2.2. Use of antemortem CT scan findings in autopsy

Questions have been raised with regards to possibility of imaging technique replacing autopsy examination; these include the issue of complete autopsy versus incomplete autopsy and use of antemortem scans to determine cause of death. Though this study was not intended to address the magnitude of TIH, it revealed that thin-layered EDH and SDH which are of forensic significance are often missed. In view of these findings, antemortem CT scan cannot replace autopsy examination. Hence, the researcher recommend that antemortem CT scan findings be used in conjunction with autopsy. Further research is this area is called upon.

5.2.3. Improving autopsy quality

For the Forensic Pathologist to better report on the missed/misinterpreted antemortem CT scan, it is recommended that CT scan reports should be submitted together with medical record form (commonly known as D28), if there is a case of head trauma. This will improve the quality of postmortem examination and reporting.

5.3. RESEARCH LIMITATIONS AND DE-LIMITATIONS

The research project was conducted in Pietersburg hospital Limpopo Province in South Africa with small sample size. The small sample size was due to missing and incomplete records which affected the total rate of discrepancy. This limits the findings to be generalizable to the Limpopo Province rather than to the entire country. Moreover, the study addressed three types of haemorrhages in the brain (EDH, SDH and SAH), therefore the result should not be generalized to any other type of intracranial haemorrhage. Further research to this effect is recommended.

In radiology, slices are processed in certain thicknesses while in autopsy the brain is viewed in its entirety and cut in much thicker slices than in radiology. The difference in examination techniques may affect the recognition of intracranial haemorrhages. Once more, the study did not address the magnitude of the intracranial haemorrhages i.e. the amount of blood found during examination.

There were medical practitioners at different levels of qualification and experience involved in interpreting the findings of which their findings may vary based on level of expertise. Furthermore, the CT scans have been interpreted and reported by the practitioners in radiology department who were not present at autopsy, which helped to reduce bias.

The issue of timing of CT imaging was not taken in consideration, this may be a contributing factor to the discrepancies. The study did not delve deeper into factors affecting doctors' performance other than experience (e.g. fatigue, burn out, etc., all the other factors mentioned in the literature review).

Cases in which surgical interventions have been performed were not included in the study as intracranial haemorrhage seen in autopsy may not represent the initial haemorrhage seen on the CT scan. This as well affected the total rate of discrepancies.

5.4. CONCLUDING REMARKS

The overall agreement was found to be fair, implying that the discrepancies exist between antemortem CT findings and autopsy findings. These findings support previous studies. Factors like severity of traumatic brain injury, level of experience and length of stay since admission to death have been established to be associated with the discrepancies. Finally, these results add value to the body of knowledge about agreement status between antemortem computed tomography and autopsy findings. Recommendations are offered and further studies are needed which may overcome limitations of the study.

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Appendix 1

COMPUTED TOMOGRAPHY (CT) SCAN AND AUTOPSY DATA TOOL FORM

ID | | |

DEMOGRAPHIC INFORMATION

Age [ ] year/month/day

Gender

Male	
Female	

Race

Asian	Black	White

Manner of injury

MVA	Assault
Fall	Unspecifi ed

Date of admission

dd	mm	yy

Date of death

dd	mm	yy

Length of admission [ ] Hours or days

GLAW COMA SCALE

Condition of the patient

Mild	
Moderate	
Severe	

PRACTITIONER FACTORS

	No. of years in Radiology	**No. of years in Pathology**
Medical officer		
Registrars		
Specialist		

TYPES OF INTRACRANIAL HAEMORRHAGES

CT scan of the head performed	Yes	No

	CT SCAN FINDINGS	AUTOPSY FINDINGS
If yes, what type		
Epidural		
Subdural		
Subarachnoid		

