Computed tomography (CT) head studies in a district emergency department: A focused study of CT related imaging and analysis of current practice

A thesis submitted to the Faculty of Health Sciences, University of Cape Town, in fulfilment of the requirements for the degree of Master of Science in Medicine in Emergency Medicine

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March 2021

DECLARATION

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ACKNOWLEDGEMENTS

I acknowledge Dr C. G. Lesar for his valuable contribution in the editing process of the dissertation.

I acknowledge Dr K. Vallabh for his valuable contribution in assisting with the setup of this dissertation.

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LIST OF ACRONYMS AND ABBREVIATIONS

AIDS	Acquired immune deficiency syndrome
ATLS	Advanced trauma life support
CC	Cerebral contusion
CCHR	Canadian computed tomography head rule
CI	Confidence interval
COPD	Chronic obstructive pulmonary disease
CT	Computed tomography
DALY	Disability-adjusted life year
DVT	Deep vein thrombosis
ED	Emergency department
ECM	Enterprise content management
EMS	Emergency medical services
EDH	Epidural haemorrhage
GCS	Glasgow Coma Scale
GSH	Groote Schuur Hospital
HECTIS	Hospital and Emergency Centre tracking information system
HICs	High-income Countries
HIV	Human Immunodeficiency virus
ICD-10	International Classification of Disease and Related Health Problems (10th revision)
LMICs	Low- and Middle-Income Countries
MPH	Mitchells Plain Hospital
MRI	Magnetic resonance imaging
NEXUS	National Emergency X-radiology Utilization Study
NICE	National Institute for Health and Care Excellence
PACS	Picture archiving and communication system
RA	Rheumatoid arthritis

SLE	Systemic Lupus Erythematous
SOL	Space occupying lesion
TB	Tuberculosis
TBI	Traumatic brain injury
TIA	Transient ischaemic attack/event
UCT	University of Cape Town
WHO	World Health Organization

ABSTRACT

Introduction: The South African population has a significant emergency burden of disease. In South Africa, immediate access to computed tomography (CT) imaging may not always be available.Globally, the number of all imaging studies is increasing annually. Due to access challenges patients requiring CT head imaging needs to be carefully selected to ensure safe management and discharge. Patient demographics, clinical presentation and type of expected emergency pathology known about this population will assist the emergency physician in making appropriate management decisions.

Methodology: This study was conducted in two parts: a literature review and a retrospective, descriptive analysis conducted at Mitchells Plain Hospital, Cape Town, exploring the type and prevalence of pathology identified by CT head imaging in the emergency department. Data for the descriptive study was collected over a one-year period and the demographics, indications and reported pathology were described for all CT head requests in the emergency department. Statistically significant differences between groups were calculated using the Chi-squared test, depending on the sample characteristics. Statistical significance was defined as p-value <0.05.

Results: There was a male predominance (57%) in this study with the most common comorbidity being hypertension. The cumulative yield of pathology was identified at 58% on imaging (new pathology 40% and existing pathology 18%). Stroke (32%), trauma (30%) and seizures (16%) were the most common indications for imaging with a yield per indication of 54%, 48% and 20% respectively. The most common imaging finding across all categories was an ischaemic stroke. Stroke indicated CT head imaging pathology demonstrated ischaemic (19%) to haemorrhagic (3%) stroke pathology. The most common finding on a trauma indicated CT head was an ischaemic stroke (13%). Seizure indicated CT head imaging demonstrated 18% with new pathology and 36% that had existing pathology. Emergency imaging was performed on average under seven hours post consultation.

Conclusion: Acquiring CT head imaging in a resource limited setting requires appropriate clinical history, examination as well as awareness of the most prevalent pathology of the community the doctor is treating. Even though yield of pathology was considered high when compared to HIC there was similarity in yield to local and international LMICs. Stroke, trauma and seizures are common indications for imaging in the South African setting with the most common pathology identified to be an ischaemic stroke.

CHAPTER 1 | THE BURDEN OF PATHOLOGY IDENTIFIED BY COMPUTED TOMOGRAPHY HEAD IMAGING IN THE EMERGENCY DEPARTMENT: A LITERATURE REVIEW

1.1 BACKGROUND AND INTRODUCTION

1.1.1 BACKGROUND

CT head imaging is a vital extension to the clinical neurological assessment of the acutely ill patient accessing emergency departments for neurological ailments. Due to the calvarium encasing the brain this soft tissue structure is impossible to examine directly and therefore CT head imaging is supplementary in the assessment of these tissues through this hard osseous structure.

In my clinical experience, while working in a district hospital level 1 emergency department, I was first exposed to the supply-demand mismatch for CT head imaging. Patients, if admitted would receive imaging within a few days of admission, however emergency CT head imaging was limited to office hours only. This made me wonder how to best ration and mitigate the supply-demand mismatch and how an emergency CT head study in a low-resourced setting should be defined. Imaging after hours in resourced challenged settings is usually restricted to tertiary (central) hospitals. Transfers to these facilities has its own challenges and is not without harm and significant delays.

It is thus important to understand the burden of disease, the indications and the positive yield of CT brain studies to be able to inform practice, especially in a resourced-challenged setting.

1.1.2 INTRODUCTION

South Africa is faced with a unique quadruple burden of disease that includes communicable diseases (specifically HIV/AIDS and tuberculosis (TB)), non-communicable diseases, trauma and injury, as well as maternal, new-born and child diseases/infections.(1) Emergency services, including prehospital emergency medical services (EMS) and hospital-based emergency departments (ED) are exposed to the full range of this burden daily, and often serve as access points to the health care system. ECs are expected to manage undifferentiated patients who present with the entire spectrum of medical, surgical or trauma conditions, in both adults and paediatric patients. It is essential that the undifferentiated patient be categorised according to provisional diagnosis for the patient to be transferred to the appropriate department for the correct continued level of care.

In South Africa there is an inadequate supply of resources required to adequately service the need for

health care. The 2018 South African NationalTertiary Health Service Plan identified a shortage of 0,66 beds per 1000 public sector dependent population.(2) By 2025 this will be less than the expected minimum figure due to accelerated rates of the population seeking health care and lack of infrastructure planning.(2) Patient demand on the emergencysystem has not been defined in South Africa however, as assessed by the high ED utilisation in United Kingdom National Health Service at 43.3 per 100 population,(3) this demonstrates a mismatch betweensupply and demand that disproportionally affects those in low- and middle-income counties (LMICs).
(4) Emergency physicians need to be aware of this mismatch and strive for faster time to disposition and appropriate discharge to alleviate pressure on patient flow and bed numbers in hospital wards. Given high rates of ED utilisation,(5) emergency physicians require suitable biochemical and imaging tools to make more accurate and timeous diagnostic decisions and allow them to dispose of their patients appropriately.

Computed tomography (CT) head imaging helps to ensure that timely disposition decisions can be made, which is especially important in a busy ED environment. Across the globe, the number of imaging studies is increasing by approximately 4.5% annually.(6) In 2016, the number of scans done in high-income countries (HICs) ranged from 64 (Slovenia) to 226 (United States of America (USA)) per 1000 inhabitants.(7) A more focused look at CT imaging utilisation rates in the USA showed an annual increase of 20%.(8) In South Africa, however, access to CT imaging is significantly lower when compared to state health care facilities in other countries. According to 2013 South African data, the rate of CT imaging is five units per one million population with a stark disparity between the public (1.7 units per one million population) and private (20.7 units per one million population) health sector.(3) In comparison, the United Kingdom, with a national public health system, has a CT utilisationrate of 8.9 units per one million population.(3) The low rate of utilisation in the South African public sector likely indicates a lack of equipment and access to imaging in this population. CT scanning services are not available at primary health care facilities. Only a few district level facilities have accessto CT equipment and, if present, the equipment is often only operational during standard office hours (Monday to Friday from 08:00 to 16:00). Furthermore, the current cost of a CT head performed in a public sector facility in South Africa is R1924.(9) This is significant when considering this as a single test in a health care system which places strain on the health care budget given the number of CT imaging done per day. The treating clinician, therefore, requires an understanding of the type of pathology that is present and when to expedite appropriate referrals for further investigations, such as CT imaging, to improve patient outcomes and manage resources. Resource management in the health sector is particularly important in LMICs as it has been shown that the lower the patient's socio- economic status, the less likely the patient is able to receive CT imaging for their pathology.(10)

In conclusion, the CT head study has become a fundamental form of investigation for early diagnosis in the emergency setting. Internationally and nationally, there are limited guidelines on the role of head CT in the ED. Therefore, assessing pathology of the brain requires careful assessment and selection for appropriate referral and the safe discharge of patients. There are pathologies that have been extensively researched, such as trauma (5,11) while other areas have not yet been extensively explored in the literature (e.g., work-up of seizures in the HIV positive patient).(12) A more focused review is, therefore, required in order to assist the clinician in making informed decisions that have an impact on patient care within the emergency setting. The purpose of this literature review is to provide an overview of the use of CT head imaging in adult ED patients and to describe the type and prevalence of pathology identified by radiologist reported CT head imaging in these patients.

1.2 AIMS AND OBJECTIVES

1.2.1 AIM:

The aim of this literature review is to assess current CT head utilisation in emergency departments with regards to access and pathology identified in both high-income countries and low- and middle-income countries.

1.2.2 OBJECTIVES

1. To explore the utilisation of CT head imaging in emergency departments.
2. To assess access to CT utilisation and how resources affect requisition practices in LMICs
3. To assess the pathology reported on CT brain scans and how the burden of pathology differs with regards to income setting.

1.3 SEARCH STRATEGY

1.3.1 Introduction

With the birth of the internet there is an ease of access to an extensive data pool. This data however does not all belong to a controlled source with ethical values. In order to ensure the purity of research write-up an appropriate search strategy to quality research sources to which must be adhered. Regarding biomedical ethics the guarded MEDLINE search engine was used. This database is transparent, easily accessible and research is guarded by publishers guidelines. It was decided to be an appropriate database to use for this chapter of the thesis.

1.3.2 Strategy

Medical Subject Headings (MeSH) and non-MeSH keywords were used to construct search strings that met the purpose of this review (Table 1). The MEDLINE biomedical literature database was searched using these queries in the PubMed search engine. The literature review included all articles published between February 2010 and February 2020. It did not include grey literature and only English studies were included. Studies were included if they described adult populations within the confines of the ED and were focused on the outcomes of pathology identified by CT head imaging.

Specific search strings were built for the three most common indications for CT head imaging, as identified in chapter three of this thesis: trauma, cerebrovascular accident (CVA)/stroke and seizures. An expanded comprehensive literature review was conducted on the prevalence of pathology associated with these indications (Table 1). The literature review also commented on the demographic characteristics of adults receiving this imaging and expanded on its use in the emergency setting or as an outpatient.

Following the literature search, the title and abstract of all identified articles were screened to identify articles that may meet the inclusion criteria above. A total of 299 articles were screened of which 70 articles met the inclusion criteria. The full text of these 70 articles was reviewed by the lead investigator. Lastly, the reference lists of included articles were screened for additional articles meeting the inclusion criteria. A total of 21 articles were included in this focused literature review.

Descriptive data was abstracted from each included article including authors, study design, study period, study population, key findings and recommendations for future research.