SITE OF HAEMORRHAGE

	CT SCAN FINDING SITE		AUTOPSY FINDING SITE	
	Frontal lobe		Frontal lobe	
	Parietal lobe		Parietal lobe	
Epidural haemorrhage	Temporal lobe		Temporal lobe	
	Occipital lobe		Occipital lobe	
	Parafalcine		Parafalcine	
	Interpenduncular fossa		Interpenduncular fossa	
	Cerebellum		Cerebellum	

	CT SCAN FINDING SITE		AUTOPSY FINDING SITE	
	Frontal lobe		Frontal lobe	
	Parietal lobe		Parietal lobe	
Subdural haemorrhage	Temporal lobe		Temporal lobe	
	Occipital lobe		Occipital lobe	
	Parafalcine		Parafalcine	
	Interpenduncular fossa		Interpenduncular fossa	
	Cerebellum		Cerebellum	

	CT SCAN FINDING SITE		AUTOPSY FINDING SITE	
	Frontal lobe		Frontal lobe	
	Parietal lobe		Parietal lobe	
Subarachnoid haemorrhage	Temporal lobe		Temporal lobe	
	Occipital lobe		Occipital lobe	
	Parafalcine		Parafalcine	
	Interpenduncular fossa		Interpenduncular fossa	
	Cerebellum		Cerebellum	

APPENDIX 2: TURFLOOP RESEARCH ETHIC COMMITTEE CERTIFICATE

UNIVERSITY OF LIMPOPO

University of Limpopo
Department of Research Administration and Development
Private Bag X1106, Sovenga, 0727, South Africa
Tel: (015) 268 2212, Fax: (015) 268 2306, Email:noko.monene@ul.ac.za

TURFLOOP RESEARCH ETHICS COMMITTEE CLEARANCE CERTIFICATE

MEETING:	**31 August 2017**
PROJECT NUMBER:	**TREC/268/2017: PG**

PROJECT:

Title:	Discrepancies between the antemortem computed tomography scan and autopsy findings of traumatic intracranial Haemorrhage at Pietersburg Hospital Forensic Pathology Department
Researcher:	MI Hlahla
Supervisor:	Dr MJ Selatole
Co-Supervisor:	Prof BL Bhootra
School:	Medicine
Degree:	Masters of Medicine in Forensic Medicine

PROF TAB MASHEGO
CHAIRPERSON: TURFLOOP RESEARCH ETHICS COMMITTEE

The Turfloop Research Ethics Committee (TREC) is registered with the National Health Research Ethics Council, Registration Number: **REC-0310111-031**

Note:

i) **Should any departure be contemplated from the research procedure as approved, the researcher(s) must re-submit the protocol to the committee.**

ii) **The budget for the research will be considered separately from the protocol.**
PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES.

Finding solutions for Africa

APPENDIX 3: REQUISITION LETTER TO CONDUCT RESEARCH

LIMPOPO
PROVINCIAL GOVERNMENT
REPUBLIC OF SOUTH AFRICA
DEPARTMENT OF HEALTH
PIETERSBURG HOSPITAL

Forensic Pathology Services

Enquiry: DR Hlahla **Mobile Number: 0823585252**

TO: RESEARCH UNIT 2017/10/20

Dear Sir/Madam

REQUEST LETTER TO CONDUCT RESEARCH

I, Dr Hlahla MI, a registrar in the Department of Forensic Medicine would like to ask for your permission to conduct a study entitled "Discrepancies between the antemortem computed tomography scan and autopsy findings of traumatic intracranial haemorrhage at Pietersburg Hospital Forensic Pathology department"

Contact details and other important information:

University Name: University of Limpopo (UL)

Student No: 210315994

School: Medicine

Department: Forensic Medicine

Qualification: MMED

Contact details: 082 358 5252

Email: idrick@webmail.co.za

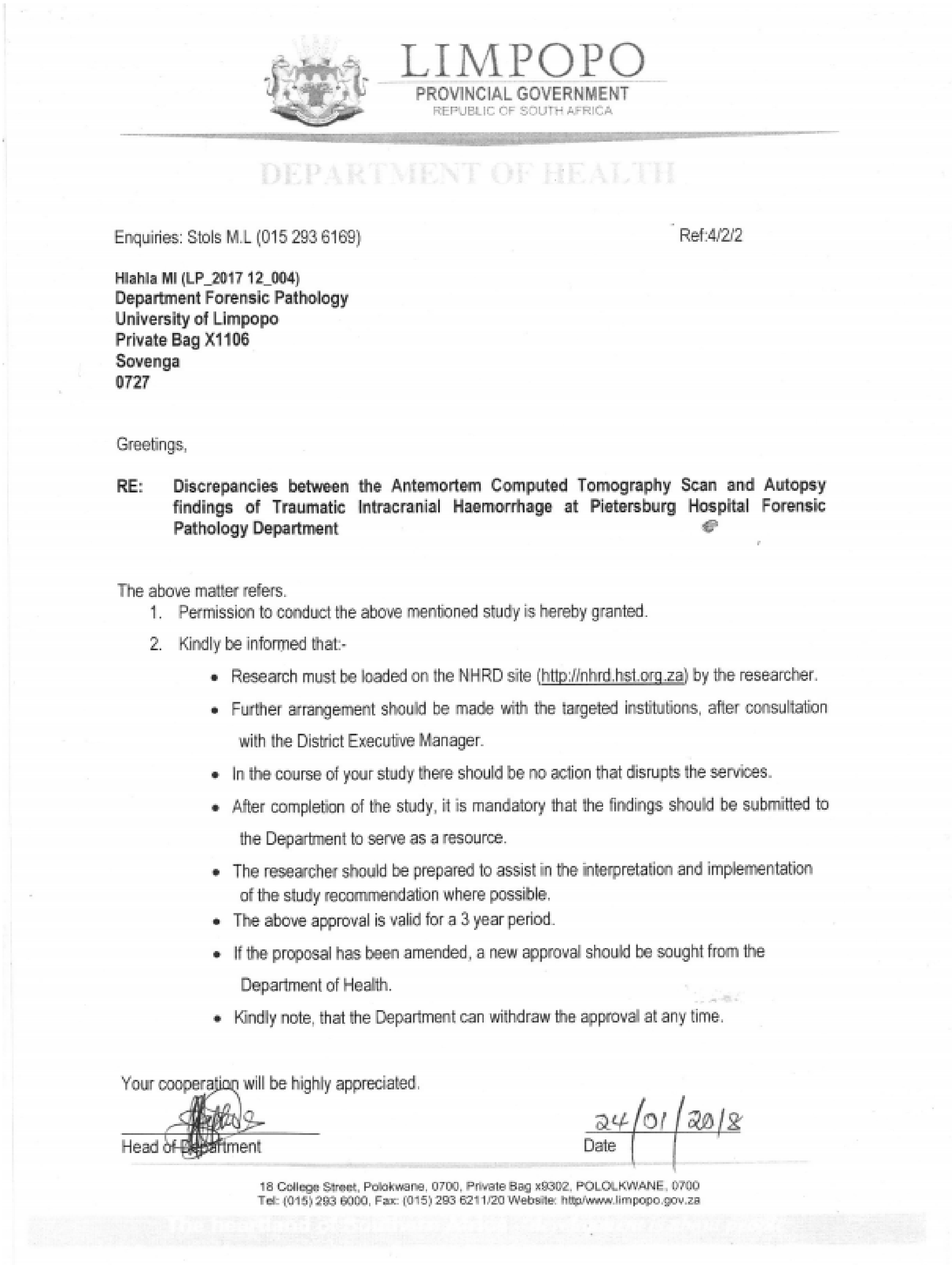
Supervisor: DR Selatole M.J

Your approval to conduct this study will be greatly appreciated

Sincerely

Dr Hlahla

APPENDIX 4: STUDY APPROVAL LETTER FROM HOD OF DOH



LIMPOPO
PROVINCIAL GOVERNMENT
REPUBLIC OF SOUTH AFRICA

DEPARTMENT OF HEALTH

Enquiries: Stols M.L (015 293 6169) Ref:4/2/2

Hlahla MI (LP_2017 12_004)
Department Forensic Pathology
University of Limpopo
Private Bag X1106
Sovenga
0727

Greetings,

RE: Discrepancies between the Antemortem Computed Tomography Scan and Autopsy findings of Traumatic Intracranial Haemorrhage at Pietersburg Hospital Forensic Pathology Department

The above matter refers.