Table 1: A breakdown of the search strings used to identify the most appropriate articles required for this literature review

Search string	Filters used	Number of articles screened	Number of articles identified from reference lists	Number of articles included in review
(((“CT scan”) OR ((“Tomography Scanners, X-Ray Computed”[Mesh]) OR (“Diagnosis/diagnostic imaging”[Mesh]))) AND ((“Brain”[Mesh]) OR (“Head”[Mesh]))) AND ((((“emergency centre”) OR (“emergency department”)) OR (((“Emergency Medical Services/aetiology”[Mesh] OR “Emergency Medical Services/history”[Mesh] OR “Emergency Medical Services/instrumentation”[Mesh] OR “Emergency Medical Services/methods”[Mesh] OR “Emergency Medical Services/standards”[Mesh] OR “Emergency Medical Services/statistics and numerical data”[Mesh] OR “Emergency Medical Services/therapeutic use”[Mesh] OR “Emergency Medical Services/therapy”[Mesh])) OR ((“Emergency Medicine”[Mesh:NoExp]) OR ((“Emergency Service, Hospital”[Mesh]) OR ((“Emergencies/diagnosis”[Mesh] OR “Emergencies/diagnostic imaging”[Mesh])))))) NOT (prehospital))	Age + 19 English Human	60	20	9
(((“head trauma”) OR ((“Craniocerebral Trauma”[Mesh]) OR (“craniocerebral trauma”))) OR (“Brain Injuries, Traumatic”[Mesh])) AND ((((“CT scan”) OR ((“Tomography Scanners, X-Ray Computed”[Mesh]) OR (“Diagnosis/diagnostic imaging”[Mesh]))) AND ((“Brain”[Mesh]) OR (“Head”[Mesh]))) AND ((((“emergency centre”) OR (“emergency department”)) OR (((“Emergency Medical Services/aetiology”[Mesh] OR “Emergency Medical Services/history”[Mesh] OR “Emergency Medical Services/instrumentation”[Mesh] OR “Emergency Medical Services/methods”[Mesh] OR “Emergency Medical Services/standards”[Mesh] OR “Emergency Medical Services/statistics and numerical data”[Mesh] OR “Emergency Medical Services/therapeutic use”[Mesh] OR “Emergency Medical Services/therapy”[Mesh])) OR ((“Emergency Medicine”[Mesh:NoExp]) OR ((“Emergency Service, Hospital”[Mesh]) OR ((“Emergencies/diagnosis”[Mesh] OR “Emergencies/diagnostic imaging”[Mesh])))))) NOT (prehospital)))	English Adults +19 years Human	23	7	Duplication as per above search
((((“Brain”[Mesh]) OR (“Head”[Mesh])) AND ((“Brain”[Mesh]) OR (“Head”[Mesh]))) AND ((“CT scan”) OR ((“Tomography Scanners, X-Ray Computed”[Mesh]) OR (“Diagnosis/diagnostic imaging”[Mesh])))) AND (((“head trauma”) OR ((“Craniocerebral Trauma”[Mesh]) OR (“craniocerebral trauma”))) OR (“Brain Injuries, Traumatic”[Mesh]))	English Adults +19 years Human The past 10 years	118	10	3
(((“Stroke”[Mesh]) OR (((stroke) OR (“cerebrovascular accident”)) OR (CVA))) AND ((“CT scan”) OR ((“Tomography Scanners, X-Ray Computed”[Mesh]) OR (“Diagnosis/diagnostic imaging”[Mesh])))) AND ((((“emergency centre”) OR (“emergency department”)) OR (((“Emergency Medical Services/aetiology”[Mesh] OR “Emergency Medical Services/history”[Mesh] OR “Emergency Medical Services/instrumentation”[Mesh] OR “Emergency Medical Services/methods”[Mesh] OR “Emergency Medical Services/standards”[Mesh] OR “Emergency Medical Services/statistics and numerical data”[Mesh] OR “Emergency Medical Services/therapeutic use”[Mesh] OR “Emergency Medical Services/therapy”[Mesh])) OR ((“Emergency Medicine”[Mesh:NoExp]) OR ((“Emergency Service, Hospital”[Mesh]) OR ((“Emergencies/diagnosis”[Mesh] OR “Emergencies/diagnostic imaging”[Mesh])))))) NOT (prehospital))	English Adults +19 years Human	70	19	3
(((seizures) OR (“Seizures”[Mesh])) AND ((“CT scan”) OR ((“Tomography Scanners, X-Ray Computed”[Mesh]) OR (“Diagnosis/diagnostic imaging”[Mesh])))) AND ((((“emergency centre”) OR (“emergency department”)) OR (((“Emergency Medical Services/aetiology”[Mesh] OR “Emergency Medical Services/history”[Mesh] OR “Emergency Medical Services/instrumentation”[Mesh] OR “Emergency Medical Services/methods”[Mesh] OR “Emergency Medical Services/standards”[Mesh] OR “Emergency Medical Services/statistics and numerical data”[Mesh] OR “Emergency Medical Services/therapeutic use”[Mesh] OR “Emergency Medical Services/therapy”[Mesh])) OR ((“Emergency Medicine”[Mesh:NoExp]) OR ((“Emergency Service, Hospital”[Mesh]) OR ((“Emergencies/diagnosis”[Mesh] OR “Emergencies/diagnostic imaging”[Mesh])))))) NOT (prehospital))	English Adults +19 years Human	28	14	6
Total number of articles		**299**	**70**	**21**

1.4 THE UTILITY OF COMPUTED TOMOGRAPHY HEAD IMAGING IN THE EMERGENCY DEPARTMENT

Radiological studies are necessary tools in the work-up of patients. CT head imaging is of importance in assessing organic brain pathology due to its unique ability to penetrate bone. Imaging studies are individually tailored to ensure that the imaging process appropriately assesses the clinical situation based on the indications for (input) and enhancing the clinical diagnosis (output) quality. There are multiple indications for requesting a CT head study, however, the focus of assessment is usually related to emergency pathology in the ED. Undifferentiated patients are assessed clinically and categorised into groups based on a combination of symptoms and signs, which include sudden loss of consciousness or focal neurology, deranged mentation, recent trauma to the head, seizures, semiology of increased intracranial pressure, psychologically dysfunctional features, headache features in keeping with a ruptured aneurysm, as well as acute deep infective eye signs.(13) The clinical diagnosis that is suspected is then stated as the indication for CT imaging and is noted as the input of the imaging process. Once the imaging has been conducted and reviewed by the appropriate radiologist, a radiological diagnosis is given, and this is the output of the imaging process. The radiological diagnosis reported can demonstrate a normal scan, chronic pathological changes or acute pathological changes.

1.5 CONSIDERATIONS IN REQUESTING CT INVESTIGATIONS

CT imaging requests may be influenced by clinical decision rules, patient out-of-pocket costs, and malpractice reviews.(14) These concepts will be further elaborated on in the following section.

1.5.1 Clinical decision tools

The guidelines for requesting CT head imaging are not clear and requests are often based on the opinions of the treating clinician.(15) It is, however, important to mention that even though clinical decision tools have been generated to assist in clinical decision making, the treating physician still considers clinical acumen an important default in the management of patients.(16) Clinical decision rules have been developed over time to assist in mitigating the need for further investigations in a limited health care resource setting as well as in safe onward referral of patients.(16) Clinical decision rules in the ED are traditionally applied separately for trauma and non-trauma related categories. For the ease of relating to the literature, this categorisation of patients will be discussed under this format. Currently the most recognised trauma related scoring systems documented in the literature in HICs are the Canadian computed tomography head rule (CCHR) (17), the National Institute for Health and Care Excellence (NICE) (11) guidelines, National Emergency X-radiology Utilization Study (NEXUS) (18) guidelines and the Advanced trauma life support (ATLS) (19) guidelines. In the South African setting, the head trauma related scoring system of interest is the Western Cape head injury guideline.(20) On review of the literature there is a paucity of well-developed and validated non-trauma scoring systems. There are some scoring systems that have tried to incorporate both the trauma and non-trauma patient. One which is of interest in the South African setting would be the Kimberley Hospital rule (KHR).(21) The KHR was developed in a South African tertiary hospital that considers trauma and non-trauma head related signs and symptoms and, therefore, sorts patients according to risk and timing of imaging. Another similar guideline in use is the Western Cape head injury guideline (20) which focuses on the trauma patient. Therefore, the decision to further image the non-trauma patient has resulted in the emergency physician relying to a large extent on clinical acumen.

With regards to trauma related indications for imaging, the American health fraternity uses the ATLS guidelines and CCHR while the British use the NICE guidelines. With regards to the ATLS principles, classifying brain injury (22) focuses on the clinical sign of the Glasgow Coma Scale (GCS). If a patient with a post traumatic brain injury has a GCS of less than 13 this would be considered moderate to severe brain injury and all of these patients would require emergency CT head imaging.(19) This represents approximately 25% of patients presenting with brain injury in the ED.(19) A GCS of 13-15 post-trauma would be considered minor and these patients would require further follow-up assessment to determine if imaging is required. This evaluation would be governed by the CCHR. Those patients classified under the GCS system as mild would, according to the CCHR, be considered to have additional risk that requires CT imaging and possible additional neurological intervention if they have one of the following: fail to reach a GCS of 15 within two hours post-trauma, suspected of having an open skull fracture, have signs of basal skull fracture, have a haemotympanum, the 'panda' eyes sign, or cerebrospinal fluid leakage from the ear or nose, Battle's sign, vomiting >2 episodes, or age >65 years. However, a recent review of the age-related subcategory in the CCHR scoring system (23) found that the age factor could be changed from greater than 65 years to greater than 75 years. This is especially relevant to prevent overuse of CT imaging in a stressed emergency department setting. Therefore, CT head imaging is indicated in the high and moderate risk patient. For the patient with minor brain injury, certain criteria need to be fulfilled for CT imaging to be indicated and unfortunately, a time limit of urgent, emergent or outpatient has not yet been adequately defined.

In contrast, the NICE and Western Cape head injury guidelines state that patients with the following indications require imaging within one hour of identifying these risk factors: GCS less than 13 on initial assessment in the emergency department; GCS less than 15 at two hours after the injury on assessment in the emergency department; suspected open or depressed skull fracture; any sign of basal skull fracture; post-traumatic seizure; focal neurological deficit or more than one episode of vomiting.(24) The NICE guidelines also state that all adults who have sustained a head injury with no other indications for a CT head imaging as previously mentioned but who are taking anticoagulant treatment, a CT head scan should be carried out within eight hours of the injury.

The primary difference between the ATLS, NICE and Western Cape guidelines is that the ATLS guidelines sort patients according to severity, i.e., mild, moderate and severe, whereas the NICE and Western Cape head injury guidelines sort patients according to a time factor, namely hours within which a risk factor was identified. Additional differences in the diagnostic clinical decision tools are that the ATLS guidelines include age greater than 65 years, amnesia before impact >30 minutes, and dangerous mechanism of injury while the NICE and Western Cape guidelines include post-traumatic seizure and focal neurology as an indication for CT head imaging. The implementation of the NICE guideline in the U.K. ED resulted in a large reduction in skull radiography and an associated modest increase in CT imaging and admission rates but with no adverse neurological events.(5)

On the other hand, with regards to non-traumatic related scoring systems, worldwide there has been no consensus on a diagnostic clinical decision tool and countries tend to create guidelines that are not internationally standardised. In 2013, Wang and You identified variables obtainable from bedside clinical assessment histories (in a HIC setting) that were independent predictors of abnormal findings amongst patients in the ED who were referred for head CT for non-traumatic indications.(25) These non-traumatic related indications for imaging were age over 70 years, focal neurologic deficit, altered mental status, history of malignancy, nausea and/or vomiting, and coagulopathy. The study further stated that a prospective study to validate a standardised clinical prediction rule in this ED population was warranted. However, when focusing on the South African ED population, the KHR which combines trauma and non-traumatic related indications and aligns with the NICE guidelines, demonstrates similar sensitivity and specificity to the NICE and CCHR scores.(21) On subgroup analysis, the KHR achieved 100% sensitivity and 33.6% specificity for the trauma group, and 79% sensitivity and 49% specificity for the non-trauma group.(21) These figures confirm the need for an improved screening diagnostic clinical decision tool in the South African setting for non-traumatic indications for CT head imaging.

NICE guidelines state the following indications for imaging within one hour of identifying factors: GCS less than 13 on initial or subsequent assessment in the emergency department; deterioration of GCS by two or more points after initial assessment; suspected skull fracture; focal neurological deficit; patients with GCS 13-14 together with vomiting, seizures, or coagulopathy history.(11) The indications for imaging within eight hours of identifying factors include all patients with a GCS <15, and all patients with a GCS of 15 with either sudden onset severe headache, history of loss of consciousness, continuous vomiting, and/or seizures. Of note, an Austrian diagnostic clinical decision tool has been shown to predict significant pathology in head injury with a sensitivity of 90% and specificity of 67%, in comparison to the CCHR score of a sensitivity of 80% and specificity of 72%.(26) There are multiple diagnostic clinical decision tools that have been generated in different countries across the world. An emergency department needs to consider all diagnostic clinical decision tools against its own population and burden of disease in order to choose one that can efficiently guide the department in making sound clinical decisions.

Clinical decision rules are of value to empower clinicians, however, these rules must be practical, user friendly and not cumbersome. Other nonclinical and human factors could influence the application of these rules thereby inhibiting the appropriate use of CT when patients present to the ED. These factors that influence the application of the clinical rules are establishing trust, anxiety (patient and provider), constraints related to ED practice, the influence of others and patient expectations.(27) It is therefore, important to note that even though evidence-based rules have been formulated, there are shortfalls due to the human element in practicing medicine. In addition, the differences between HIC and LMIC environments affect the wide generalisability of these rules. Implementation is important and further validation of a South African rule can assist in implementation.

1.5.2 The cost and risk of CT imaging:

In South Africa, the public health sector services approximately 80% of the population while the remaining 20% of the population is insured and served by the private sector.(28) There is a financial risk to acquiring a CT head study. The current cost of a CT head performed in a government hospital in South Africa is R1924.(9) This is significant when considering this as a single test in a health care system and, therefore, places strain on the health care budget when one considers the amount of CT imaging done per day. In South Africa, trauma is seen daily in the ED where patients presenting with blunt force trauma to the head require CT head imaging 61.5% of the time.(29) It has been noted in a referral trauma level 1 hospital in South Africa that the cost of blunt trauma imaging to the hospital is 0.92% of the total hospital expenditure for the year.(29) This shows one area of trauma related investigations however, this links back to one of the great burdens of disease that plague South Africa. This burden of disease, injury and trauma, demonstrates how funds, as noted above, are focused on injury and trauma and, therefore, focusing these funds can cripple the monetary resources resulting in the hospital supply and demand mismatch and, therefore, resulting in funds being re-distributed accordingly.(29) In summary, the economic cost of CT imaging to the state and the patient is high and needs to be considered when ordering this study.

It is important to note that CT imaging also carries acquired biological risks – radiation induced and contrast exposure. The risk of radiation can be further divided into deterministic effects and stochastic effects. This array of biological changes can be predicted over a certain radiation exposure or can add to one’s life term risk of stochastic effects.(30) Iodine-base contrast has two rare risks: anaphylaxis and contrast-induced nephropathy.(31) Most people who develop iodine-based complications do not die from them.(32) Therefore, in summary one needs to always consider the risk versus benefit to the patient when ordering a CT head investigation.

Another important risk area to highlight is to look at the patient in his/her context. The socio-economic status of a patient has been linked to health outcomes. There have been multiple described factors associated with this that include health status on arrival to the facility, access to health, and care provided by the clinician.(10) When reviewing investigations of patients with a low socio-economic status (SES), the patients with the lowest SES are less likely to receive CT head imaging for ED complaints than other patients.(10) Therefore socioeconomic status is an important component in managing and treating disease in a patient when considering the biological-psychological and social model.(33)

1.5.3 Access to CT imaging:

Access to health care is a concept that has multiple modifiable and non-modifiable factors that impacts the health seeking behaviour of a patient. Access encompasses concepts of financial, security, geolocation and understanding of illness to name a few.(34) Access to immediate CT head imaging may not be available in all EDs across South Africa due to resource limitations. Statistics on access to emergent CT head imaging have not been described in the South Africa setting, however, according to delegates at an international emergency medicine conference, hospitals in LMICs have statistically lower 24-hour access to CT scans than those in HICs with regards to imaging emergencies like stroke and trauma.(4) With specific reference to access to emergency imaging of the brain, Chunga et al (2019) report that 81% of LMICs had access to CT scans with 84% of them having 24-hour access to radiology services, compared to HICs with 83% and 98% respectively. Access to health, and what is highlighted here in particular is access to CT imaging, is a multifactorial concept that is crippling LMICs like South Africa and, therefore, requires multimodal changes to improve access to CT imaging.

In South Africa, there is a discrepancy in availability of CT imaging between the public and private sectors. According to recent South African statistics, CT imaging performed in the health sector shows an average of five units performed per one million population (1.71 per million population in public and 20.7 units per million population in private health sector).(3) In comparison, the United Kingdom, using a national health system has 8.92 units per million population CT statistic. South Africa is planning to initiate a national health system, however, the public statistics of 1.71 units per million population (3) shows there is a severe underservicing of this population and, therefore, an implied lack of equipment and access to imaging of this population. The public health sector in South Africa in generalised terms services mostly patients of a low to middle socio-economic background. Therefore, the study of Bhayana et al (2014) stating that hospitals in LMICs have statistically lower 24-hour access to CT scans than those in HICs links with the above statistics (3) demonstrating the lower units per million of patients obtaining imaging in the public sector versus the private sector. This is important to consider in the management of the patient as the treating physician will need to make provision for limited access of imaging in the patient’s management in a resource stressed setting. Therefore, a supply-demand mismatch that is proportionally more significant in LMICs, as previously noted.(35)

These concepts of access are of value to highlight as even if the patient has overcome other barriers of access to the ED the supply of CT imaging is not always accessible.

1.5.4 Pathology yield and unnecessary CT imaging

Further combined rules for the non-traumatic and traumatic South African population requiring CT head imaging (using the KHR) shows a 90-100% sensitivity and specificity of 34-45%.(21) These figures describe a good screening tool but not a good diagnostic clinical decision tool, therefore, indicating that unnecessary imaging may have been performed. The rate of unnecessary imaging cannot be finitely reported as even though a study may not show pathology this may still assist the physician is ruling in/out pathology.(21) Therefore, a CT study without pathology identified does not equate to unnecessary imaging. There is value in identifying no pathology when an emergency physician is using the CT imaging as an instrument to rule out clinically relevant pathology. It is also of importance to note that not all CT head studies requested in the emergency department should have pathology as the emergency physician may be missing occult pathology due to the high threshold for imaging patients. This leads to the idea of suggestive yields identified by local guidelines in South Africa for non-trauma and trauma imaging of 61.8% and 47.1% respectively,(36) with a combined positive rate of 53.8%.(36) Internationally a positive yield rate of overall CT head imaging for trauma and non-trauma requested imaging has been identified as 39%.(37) Therefore, there is still value in using CT head imaging in the ED as a screening tool when indicated and not always as a diagnostic tool.

The ED is vulnerable to access block, saturation, and overcrowding when regarding the load of patients. In South Africa, restriction of resources and the disease profile experienced enhances this vulnerability. Patient flow directly impacts overcrowding as confirmed by a survey where 94% of professionals agree that poor patient flow usually results in emergency department overcrowding and that is usually caused by the inability to move patients to admission.(38) Unnecessary imaging has serious implications for patient flow. In a resource constrained setting there may be limited access to CT imaging in a 24-hour period and this can result in patients waiting in the ED for imaging. This decreased flow links to the fact that overcrowding is strongly associated with poorer outcomes.(38) The appropriate flow of patients in an ED is advantageous to all patients and when CT imaging reduces patient flow it must be strongly considered as patient care is at risk. Unnecessary CT head imaging ordering still plagues the ED where 10-35% of CT head imaging of minor head trauma does not meet standardised CCHR for imaging.(39) It is of value for the emergency physician to note that the patients who acquire higher rates of unnecessary imaging are patients in at least one of these categories: age (41-64 years), drug addicts, vehicle injury and requirements of surgery in 24 hours.(39)

These patient factors can be considered by the emergency physician when deciding if CT head imaging is necessary on the patient. In the USA, 91% of the total emergency department visits are patients who can be safely discharged.(40) Therefore, efficient patient management requires the emergency physician to align with departmental protocols that incorporate clinical decision rules which will result in less overcrowding and better patient outcome. This factor is to be considered by the emergency physician when consulting with a patient and determining the need for imaging.

1.5.5 Urgency of CT imaging

With regards to the timing of imaging, the clinical severity and indication will determine the urgency of imaging. According to advanced cardiovascular life support (ACLS) principles of managing acute stroke, imaging should be performed within 25 minutes of patient arrival at the ED and a final report issued within 20 minutes of imaging.(41) This guideline is particularly important due to the window period for management of these patients. However, this is not the guideline for all imaging in the ED. According to NICE guidelines and the KHR, imaging can be divided into immediate (within 1 hour of arrival at EC) and urgent (within 8 hours of arrival at EC) depending on clinical presentation.(41) There is no stipulation of recommended timing of reporting for CT head imaging as accuracy is more important than completion of report. In the literature other CT head imaging can extend past the 24-hour threshold. No standardised CT turnaround time, as well as CT reporting time exists within South Africa.

1.5.6 Summary

In conclusion, the ED demonstrates a high rate of patients being discharged from the ED and in South Africa emergency personnel manage a large patient load with limited resources. The population have multiple tangible and non-tangible constraints in accessing the emergency care required. South African emergency physicians need to be empowered to navigate the high burden of disease to allow for appropriate and safe treatment of the patient.

There are areas, such as trauma, that have been extensively researched and diagnostic clinical decision tool that have subsequently been developed, for example, the trauma imaging CCHR and NICE together with ATLS.(11) Other areas have not yet been adequately explored and assessed. For example, a CT head study would be a valuable tool in differentiating between a primary, secondary or dual brain dysfunction. There is a global lack of consensus identifying diagnostic clinical decision tools required to request CT head imaging on the emergency patient. An in-depth review of the outcomes of patients that have had emergent CT head imaging in the ED will provide an evidence base to add to our understanding of the ‘pre-test probabilities’ to assist in clinical decision making.

1.6 AN OVERVIEW OF THE BURDEN OF DISEASE WITH INDICATIONS FOR CT HEAD IMAGING IN THE EMERGENCY DEPARTMENT

1.6.1. Background

As mentioned, South Africa has four overlapping epidemics: maternal, neonatal and child health; HIV/AIDS and tuberculosis (TB) (communicable diseases); non-communicable diseases; and violence and injury.(42) In ED patients, these epidemics often overlap, and comorbidities are common, so the emergency physician needs to ensure he/she manages all facets of disease. For the simplicity of this overview these categories will be discussed briefly in isolation.

Signs and symptoms are formulated into syndromic categories to create indications for imaging. These later assist in identifying a trend for pathology. Sinclair et al (1993) identified this trend that emergency departments use today.(37) Categorical trends where pathology was noted in varying percentages with an overall yield of pathology of 39% (37) were: headache (26%), seizures (17%), focal weakness (46%), acute trauma (37%), late trauma (22%), altered mental status (32%), coma (54%), and other (32%). These are therefore, appropriate indications to consider for emergency imaging. There is little evidence that abnormalities seen on CT imaging correlate with symptoms.(43) In the era of defensive medicine, imaging protocol are tailored to assist in confirming a diagnosis and a blanket indication can limit the process of identifying pathology. A trend towards using imaging as a screening tool should be advised against due to the previously discussed multifactorial aspects to access especially in the LMIC environment. Therefore, diagnostic clinical decision tools can assist in limiting imaging exposure. Diagnostic clinical decision tools do show high sensitivity, but not high specificity. Thus, further investigation on indications is required, especially within the South African context.

1.6.2 Injury and Trauma

Sixty-nine million individuals worldwide are estimated to sustain traumatic brain injury (TBI) each year.(44) There is a discrepancy between HIC and LMIC ED units where it is shown that 80% of all traumatic brain injuries occur in LMIC.(45) On further dissection of the broad categories of the quadruple burden of disease that plagues South Africa, violence and injury demonstrate an acute presentation, therefore, this pathology is predominantly managed in the EDs. Examples of the burden of trauma in South African show that injury related mortality rates are six times that of the global rate and road traffic injuries are double of the global rate.(46) Of note, road traffic injuries predominantly affects the younger population between 25 and 34 years old within South Africa.(35) Another example of the burden of trauma in South Africa is that the age-standardized homicide rate of 64.8 per 100 000 population places South Africa among the most violent countries in the world.(35) If one explores deeper there are age-specificrates that are higher in certain geographical areas like in Cape Town's informal settlements of Khayelitsha and Nyanga. In these settings, male youth violence is reflected in extremely high homicide rates (451 and 485 per 100 000 population, respectively) in the 15–24 age group.(46,47) These statisticsfrom the World Health Organization (WHO) demonstrate the extent of trauma in South Africa and whytrauma is one of the predominant categories in the quadruple burden of disease.

The morbidity of the injury and trauma epidemic in South Africa is devastating as demonstrated in 2000 where it was noted that interpersonal violence caused around 1.0 million (6.5% of all) disability-adjusted life years (DALYs) in South Africa, followed by road traffic injuries, which were responsible for almost 0.5 million (3.0% of all) DALYs.(46) Intentional and unintentional injuries combined were the second leading cause of all DALYs after HIV/AIDS, accounting for 14.3% of the total 16.2 million DALYs.(46,47) This indicates the extent of violence and injury related morbidity and mortality in the South African population.