1. Permission to conduct the above mentioned study is hereby granted.
2. Kindly be informed that:-
   - Research must be loaded on the NHRD site (http://nhrd.hst.org.za) by the researcher.
   - Further arrangement should be made with the targeted institutions, after consultation with the District Executive Manager.
   - In the course of your study there should be no action that disrupts the services.
   - After completion of the study, it is mandatory that the findings should be submitted to the Department to serve as a resource.
   - The researcher should be prepared to assist in the interpretation and implementation of the study recommendation where possible.
   - The above approval is valid for a 3 year period.
   - If the proposal has been amended, a new approval should be sought from the Department of Health.
   - Kindly note, that the Department can withdraw the approval at any time.

Your cooperation will be highly appreciated.

Head of Department

24/01/2018
Date

18 College Street, Polokwane, 0700, Private Bag x9302, POLOLKWANE, 0700
Tel: (015) 293 6000, Fax: (015) 293 6211/20 Website: http/www.limpopo.gov.za

APPENDIX 5: PIETERSBURG RESEARCH ETHIC COMMITTEE APPROVAL LETTER TO COLLECT DATA

LIMPOPO
PROVINCIAL GOVERNMENT
REPUBLIC OF SOUTH AFRICA

DEPARTMENT OF HEALTH AND SOCIAL DEVELOPMENT

Enquiries: Mr MA Poopedi
Manager: Clinical Research
University of Limpopo - School of Medicine
ananiaspoopedi@gmail.com

Ref: PMREC 27 September UL2017/C
Date: 27 September 2017

To: **Candidate: Dr M I Hlahla (Principal Investigator)**

Department: Forensic Pathology Medicine

Protocol Title:

Discrepancies between the antemortem Computed Tomography scan and autopsy findings of traumatic intracranial haemorrhage at Polokwane Hospital Forensic Pathology Department.

Supervisors: Dr MJ Selatole

Co-Supervisor: Dr BL Bhootra

Assessment Outcome: Approved Unconditionally

Kind regards

Dr FLM Hyera
Chair of Research: Polokwane/Mankweng Complex
Head: Public Health Medicine
University of Limpopo - School of Medicine
REC 300408-006

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APPENDIX 6: LANGUAGE EDITING LETTER

University of Limpopo
T.W Molotja (PhD)
(Senior Lecturer)
LSEMS Department (English for Education)
School of Education
Department of Languages, Social & Educational Management Sciences
(LSEMS)
Private Bag X1106, Sovenga, 0727, South Africa
Tel: (015) 268 3722/0736266621 Email:wilfred.molotja@ul.ac.za

TO WHOM IT MAY CONCERN

This letter serves to confirm that I, **Dr T.W Molotja** of the **Department of LSEM**, School of Education, University of Limpopo, have proofread and edited the mini-dissertation for **Hlahla**, **M.I., entitled: DISCREPANCIES BETWEEN ANTEMORTEM COMPUTED TOMOGRAPHY SCAN AND AUTOPSY FINDINGS OF TRAUMATIC INTRACRANIAL HAEMORRHAGE AT PIETERSBURG HOSPITAL FORENSIC PATHOLOGY DEPARTMENT**

The proposal is being edited focussing on the following:

- Coherent writing.
- Eliminating spelling errors.
- Fluency in reading
- Academic writing

I therefore recommend for its submission.

Yours Sincerely Date: 03 October 2018