Pillow et al (2019) in their study in the USA, a HIC, found that traumatic brain injury affected approximately 1.4 million people (0.41% of the population) resulting in more than 50 000 deaths per annum.(48) Trauma to the head can be inflicted by either a blunt force or a penetrating force and the resultant injury can be to either bony or soft tissue. The severity of the head injury can be categorised using the Glasgow Coma Scale (GCS). The lower the patient's GCS score, the more likely the chance of a significant intracranial injury. The site of injury and number of intracranial haemorrhages also predicts the type of injury a patient may obtain. Most of the patients with a single traumatic lesion on CT scan (42%) will have a single epidural haemorrhage (EDH), whereas most of the patients with multiple traumatic lesions on CT scan (27%) have cerebral contusions (CC).(49) Further when considering fractures most of the patients with anterior fossa skull base fractures will have an EDH, whereas most of those with middle fossa skull base fracture had accompanying CC.(50)

Head trauma that is clinically classified as minor has been shown to have a 10% positive yield of injury (skull and intracranial) on CT imaging.(51) The positive yield of injury decreases to 6-9% for patients with a GCS of 15.(51) In the older population it is noted that the mechanism of injury of a fall versus a motor vehicle accident in the elderly is more likely to have skull or intracranial acute traumatic finding on head CT.(51) In traumatic brain injury the cranial nerves are also prone to injury with similar percentiles in mild, moderate and severe grades of head injury.(52) The highest incidence of nerve palsy is noted in the olfactory, facial, and oculomotor nerves, whereas the trigeminal nerve and lower cranial nerves are rarely damaged. Further, residual nerve deficit at one year was noted in 81.26% of patients with base of skull fractures.(52)

An additional factor to consider in patients with an acute minor head injury is the possibility that these patients might be on antiplatelet or anticoagulation treatment. In a Swiss study it was interesting to note that the risk of developing intracranial bleeding was significantly higher for patients on antiplatelet therapy compared to those patients on the anticoagulation therapy.(53) It was further noted that the risk of intracranial haemorrhage in a patient on anticoagulation therapy was the same as that of the general population. (53) Therefore, taking these findings into account and considering the Canadian head CT scoring systems a discussion to expand upon is if it is warranted to adjust the scoring system to remove anticoagulation therapy category or to include antiplatelet therapy category to enhance the sensitivity of the clinical decision tool. The South African population is prone to head trauma due to multifactorial pressures and the range of subsequent developing pathology needs to be urgently addressed. Therefore, a South African specific scoring system would be of invaluable assistance to the treating trauma physician.

1.6.3 Communicable diseases

HIV/AIDS has been noted to create significant morbidity as it is the leading cause of all DALYs in South Africa.(46) There is a high HIV prevalence in South Africa stated to be approximately 12.7% of the total South African population.(54) Adults aged 15 to 49 years old make up an estimated 18.9% of the population having a positive HIV status. Another communicable disease in South Africa is TB and the statistics show that 454 000 (about 0.8% of the South African population) cases of active TB were documented in 2015 (54) and it is estimated by the WHO that about 57% (258 000) of these patients have comorbid infection with HIV. (55) This co-morbid infection is what is a further epidemic in the quadruple burden of disease in South Africa. The patients that have HIV and TB requires constant long term supportive care due to the chronicity of the diseases. There is a large population who are co-infected and due to challenges to access of care place these patients in a vulnerable situation. If a patient defaultsmedical treatment there can be grave acute complications (e.g., infectious and vascular) that will require emergent management in the ED. Patients with HIV and TB can present with an array of vascular, infective and inflammatory emergencies (56) and, therefore, are an important patient to consider in the emergency setting that require urgent CT head imaging.

When considering a large portion of the South African population that are immunocompromised secondary to HIV, the way in which we initially learnt to manage this patient group in the ED with regards to imaging is based on a study which unfortunately has a small sample size.(57) The indications for CT head imaging of patients with HIV were new-onset seizures, depressed or altered orientation, and a headache that was different in quality. These indications were statistically significant indications for CT head imaging and demonstrated that imaging revealed 95% of the time new focal intracranial lesions. These above described indications further decreased the number of CT by 53% which demonstrates a pleasing (57) A South African HIV study noted that focal signs (p = 0.0001), neck stiffness (p = 0.05), vomiting (p = 0.018) and a Glasgow Coma Scale (GCS) < 15 (p = 0.002) to be predictors of space occupying lesions (SOL) and cerebral oedema however brain shift identified contraindicated a lumbar puncture in 5% of all patients.(12) It is noted that the most common intracranial lesion amongst patients with a CD4 count of less than 200 cells/mL is toxoplasmosis, while cerebrovascular accidents (ischemic or haemorrhagic) is most common in those patients with a CD4 count greater than 200 cells/ml.(57) It is noted here that HIV-positive patients have a high prevalence of SOL and cerebral oedema however majority of these patients have no brain shift, therefore, clinical parameters can assist the doctor in identifying the HIV positive patient that is most at risk of pathology.

1.6.4 Maternal and child health and nutritional diseases

Maternal and child health, together with nutritional diseases, is a further epidemic in the quadruple burden of disease. In the emergency setting, few maternal and child emergencies require CT head imaging. In 2015, children under the age of five years had a high estimated mortality of 37 – 40 deaths per 1 000 live births, with an estimated infant mortality rate of 27 – 33 deaths per 1 000 live births.(58) Diarrhoea, pneumonia and HIV infection remain the most important causes of death outside of the neonatal period.(58) Maternal care also places a demand on the health services shown by the growth rate for the female population is lower than the male population, but as a finite number there are still more females than males in South Africa as per the census.(35) The estimated maternal deaths is 135 per 100 000 population in South Africa stating a significant at risk female population requiring urgent intervention.(59) Maternal compromise can occur at any time but most emergencies occur in the perinatal period.(59) By this time in the management the female patients are often admitted to obstetric wards however some patients can present to the ED. Due to the low risk of radiation to the foetus (0.001-0.01mGy) with regards to CT head imaging, this diagnostic tool can be performed during pregnancy however the teratogenicity of contrast in the first trimester is unknown (Category B drug in Pregnancy).(60) CT head imaging is, therefore, not a common diagnostic tool used in the emergency setting in the maternal and child category of the quadruple burden of disease. .

1.6.5 Non-communicable diseases

As one ages, the likelihood of increase in comorbidities is noted.(61) Non-communicable diseases are expected to increase as the estimated annual population growth rate of people older than 60 years is greater (3.04) than the 15-34 years age group growth rate (0.85).(35) South Africa has an accelerated older population growth rate shown by year-on-year values, therefore, increasing the likelihood of non-communicable diseases. In a large sample study of non-communicable diseases in a primary health care setting, hypertension was the most common encountered (13.1%) communicable disease, followed by type 2 diabetes mellitus (3.9%), osteoarthritis (2.2%), asthma (2.0%), epilepsy (1.9%) and chronic obstructive pulmonary disease (COPD) (0.6%).(62) According to the WHO in 2014, 26.8% of South Africans were obese.(62) Metabolic syndrome can accompany obesity which includes hypertension, diabetes type 2 and dyslipidaemia. A patient consulting a health care facility can have multiple non-communicable morbidities noted to be approximately 14.4% of patients.(62) Non-communicable diseases are common, and a patient can have multiple comorbidities, therefore, increasing their risk factors for disease.

In the South African setting, when considering the burden of non-communicable diseases, major adverse events like stroke produces a great burden. Risk factors and aetiology of stroke are multifactorial. In the USA, stroke is the third leading cause of death behind heart disease and cancer and is the leading cause of long-term disability and morbidity.(48) An estimated 80-85% of strokes are infarction (either thrombosis or embolism), whereas 15-20% of strokes are haemorrhagic.(48) In Pakistan, the prevalence of haemorrhagic stroke noted in this LMIC country was 17.3% (n=177) and 82.7% (n=846) for infarction.(63) Therefore, the findings of the HIC & LMIC countries correlate. In the acute setting of a resource limited unit where CT imaging is not readily available, such as South Africa, it may be of value to be able to predict an infarct or haemorrhagic stroke event. Early prediction could assist in activating fibrinolytic therapy timeously. A study comparing two diagnostic clinical decision tools in predicting the cause of stroke to be haemorrhagic included the Siriraj and Allen scores. The sensitivity of the diagnostic clinical decision tools for the haemorrhagic event was 63% and 49%, respectively.(63) Both scores had high specificity (85% and 84% for Siriraj and Allen scores, respectively) and negative predictive value (92% and 91% for Siriraj and Allen scores, respectively), with an overall accuracy of 81% and 79%, respectively.(63) This type of diagnostic clinical decision tool implementation shows value and can be considered in the South African setting to assist in resource limited emergency care and, therefore, predict aetiology of stroke and possible safe use of fibrinolytic therapy

As noted, there are multiple aetiologies of stroke, therefore, considering the TOAST criteria (trial of acute stroke treatment), one can accurately determine the cause in 70.5% of patients using clinical features, CT scans, electrocardiogram, ultrasonography of the extracranial arteries and transthoracic echocardiography. The causes of stroke were noted to be 22.7% with large artery atherosclerosis, 19.1% with cardioembolic stroke, 26.4% with lacunar stroke, and 1.4% with other or indeterminate aetiology. The remaining patients required transoesophageal echocardiography which elicited cardio embolism as aetiology in 12.5% and 5.1% had atherothrombotic or lacunar aetiology. In addition, 9.5% of patients had a totally negative evaluation.(64) Multiple risk factors of stroke are also well documented and include hypertension, diabetes mellitus, smoking, heart disease, hyper-coagulopathy, sickle cell anaemia and cardiac bruits.(41) In the South Africa setting 11 % of patients with AF-related stroke only have this arrhythmia diagnosed at the time of the stroke, therefore, highlighting this important risk factor (65) in an LMIC setting. Transient ischaemic attacks (TIA) are also a risk factor for stroke development. The ABCD risk score was developed to help risk stratify short term stroke risk in patients with TIA. TIA risk factor for stroke has been defined as 2.55% at two days (95% CI, 1.0 to 5.2), 3.6% at seven days (95% CI, 1.8 to 6.6), and 5.5% at one month (95% CI, 3.1 to 8.9) when validating the ABCD score.(66) Understanding risk factors and considering aetiology can better help the emergency physician in managing the patient further.

Risk factors are relevant in the South African setting as they add to the burden of disease that stroke produces and, therefore, impact on the mortality and morbidity of the population. One recalls that Chunga et al (2019) reports that with regards to emergency access to imaging of the brain, 81% of LMICs had access to CT scans (4), with 84% of them having 24-hour access to radiology services (4), compared to HICs with 83% and 98% respectively.(4) As per the ACLS guidelines with regards to stroke type, CT head imaging is vital to determine an infarct versus a haemorrhage to allow for fibrinolytic therapy in the low risk patient to decrease morbidity and mortality. According to the stroke pathway highlighted by the ACLS protocols, imaging should be complete and reported at 45 minutes once the patient has arrived in the ED.(41) This is to necessitate appropriate time to initiate therapy within 3 hours of symptomatology and 4.5 hours in the selected patients.(41) Since time is of the essence in stroke management this is, therefore, considered an emergency and priority will be given to this CT head imaging that is requested. There is however some disconnect in the consensus regarding the appropriateness of fibrinolytic therapy, but this is beyond the scope of this literature review. If a patient arrives at the ED after the allotted time interval, imaging can be postponed to the next available booking slot, provided the patient is stable, as intervention is no longer urgent, however imaging still helps to exclude other pathology. Stroke is common in the South African ED, as indicated by the South African burden of disease, and it will be of value to note at what time interval the ED is achieving imaging for these patients to decrease morbidity and mortality.

Seizure syndromes are an array of neurological movement disorders. These syndromes can present as index or non-index seizures. Adult index generalised seizure is a common cause of admission in EDs, accounting for nearly 1% of all ED visits (67) and approximately 11-20% of all neurologic ED visits.(68) This places a considerable burden on the ED as well as increasing the need for CT head imaging. Indications can be associated with many different diseases: accidents and injury, communicable, non-communicable and maternal health related disease. There is a male to female predominance of 2:1 with a median age group of presentation of 30-60 years old.(67) It has been noted that one in seven patients with first onset seizures has significant intracranial pathology (69), therefore, the work up on these patients is vital. Keeping this in mind, 68.8% of all patients imaged show no pathology while 31.2% showed some form of pathology (70) however, not all pathology identified was significant pathology (significance is defined as neurosurgical or medical intervention required). Moreover, between the ages of 15 and 30 years, no aetiology was diagnosed in 48.8% of patients. The most prevalent aetiology between the ages of 30 and 60 years was chronic alcohol consumption (29.8%), and for patients older than 60 years it was cerebral vascular infarct (18.2%). The rate of seizures "without a cause" decreased when age increased.(inverse relationship)(67) The following aetiologies have been noted in varying percentages in different studies: vascular (2-27.8%), neoplasm or metastasis (3.4-13.4%), alcohol abuse (19.8%), intoxication (9.3%), infection (0.9-9.2%), sleep or substance deprivation (3.5%), trauma (2.6%), metabolic aetiology (2.6-4.9%) and multiple sclerosis (1.7%).(69); (67) Overall, neuroimaging in adults presenting with an index seizure has resulted in change in management for 9-17% of patients due to the above described pathology identified.(68) It is recommended that urgent imaging is to be considered in the index presentation of seizures.

The majority (78%) of ED visits for seizures were for non-index seizures.(68) According to Salinsky et al, approximately 46% of ED patients receive imaging and only 3% of patients with non-index seizures had change in patient management. Of these patients, it was noted that acute head trauma, prolonged alteration of consciousness, and focal neurologic deficit was associated with an increased yield in pathology identified in CT imaging.(68) With the absence of these three clinical features, the positive yield was 0%, in other words, it is not necessary to image if none of these indications are present. This is echoed by a further study (67) that stated that the rate of cerebral focal lesions diagnosed by CT scan was 81% in patients with an abnormal neurological examination. The necessity of urgent neuroimaging in patients with known non-indexed seizure disorders is uncertain due to the limited study thereof.(68)

Timing of imaging can be confusing, however, CT imaging and EEG, which remain indispensable, will be outpatient procedures when considering seizure work up (67) However, in another study (71) states that all CTs were to be obtained in the EC, then further work up can be done on an outpatient basis. Lesion detection on neuroimaging and EEG abnormalities are the most reliable predictors of a correct diagnosis when considering seizure work up. Patients with spontaneous seizures and no abnormalities on these tests should undergo further examinations such as Magnetic resonance imaging (MRI) and prolonged video-EEG to establisha definite diagnosis.(70)

With regards to the South African setting, (12) related to the HIV population that presents with seizures to the ED has been noted in a study by Moolla, Rajkumar & de Vries, 2015. The standard practice of obtaining a CT head scan before the assessment for infection via a lumbar puncture was investigated and it was noted that 5% of patients had a brain shift which contra-indicated the work up with a lumbar puncture. Seizure presentation were not in isolation as these patients also presented with a decreased level of consciousness, focal signs, headache and neck stiffness. Furthermore, 25% of patients had a space-occupying lesion (SOL) or cerebral oedema. A CD4 count <50 ($p = 0.033$) was to be a statistically significant predictor of patients with SOL and cerebral oedema. Further focal signs ($p = 0.0001$), neck stiffness (p = 0.05), vomiting (p = 0.018) and a Glasgow Coma Scale (GCS) < 15 (p = 0.002) could predict SOL and cerebral oedema. Therefore, even though this population has a high chance of SOL and cerebral oedema, most of them were safe to perform a lumbar puncture. Linked to the above clinical parameters of acute head trauma, prolonged alteration of consciousness, and focal neurologic deficit, neck stiffness and vomiting are further important parameters in the HIV infected population when considering CT head imaging in an urgent setting.(12)

1.7 SUMMARY

The South African emergency physician is faced with an array of medical conditions which present a huge burden on the system. Diagnostic clinical decision tools are available to assist the emergency physician in the diagnosis, management and flow of patients. The South African health care system has limited resources, especially during after-hours periods and because of this the patient population that is of a low- and middle-income background has a greater risk of not receiving imaging. The number of imaging studies is increasing annually resulting in demand outstripping supply. CT imaging is a valuable tool in assessing for intra-cranial pathology. Trauma cases are significantly prevalent with the most common intra-cranial pathology of a single traumatic lesion being an epidural haemorrhage and with multiple traumatic lesions on CT scan being cerebral contusion. Stroke is globally identified as the third most common cause of mortality. In stroke cases, the pathology in HICs and LMICs are aligned with ischaemia being approximately four times more common than haemorrhage. Seizure syndrome also places a significant burden of work on the ED. Index seizures require an extensive and urgent work up, however, a no-index seizure requires a less urgent approach. Young patients that present with index seizures have a higher probability of not having intracranial aetiology, yet this probability decreases inversely with age. The most common causes for index seizures are vascular, neoplasm or metastasis, alcohol abuse, intoxication, infection, and trauma.

When considering the emergency setting resources, the patient, and the pathology, the physician must collate the patient's clinical signs, symptoms and use of diagnostic clinical decision tools to decide if ED CT head imaging is indicated. The mapped data has allowed for identification of evidence gaps as well as evidence saturation related to the type and prevalence of pathology identified by CT in the adult ED patient. Through understanding disease profiles and prevalence of pathology, the ED physician will be more adept at predicting the type of pathology expected to be managed daily. The urgency of imaging is performed on a case-by-case basis with the only true emergency imaging being the acute stroke patient. Moreover, through understanding timing of imaging and the possible multiple pathologies with which the patients can present, the physician can ensure safe disposal of patients thereby assisting in the further management of patients.

CHAPTER 2 | MATERIALS AND METHODS

2.1 INTRODUCTION

Drawing from the understanding gained in the literature review a computed head (CT) head imaging study involving emergency department patients in a South African context was identified as a gap in the literature. The retrospective approach was adopted to obtain a high volume study number. A generalised overview of patient factors and presentation was identified as a key factor to understand the context of patient pathology. A further focused review of the three most common indications for CT head imaging was deemed necessary to assist emergency physicians in understanding the most prevalent conditions in their environment.

2.2 AIMS OF THE THESIS

The overarching aim of this thesis was to conduct a focused study of computed tomography (CT) head imaging in a district level ED in South Africa.

The specific aims of each study were to:

- describe the indications and pathology of CT head studies of all adult patients in a district level ED over a period of one year (chapter 3)
- conduct a sub-group analysis of the three most common indications for CT head studies, including clinical signs and comorbidities (chapter 4)

2.3 STUDY DESIGN

The studies described in this thesis were retrospective, descriptive analyses of data from existing clinical databases.

This study was reviewed and approved by Human Research Ethics Committee of the University of Cape Town (HREC Ref 440/2019). Institutional approval was also obtained from Mitchells Plain Hospital (WC_201907_007) through the National Health Research Database.

2.4 STUDY SETTING AND POPULATION

According to Statistics South Africa, South Africa has an estimated mid-year 2020 population of 59.6 million inhabitants, with the Western Cape population projected provincial share of the total population at 11.3%.(72) In 2016, life expectancy at birth in South Africa was estimated at 59.7 years for males and 65.1 years for females.(35) The Western Cape has a diverse population with 48.8% Coloured, 32.8% African, 15.7% White and 1.0% Indian/Asian inhabitants.(35) The disease profile of the community mirrors the quadruple burden of diseases that is prevalent across South Africa, including non-communicable conditions, mother and child mortality, communicable diseases (TB and HIV/AIDS) and trauma. (42)

This retrospective, descriptive study was conducted at Mitchells Plain Hospital (MPH) in Cape Town, South Africa. MPH is a district hospital in the Mitchells Plain Health District of the Metro Region, which is approximately 32 km from Cape Town's city centre and serves a population of more than 546 000 people.(72) The ED's monthly attendance is approximately 4200 visits, and approximately 38% of these patients are admitted to the inpatient wards.(73)

The MPH radiology department is overseen by one permanently employed radiologist and serves approximately 400 inpatients. CT imaging is only performed during office hours (from 08h00 to 16h00) on weekdays, and approximately five slots are available to the ED during the working day for any emergency CT imaging. Emergency or very urgent CT imaging outside of these times requires transfer to a tertiary hospital, 20 kilometres away. To minimise unnecessary imaging and patient transfer, the current practice at Mitchells Plain Hospital, is that all CT imaging requests are reviewed for approval by consultants of the various departments.

2.5 SAMPLING:

2.5.1 Inclusion criteria

All adult patients (18 years of age or older) who presented to MPH ED and who had a CT head study performed between 1st of June 2018 and 31st of May 2019 (one year) were eligible for inclusion. This includes both emergency and outpatient CT head studies. Only radiologist reported scans were eligible for inclusion.

2.5.2 Exclusion criteria

No minors (less than 18 years of age) were included in this study. CT head imaging ordered by other departments within MPH and GSH and not directly from the ED were not included in this study. Imaging studies not reported by a radiologist were excluded from the study.

Cases were excluded if patients' clinical data were missing or inaccessible. The number of missing cases is described in chapter 3. The investigator made every effort to source missing data, including meeting with ECM or PACS administrators to locate missing/lost data.

2.6 DATA COLLECTION PROCEDURES

All data were retrospectively extracted from the following existing clinical

databases: Enterprise content management (ECM)

This is an electronic archiving system referenced by the patients' allocated hospital numbers, containing scanned copies of patients' clinical notes of previous encounters/admissions to hospital, some test results, medication prescribed and discharge summaries.

Hospital and Emergency Centre Tracking Information System (HECTIS)

This is an electronic register of all patients that are managed in the ED. It includes information regarding patient demographics, location within the EC, ICD-10 diagnostic codes, and process times. This electronic application also integrates the South African Triage Scale (SATS).

Picture archiving and communication system (PACS)

This programme for medical imaging technology is used primarily in healthcare organisations to securely store and digitally transmit electronic images and clinically relevant reports. Patient's name, date of birth, date of examination and image modality were used to identify the relevant information.

The following categories of data were collected for each study participant: demographic descriptors, clinical signs, indication for imaging, pathology identified on CT report and time delays (timestamps) in the ED. Data collection took place in in two phases as described below. Hospital folder numbers were used to identify patients and link the phases of the data collection period.

Phase 1:

The list of patients who received CT head imaging during the study period was obtained from the MPH PACS system. All patients were scrutinised against the specified inclusion and exclusion criteria. The following information was collected in phase 1: Folder number, radiology report, outpatient or Emergency study, time of request, time of study, time of report, and indication as documented on request form.

The CT indication were categorised per patient into one of the following: trauma; stroke, seizures, focal neurology, altered mental state, raised intracranial pressure, psychotic symptoms, mood changes, suggestive space occupying lesion, subarachnoid haemorrhage, hydrocephalus, orbital cellulitis, and/or cerebellar signs.

The Clinical signs were categorised from the CT report and ECM clinical notes at time of access to the emergency department. These were categorised as: altered mental status, motor focal neurology, headache, seizures-generalised, cranial nerve focal neurology, cerebellar focal neurology, history of loss of consciousness, >20minutes, More than or equal to 2-episode vomiting, skull fracture, psychosis, seizures-focal, aphasia, soft tissue injury, sensory focal neurology, gaze palsy and racoon eye sign.

CT report pathology was categorised as one of: old pathology only, new pathology, existing pathology. These categories were filled by observing the comment given by the radiologist. If words like chronic or old were used then this would be listed under the 'old pathology' category. If words like unchanged or persistent were used the this would be listed under the existing pathology. If none of these words were used then it would be identified as new pathology. This was reviewed by a qualified medical doctor.

New pathology was categorised as one of: infarction; space occupying lesion, fracture; traumatic haemorrhage; non-traumatic haemorrhage; oedema; hydrocephalus, soft tissue injury, aneurysm, intracranial infective, extracranial infection or metastasis.

Phase 2:

Hospital folder numbers were used to identify matching records in HECTIS. Demographic data such as age, gender, process times (time of initial ED arrival, time of consultation by doctor disposition time and time of discharge from EC), and type of disposition were extracted from HECTIS. ECM was used to corroborate and crosscheck if any variables were missing or incomplete, or if additional information was necessary. ECM was also used to identify time of CT performed. Detailed analysis was performed on the three most prevalent CT head indications and additional variables, including comorbidities and clinical signs, were sourced from clinical records on ECM.

2.7 STATISTICAL METHODS

Data are presented using descriptive statistics. Continuous variables, such as age, are presented as medians while categorical variables are presented as proportions and distributions as appropriate. Where appropriate, 95% confidence intervals (CI) for point estimates are provided. Statistically significant differences between groups (categorical variables) were calculated by using the Fisher's exact test or the Chi^2 test, depending on the sample characteristics. Statistical significance was accepted at $p<0.05$. A detailed sub-group analysis of the three most prevalent indications that require CT head imaging on presentation to the ED was conducted.

CHAPTER 3 | COMPUTERISED TOMOGRAPHY HEAD UTILISATION IN A DISTRICT LEVEL EMERGENCY DEPARTMENT: A DESCRIPTIVE ANALYSIS OF INDICATIONS AND PATHOLOGY

3.1 PROBLEM STATEMENT

The South African health system is faced with a quadruple burden of disease, which includes communicable diseases (HIV/AIDS and tuberculosis); non-communicable diseases; maternal and child mortality, as well as trauma.(1) An ED is the point of first contact for most patients and, therefore, requires appropriate diagnostic clinical decision tools to manage patients according to evidence based guidelines. Special investigations are often required in the process of diagnostic reasoning. A computed tomography (CT) study of the head is a frequently requested investigation and evidence-based guidelines to inform appropriate indications are often not available in low resourced settings. In low- to middle-income countries (LMICs), where resources are scarce, careful consideration and patient selection is necessary to ensure cost effective and safe management of patients.

Indications for a CT head comprises of both trauma and non-trauma related pathology. With regards to indications, there are areas of research that have been assessed extensively (such as trauma imaging) (5,11) while other areas require further research to address knowledge gaps (such as work-up of seizures in the HIV positive patient (12)). A more focused assessment of current practice is, therefore, required to understand the type of patient and pathology that present at a district level ED. Thus, a descriptive study to collate and assess the available data describing the type and prevalence of pathology identified by radiologist's reports of CT head imaging in the adult patient in the ED setting is required.

3.2 AIM AND OBJECTIVES

The aim of this chapter is to describe the indications and pathology of CT head studies of all adult patients in a district level ED over a period of one year.

The specific objectives were:

1. To describe the demographics of all adult patients who received CT head imaging during the study period.
2. To describe the indications for CT head studies for all adult patients.
3. To describe the radiologist reported pathology for all CT head studies.
4. To calculate the positive yield of pathology on CT head imaging as reported by a radiologist.
5. To describe the timing of CT head imaging, with regards to whether the study was performed as Emergency or outpatient, urgent or elective.

6. To describe the disposition plans (outcomes) for patients who received Emergency CT head studies.
7. To describe the time delays of CT head studies (from time of request to CT being performed) and reports (from time of request to time of report).

3.3 RESULTS

3.3.1 Participant characteristics and demographics

A total of 729 participants were included in the study after assessing 1 113 patient records for eligibility at the beginning of the data collection process. A total of 376 (34%) met the exclusion criteria and eight (<1%) were excluded due to missing/incomplete data. Figure 1 details the included and excluded participants. CT head imaging was categorised into emergency (less than 24-hours from consultation), urgent (24-hours to one week) and elective (greater than one week).

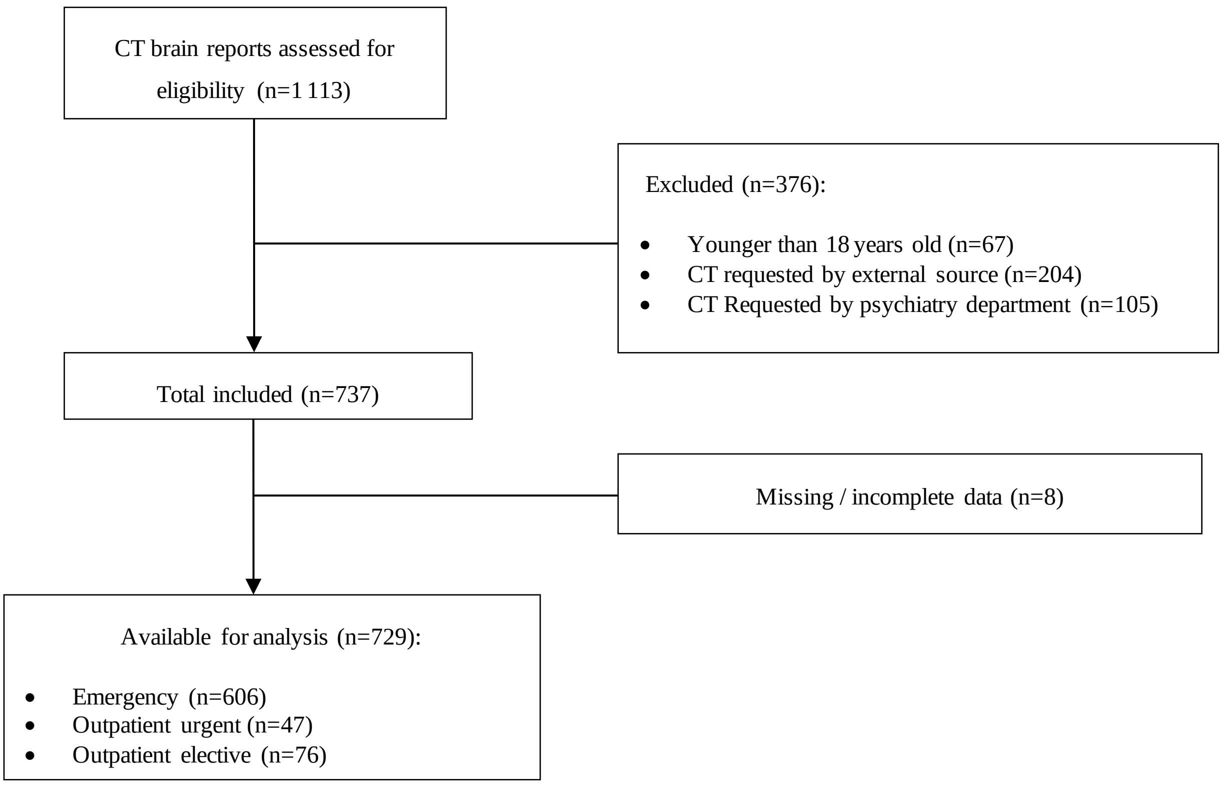

Figure 1: Flow diagram of study participants

The age distribution of patients was skewed to the right with a Shapiro-Wilk p-value of 0.97 (Figure 2). The median age of patients was 47 years of age with a range between 18 and 91 years of age. The median age of male patients that received imaging was 43 years (18-91) of age and female patients was 49 years (19-91). As depicted in Figure 2, male patients predominated in the younger age categories, especially for emergency imaging. Female patients were more evenly distributed across all age groups but dominated the older age groups. As noted from Figure 2, there was an insignificant difference in distribution of patients across age categories (p=0.55) and between males and females (p=0.98) with regards to urgency of CT-head imaging.

The age category with the highest proportion CT head studies in the emergency setting was the 26–35-year-old (21%) and 36-45-year-old (23%) groups (Table 2). The age category with the highest proportion of CT head studies in the outpatient setting was the 46-55 years age group, accounting for 21% or urgent and 29% of elective CT head studies, respectively.

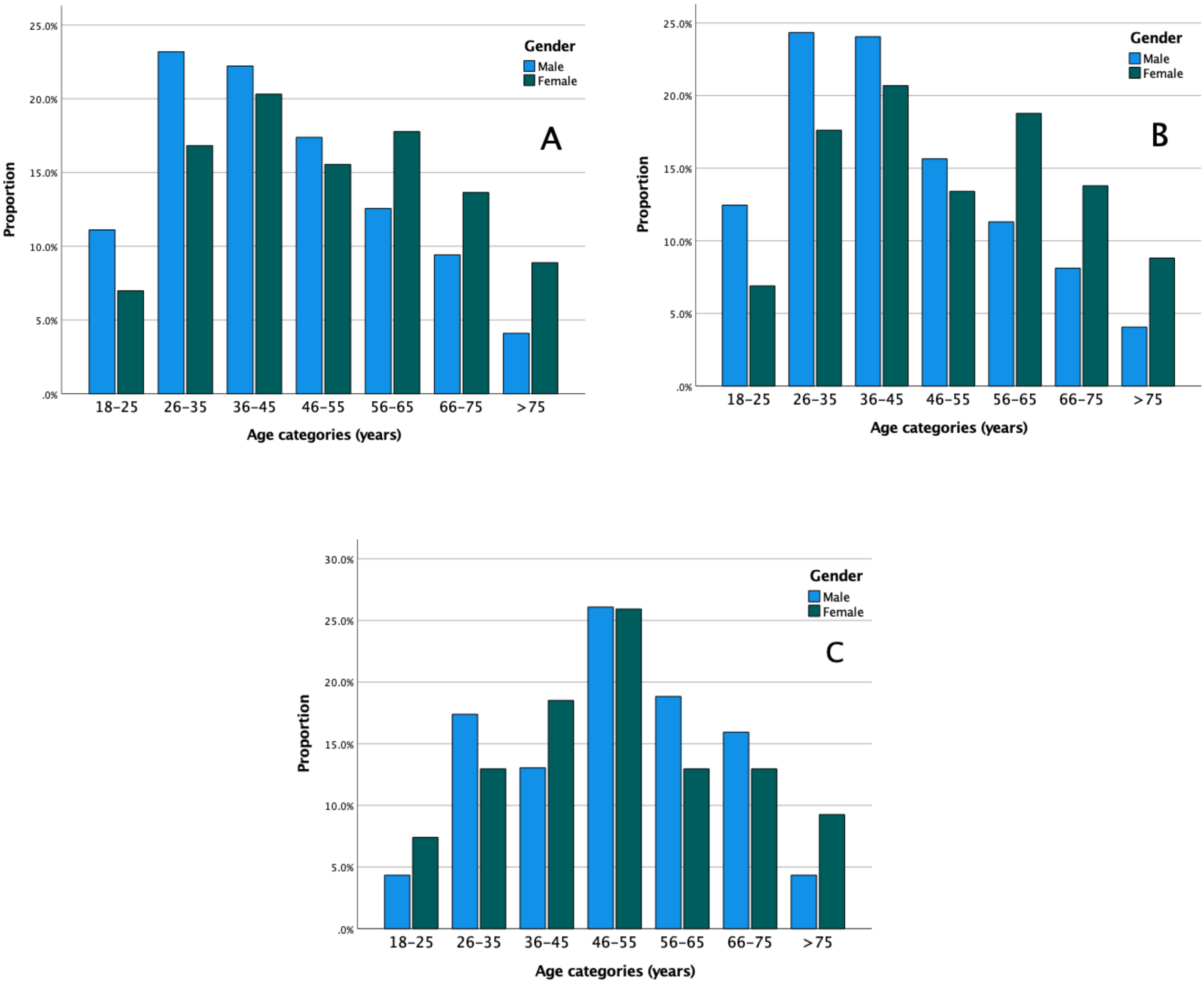

Figure 2: The age distribution and gender categories of (A) all patients, and patients requiring (B) emergency and (C) outpatient CT head imaging

Table 2: Demographics of patient sample categorised by CT head imaging urgency

n (column%)	All patients (n=729, 100%)	Emergency imaging (n=606, 83%)	Outpatient urgent imaging (n=47, 6%)	Outpatient elective imaging (n=76, 11%)	p-value
Gender					
Male	414 (57%)	345 (57%)	26 (55%)	43 (57%)	0.98
Female	315 (43%)	261 (43%)	21 (45%)	33 (43%)	
Age					
18-25	70 (10%)	61 (10%)	4 (9%)	5 (7%)	0.55
26-35	147 (20%)	130 (21%)	8 (17%)	9 (12%)	
36-45	156 (21%)	137 (23%)	5 (11%)	14 (18%)	
46-55	121 (17%)	89 (15%)	10 (21%)	22 (29%)[A]	
56-65	108 (15%)	88 (15%)	8 (17%)	12 (16%)	
66-75	82 (11%)	64 (11%)	9 (19%)	9 (12%)	
>75	45 (6%)	37 (6%)	3 (6%)	5 (7%)	

A Statistically significantly higher proportion than Emergency category ($p<0.05$)

On average, emergency CT head scans occurred just under seven hours after initial consultation in the ED (Table 3), whereas outpatient scans took substantially longer. Urgent outpatient scans occurred on average 57 hours and 45 minutes after the initial consultation with the elective imaging occurring on average 27 days after the initial consultation. Due to the retrospective nature of this study, the time of CT request to the time of CT report could not be identified due to the former being a paper-based request and the latter being a digitised report. These two systems did not link as time documentation of paper-based requests were not appropriately recorded. Therefore, the time to CT was used as the time the CT imaging was performed.

Table 3: Mean time delay with regards to CT imaging obtained and discharge of patients from the Emergency Department

	Emergency imaging (minutes)	Outpatient imaging-urgent (minutes)	Outpatient imaging-elective (minutes)
Average time to CT (minutes, Std. Dev.)	415 (±353)	3 465 (±2 436	39 313 (±24 190)
Minimum-maximum time to CT (hh:mm)	00:01 – 23:51	24:03 – 165:02	188:22 – 3587:27
Average time to discharge (minutes, (Std. Dev.))	614 (±445)	817 (±963)	287 (±277)

3.3.2 Yield of pathology identified on CT head imaging.

The age group with the highest yield of new pathology was the 36–45-year-old group (46%), and the age group with the highest yield of existing pathology were the >75-year-olds (40%) (Table 4).

The five most common comorbidities were hypertension (23%), HIV (18%), diabetes mellitus (10%), smoking (7%) and epilepsy (7%) (Table 4). The six most common comorbidities with new pathology yield in descending order were hypertension (30%), HIV (18%), diabetes mellitus (13%), dyslipidaemia (7%), epilepsy (7%) and smoking (7%)The five most common comorbidities with existing pathology in descending order were hypertension, diabetes mellitus, HIV, epilepsy andsmoking. The distribution of hypertension was significantly different across the three groups ($p < 0.05$).

Table 4: Age, gender and comorbidities associated with yield of pathology identified on CT head imaging

n (row) %	Total patients 729 (100%)	New pathology (n=292,40%)	Existing pathology (n=133,18%)	No Pathology (n=304,42%)	P-value
Gender					
Male	414 (57%)	176 (43%)	74 (18%)	164 (40%)	0.424
Female	315 (43%)	119 (38%)	59 (19%)	137 (44%)	
Age					
18-25	70 (10%)	39 (44%)[B]	3 (4%)	36 (53%)[B]	**<0.001**
26-35	147 (20%)	65 (44%)	23(15%)	61 (41%)	
36-45	156 (21%)	71 (46%)[B]	11 (7%)	74 (47%)[B]	
46-55	121 (17%)	39 (32%)	33 (27%)[A]	49 (41%)	
56-65	108 (15%)	42 (39%)	21 (19%)	45 (42%)	
66-75	82 (11%)	35 (43%)	24 (29%)[C]	23 (28%)	
>75	45 (6%)	14 (31%)	18 (40%)[AC]	13 (29%)	
Comorbidities					
Hypertension	166 (23%)	87 (38%)	56 (25%)	85 (37%)	**0.011**
HIV	132 (18%)	52 (37%)	22 (16%)	68 (48%)	0.198
Diabetes Mellitus	72 (10%)	37 (40%)	23 (25%)	33 (36%)	0.168
Smoking	50 (7%)	19 (37%)	13 (25%)	20 (39%)	0.423
Epilepsy	48 (7%)	20 (42%)	9 (19%)	19 (40%)	0.222
Dyslipidaemia	39 (5%)	21 (53%)	9 (23%)	10 (25%)	0.098
Active TB	32 (4%)	12 (39%)	5 (16%)	14 (45%)	0.895
Mental health condition	15 (2%)	9 (33%)	6 (22%)	12 (44%)	0.718
Malignancy	9 (1%)	5 (36%)	2 (14%)	7 (50%)	0.793
Obesity	6 (1%)	32 (40%)	0 (0%)	3 (0%)	0.510
Atrial fibrillation	3 (0%)	0 (0%)	1 (33%)	2 (37%)	0.356
DVT on Warfarin	3 (0%)	0 (0%)	0 (0%)	3 (100%)	0.077
Valve replacement	2 (0%)	0 (0%)	2 (67%)	1 (33%)	0.117
Cardiomyopathy	1 (0%)	0 (0%)	0 (0%)	1 (100%)	0.491
SLE	1 (0%)	0 (0%)	0 (0%)	1 (100%)	0.491
RA	1 (0%)	0 (0%)	0 (0%)	2 (100%)	0.240

Patients may have more than one comorbidity
A Statistically significantly different proportion to New Pathology category ($p<0.05$)
B Statistically significantly different proportion to Existing Pathology category ($p<0.05$)
C Statistically significantly different proportion to No Pathology category ($p<0.05$)

3.3.3. Clinical signs of patients requiring CT head imaging in the emergency setting.

The five most common clinical signs were altered mental status (23%), motor focal neurology (16%), headache (13%), seizures-generalised (11%) and cranial nerve focal neurology (9%) (Table 5). The clinical signs with the highest yield of new pathology were soft tissue injury (56%), sensory focal neurology (53%), aphasia (50%), racoon eye sign (50%) and cranial nerve-focal neurology (47%). The clinical signs with the highest yield of existing pathology were headache (21%), cranial nerve focal neurology (20%), seizures-generalised (19%), altered mental state (17%) and motor focal neurology (17%). Of importance, the clinical signs that most commonly yielded no pathology were altered mental status (44%), motor focal neurology (42%), headache (34%), generalised seizures (37%) and cranial nerve focal neurology (33%). The proportion of patients with cerebellar signs who had new pathology on CT head imaging was statistically higher when compared to those patients with existing pathology on CT ($p<0.05$) and the distribution was significantly different across the three categories

3.3.4 Clinical indications of patients requiring CT head imaging in an emergency setting.

The most CT head scans were performed to diagnose a stroke (32%). This is followed closely by trauma (30%) and then seizures (16%). The most common indication for emergency CT head is trauma (37%), for outpatient urgent (32%) and elective imaging (47%) this was CVA/intracranial haemorrhage in both categories. Of note focal neurology, altered mental state, trauma and CVA/intracranial haemorrhage showed more pathology when performed in the emergency setting as opposed to outpatient urgent setting. Seizures and headaches have the reverse relationship to the above.

The overall yield of new pathology is 40% of all CT head imaging requested by the ED. The yield of new pathology identified in an emergency CT head imaging is noted at 42% of all emergently requested CT brains, 26% of urgent outpatient imaging and 32% of elective CT head imaging. Of note cumulatively existing pathology noted for 18% of imaging. Therefore, the cumulative yield of pathology is the sum of new and existing pathology which is 58% of all CT head imaging requested in the ED. The distribution of emergency CT head imaging is significantly different across the three categories ($p>0.001$).

Table 5: The clinical signs of patients and associated yield of pathology identified on CT head imaging

N (row %)	Total N=1183 (100%)	New pathology n=493, 42%	Existing Pathology n=228, 19%	No pathology n=462, 39%	P value
Altered mental status	273 (23%)	108 (40%)	46 (17%)	119 (44%)	0.573
Motor focal neurology	191 (16%)	77 (40%)	33 (17%)	81 (42%)	0.899
Headache	148 (13%)	67 (45%)	31 (21%)	50 (34%)	0.114
Seizures-generalised	129 (11%)	56 (43%)	25 (19%)	48 (37%)	0.583
Cranial nerve focal neurology	106 (9%)	50 (47%)	21 (20%)	35 (33%)	0.165
Cerebellar focal neurology	61 (5%)	21 (34%)	20 (17%) [AC]	20 (33%)	**0.009**
History of loss of consciousness > 20minutes	55 (5%)	21 (38%)	11 (20%)	23 (42%)	0.913
More than or equal to 2-episode vomiting	51 (4%)	17 (33%)	9 (18%)	25 (49%)	0.474
Skull fracture	38 (3%)	16 (42%)	11 (29%)	11 (29%)	0.134
Psychosis	31 (3%)	14 (45%)	3 (10%)	14 (45%)	0.450
Seizures-focal	29 (2%)	12 (41%)	6 (21%)	11 (38%)	0.910
Aphasia	20 (2%)	10 (50%)	2 (10%)	8 (40%)	0.539
Soft tissue injury	18 (2%)	10 (56%)	4 (22%)	4 (22%)	0.244
Sensory focal neurology	17 (1%)	9 (53%)	1 (6%)	7 (41%)	0.345
Gaze palsy	10 (8%)	2 (20%)	4 (40%)	4 (40%)	0.158
Racoon eye sign	6 (1%)	3 (50%)	1 (17%)	2 (33%)	0.888

A Statistically significantly different proportion to New Pathology category ($p<0.05$)
B Statistically significantly different proportion to Existing Pathology category ($p<0.05$)
C Statistically significantly different proportion to No Pathology category ($p<0.05$)

Table 6: The indications of patients and associated yield of pathology on CT head imaging

	CT indications n (row %)	Total n=729 (100%)	New pathology n=292(40%)	Existing Pathology n=133(18%)	No pathology n=304(42%)
Emergency imaging	**Trauma**	209 (29%)	101 (48%)A	20 (10%)	88 (42%) A
	Stroke	185 (25%)	100 (54%) C	31 (17%)	54 (29%)
	Seizures	85 (12%)	17 (20%)	31 (37%) B,C	37 (44%) B
	Altered mental	80 (11%)	24 (30%)	8 (10%)	48 (60%) A,B
	Focal neurology	18 (2%)	9 (50%)	2 (11%)	7 (39%)
	Headaches	14 (0%)	3 (21%)	4 (29%)	7 (50%)
	Subarachnoid	11 (2%)	3 (27%)	1 (9%)	7 (64%)
	Cerebellar signs	3 (0%)	1 (33%)	1 (33%)	1 (33%)
	Orbital cellulitis	1 (0%)	1 (100%)	0 (0%)	0 (0%)
Subtotal		606 (83%)	256 (42%)	98 (16%)	252 (42%)
Outpatient- urgent imaging	**Stroke**	15 (2%)	6 (40%)	4 (27%)	5 (33%)
	Seizures	10 (1%)	1 (10%)	4 (40%)	5 (50%)
	Altered mental	9 (1%)	0 (0%)	2 (28%)	7 (78%)
	Trauma	6 (1%)	2 (33%)	1 (17%)	3 (50%)
	Headaches	4 (1%)	1 (25%)	1 (25%)	2 (50%)
	Focal neurology	2 (0%)	1 (50%)	0 (0%)	1 (50%)
	Subarachnoid	1 (0%)	1 (100%)	0 (0%)	0 (0%)
Subtotal		47 (6%)	12 (26%)	12 (26%)	23 (48%)
Outpatient – routine imaging	**Stroke**	36 (5%)	14 (39%)	11 (31%)	11 (31%)
	Seizures	25 (3%)	4 (16%)	8 (32%)	13 (52%)
	Altered mental	5 (1%)	2 (40%)	3 (60%)	0 (0%)
	Headaches	4 (1%)	2 (50%)	0 (0%)	2 (50%)
	Focal neurology	4 (1%)	1 (25%)	1 (25%)	2 (50%)
	Trauma	2 (0%)	1 (50%)	0 (0%)	1 (50%)
Subtotal		76 (10%)	24 (32%)	23 (30%)	29 (38%)

A Statistically significant difference with existing Pathology category ($p<0.05$)
B Statistically significant difference with new Pathology category ($p<0.05$)
C Statistically significant difference with no Pathology category ($p<0.05$)

3.3.5 Pathology identified on CT head imaging.

The top five most diagnosed pathologies (Table 7) in the emergency setting in descending order were stroke-infarct (38%), fracture (14%), soft tissue injury (13%), trauma-intra-cranial haemorrhage (11%) and space occupying lesion (10%). Of note, cerebral oedema was statistically significant in outpatient elective imaging when compared to emergency CT head imaging. p-value <0.05). Cerebral oedema and intracranial infection had a significantly different distribution between the three groups. (p <0.05) Both were significantly more prevalent in the emergency groups (p<0.05).

Table 7: The type of pathology identified on imaging in relation to timing of CT head imaging

N (row %)	Total n= 336 (100%)	Emergency imaging n=282 (83%)	Outpatient-urgent imaging n= 17(5%)	Outpatient-routine imaging n=37 (13%)	P value
Stroke-Infarction	127 (38%)	108 (85%)	8 (6%)	13 (10%)	0.980
Fracture	47 (14%)	40 (85%)	2 (4%)	5 (11%)	0.501
Soft tissue injury	41 (13%)	37 (88%)	2 (5%)	3 (7%)	0.674
Traumatic intracranial haemorrhage	38 (11%)	32 (84%)	0 (0%)	6 (16%)	0.400
Space occupying lesion	33(10%)	28 (85%)	3 (9%)	2 (6%)	0.601
Hydrocephalus	18 (5%)	15 (83%)	0 (0%)	3 (17%)	0.391
Stroke-Haemorrhage	17 (5%)	13 (77%)	1 (6%)	3 (18%)	0.615
Cerebral oedema	11 (3%)	7 (64%)	0 (0%)	4 (36%) A	**0.015**
Intracranial infection	2 (0%)	1 (50%)	1 (50%) A	0 (0%)	**0.041**
Aneurysm-non-ruptured	1 (0%)	1 (100%)	0 (0%)	0 (0%)	0.903
Extracranial infection	1 (0%)	1 (100%)	0 (0%)	0 (0%)	0.903
Metastasis	1 (0%)	1 (100%)	0 (0%)	0 (0%)	0.903

A Statistically significant difference with emergency imaging category (p<0.05)

3.4 DISCUSSION

The most important finding in this study demonstrated that CT head imaging in the emergency department had a high yield of pathology of 58% (new 40% and existing 18%). According to international standards this is considered not to align with HIC trends of 39% of overall scans being abnormal.(37) Taking these values into consideration in a LMIC, like South Africa, the emergency physician may consider the use of more precise clinical judgement to select patients to receive a CT head in order to conserve their resources and therefore the yield of imaging would be higher. Another South African study that analysed all types of CT scans in an ED demonstratedan overall 53.8% positive rate for pathology (non-trauma positive yield rate was 61.8% compared with the trauma positive yield rate of 47.1% ($p<0.001$).(36) This study was not CT head specific but suggestsa correlation with yield of pathology as the majority (58%) of CT imaging done in this study were CT head imaging. The reason for this HIC LMIC mismatch may be due to the challenges with access to health care. Access challenges result in delayed presentation due to multiple modifiable and non- modifiable factors that impact on the health seeking behaviour of a patient, for example, financial, security, geolocation and understanding of illness to name a few.(34) Access to immediate CT head imaging may not be available in all Eds across South Africa due to resource limitations. With specificreference to access to emergency imaging of the brain, Chunga et al (2019) reported that 81% of LMICsin Africa had access to emergency CT scans.(4) In South Africa, there is a discrepancy in availability of CT imaging between the public and private sector of 1.71 per million population and 20.7 units per million population, respectively.(3) This demonstrates a supply-demand mismatch that is less in favour of the public health sector.(35) These concepts of access are of value to highlight as even if the patientsovercome pre-hospital barriers of access to the EDs, CT imaging is not always accessible. This could impact on yield as delay in imaging acquisition could result in the persistence of undiagnosed symptomswhich could worsen pathology, therefore, resulting in more positive CT imaging. Further, the personal cost of transport to the health care facility in the impoverished population is a key factor in barriers to access (35) (9) delays presentation to a health care facility. Community factors impact access as in thepure form of the African tradition, decision-making about seeking health care is not an individual's decision in patients and is shared with the family. Family members are guided by how the symptoms are perceived, either a Western illness or an African illness.(73) This demonstrates the pre-hospital barriersto access in a South African context can further impact on yield as patients may present later with temporal worsening of symptoms.

Yield of new pathology has a gender difference of 42% in males and females 37% in females. Galdas et al state that a further delay in males seeking health care when ill is due to the traditional masculine behaviour imparted upon them.(74) This is congruent in our study as there is a high incidence of males obtaining imaging due to trauma (73% of trauma imaging). Trauma is one of the quadruple burdens of disease in South Africa, therefore, the male patient presents predominantly for trauma and less for other ailments demonstrating this masculine trait.(75) Yield with regards to existing pathology was noted to be similar in males and female (18 and 19% respectively).

A CT request can be considered appropriate even though new pathology was not identified, and conversely pathology identified on a CT study can still be identified in an inappropriate study. The appropriateness is fundamentally structured around the indication for the imaging and not the resultant positive percentage yield. American College of Radiology (76,77) assists emergency physicians with appropriateness criteria which countries can use in their setting. However local evidence should adapt these criteria to the current indications and make more specific CT imaging requests based on local trends and pathology. In summary the appropriateness of the study should be judged on clinical indications andnot whether pathology was identified. Therefore, considering the above multifactorial categories of access to imaging yield of pathology is perhaps considered a direct relationship to the barriers placed upon the patient with regards to emergency CT head imaging. Yield of pathology is greatest in LMICs when compared to HIC and access to emergency imaging may be the cause for this differentiation.

The apparent trend of a younger male and an older female patient requiring CT head imaging in the emergency setting correlates with the median age of CT imaging in the emergency department (43 years for males and 49 years for female).(21) The male predominance in emergency CT scans (57%) is congruent with the literature (78) and this is most likely because of the significant trauma burden resulting in traumatic brain injuries. Trauma imaging in males constitute 38% of all CT head imaging in the ED in this study. The female predominance of CT head imaging in the older age group is predominantly due to stroke which could correlate with the loss of protective hormones due to menopause (79) and in this study female stroke imaging makes up 15% of all imaging in the ED and 34% of all female imaging.(79) The South African setting has an increasing ageing female population which is harmonious with these ideas.(35,80)

A minority of patients were noted to have multiple comorbidities while others had no comorbidities. This aligns with 25% of patients depicted to have multimorbidity with an age of onset to be 10-15 years earlier in deprived settings compared to affluent settings.(81) The most prevalent comorbidity in our sample population was hypertension (23%). Hypertension affects 26% of the world’s population.(82) Considering the comorbidities in this study there is a variety of pathology noted in patients with comorbidities aligned with metabolic syndrome (hypertension, diabetes mellitus, obesity, and dyslipidaemia).(83) These comorbidities are risk factors for vasculopathy. The most common finding on CT head imaging is a stroke. Stroke is a consequence of vasculopathy, therefore, this is congruent with the above risk factors for vasculopathy. Smoking adds to the risk of vasculopathy of the patient (84) and this is confirmed with the literature that 62% of patients that smoke in this study showed pathology. This is the highest yield of pathology per comorbidity.

Altered mental state was one of the top three clinical signs for imaging and imaging showed a 40% yield (30% new and 10% existing). This is significant as 30-40% of patients would require a full acute assessment to see if urgent medical or surgical attention is necessary. Falgun et al (2016) identified that 22.6% of patient with acute mental status changes yield abnormal intracranial findings which correlates with this study's findings.(85) This higher positive yield value could also suggest that in the South African population the indication of altered mental state may be a subpopulation to further investigate as to identify the prevalence and what pathology is identified. Therefore, altered mental state as an indication shows there is either a lack of CT scans requested for this indication or there is a niche population to be studied further.(85)

The main indications for imaging were stroke (32%), trauma (30%) and seizures (8%) with a proportion of 70% for non-trauma indications and 30% for trauma indicated CT head imaging. The non-trauma indications dominate the indications for CT head imaging. This concept correlates with the literature which showed a further LMIC study from Pakistan, with CT indications of 54.1% for non-traumatic CT head imaging and 46.9% for traumatic indications.(86) Another point is that the overall burden of disease in this study sample was noted to be stroke (17%), trauma (10%) and space occupying lesions (5%) which equated to pathology identified on non-trauma CT head imaging in 59% of non-trauma indicated CT head imaging and trauma identified in 58% of trauma indicated CT head imaging. A study from Pakistan showed 40.7% of non-trauma indicated scans had pathology and 59.3% of trauma studies showed pathology. (86) A further study from South Africa showed non-trauma 61.8% of non-trauma indicated scans had pathology and 47.1% of trauma indicated scan had pathology ($p<0.001$)).(36) Therefore, this demonstrates similarity of imaging yield for non-trauma and trauma related CT head imaging to other LMICs. When one focused on seizure imaging, in total, 20% of patients imaged in the emergency setting for seizures showed new pathology which correlates with the literature.(70) In the emergency setting, at all requested timing of imaging, ischaemic stroke and trauma are the most prevalent pathologies reported on CT head imaging. Considering that the most CT head imaging was performed at age groups 26-35 (21% of all imaging) and 36-45 (23% of all imaging), this suggests that these two pathologies are present at these younger than expected age groups which correlates South African literature showing 15% of stroke in patients below the age of 45 years old.(87) Stroke is the most common pathology identified in any interval of imaging in the study. This is congruent with the common vasculopathy risk factors identified in this study: HIV and hypertension. Cardiovascular disease risk factors are impacting younger populations more than previously thought. In young adults 42% of stroke is secondary to cerebral infarction, the majority due to cardiogenic emboli and premature atherosclerosis.(88) Atherosclerosis is secondary to vasculitis and there are multiple causes of vasculitis for example hypertension and HIV to name a few.(89) South Africa has the highestnumber of people living with HIV in the world (54), therefore, South Africa has a potentially higher population at risk of vasculopathy. A further population at risk of vasculopathy is the patient that smokes tobacco cigarettes.(84) High school going children have a 36.2% annual prevalence rate of tobacco smoking in the Mitchells Plain district. Therefore, by the time the patients are of working age their risk for cardiovascular disease would have increased. Although smoking, active tuberculosis and valvopathies are thought to be common risk factors in the literature (90) these were not found in our study. This could be due to the retrospective study design not appropriately identifying if these risk factors were present This study demonstrated that there is an increased amount of non-trauma indicatedimaging in relation to trauma related imaging, The study did demonstrate in this study sample the risk factors for ischaemic stroke which correlated with the high incidence of stroke identified in the CT headimaging reports.

Trauma pathology, with fractures at 6% and intracranial haemorrhage at 5%, gives a total of 11% contributing to pathology relating to trauma. The study site (district health ED), due to its referral criteria would transfer patients with moderate to severe head injury instead of delaying their urgent specialist management by obtaining imaging. Therefore, minor head injury is more commonly imagedat this level of care. In the international literature minor head injury (according to GCS), has a 10% positive yield of injury identified on CT imaging (51) which correlates with this study's findings. Thereis a noticeable age group of patients over the age of 65 that require imaging in the ED (n=27, 12% of trauma imaging). Due to the brain parenchymal changes of ageing, chronic medication uses and risk of falling these patients are at greater risk of subdural haematomas post-trauma.(91) This study did not differentiate the type of intracranial haemorrhage post-trauma. This demonstrates an appropriate studysample for future subgroup analysis. Trauma, stroke and seizures are common indicators for CT imaging with varying yield of pathology.

The mean waiting time from consultation to emergency CT head reports were approximately seven hours, outpatient urgent imaging 58 hours, and outpatient elective at 655 hours. These values show an ascending order of amount of time to wait which is in keeping with the inverse nature of the urgency of imaging. In the USA, in a HIC, the average time from requesting CT to the radiologist report is 5 hours and 54 minutes.(92) In this study the concern for emergency imaging is of importance when the most common documented pathology is an ischaemic stroke. Patients that present with acute stroke and require emergent thrombolysis to decrease the chance of sequela require to do so within the stroke windowof three hours from onset of symptoms or 4.5 hours in specific cases.(41,92,93) The seven-hour time delay can also be concerning for patient with traumas if a patient requires urgent neurosurgical evacuation, an extradural haematoma for example. By improving CT acquisition times one can assist flow of patients through the ED. It is of value to note that in the USA, a multidisciplinary team were able to reduce the CT waiting time by 1 hour 12 minutes.(92) They recommended that a multi-disciplinary team of physicians, nurses, technicians, transporters, informaticians, and engineers identify barriers and implement technical as well as human-factor solutions, and CT imaging time delay could be reduced to 3-4.2 hours.(92) Visual analysis, communication, automation and education and feedback were four pillars assisting the implementation and longevity of the time reduction.(92) Like any efficient new strategy with regards to reduction in waiting times, such as in our setting, one would agree with Perotte et al (2018) that good communication, automation, feedback and evaluation (92) is necessary.

There is a significant barrier to the flow of patients through the ED noted from the time of consultation to discharge. The average time from consultation to discharge in the emergency CT imaged patient was approximately 10 hours. Bearing in mind that, on average, emergency imaging occurs at seven hours after consultation, there is a three-hour delay till discharge. In the South African setting due to the demand on the prehospital service, this could appear appropriate if the patient is being transferred to a higher level of care. There are multiple factors that could allow for delay like patient factors, doctor decision factors and transport factors. HIC quality indicators state a patient is seen and discharged/transferred from the ED within four hours of admission to the ED. In this study's setting this timing is more than tripled which shows the ability to meet the quality indicator for MPH ED is different. Flow of patients may be hindered however this does not equate to poorer care. Longer waiting times in the MPH ED compared to the HIC ED is suggested to be an area of improvement in the flow of patients.(93)

In summary this study demonstrated that even though yield of pathology was considered high when compared to HIC there was similarity in yield to local and international LMICs. The high yield of pathology may have been due to the challenges faced by the patient to obtaining access to CT head imaging for example financial, security, geolocation and understanding illness to name a few. Trauma and non-trauma indicated pathology yield were similar to other LMICs with the most common indication for imaging to be stroke, trauma and seizures. CT head imaging had on average been performed on a younger male and older female (6 years mean age difference). There was a notable higher proportion of risk factors for vasculopathy for example hypertension and HIV. Waiting times for imaging and discharge from the MPH ED were not in line with HIC however it has been noted to change these times would require a multidisciplinary approach with a variety of clinical and non-clinical stakeholder input.

CHAPTER 4 | COMPUTERISED TOMOGRAPHY HEAD UTILISATION IN A DISTRICT LEVEL EMERGENCY DEPARTMENT: A DESCRIPTIVE ANALYSIS OF THE THREE MOST COMMON INDICATIONS FOR CT HEAD IMAGING

4.1 PROBLEM STATEMENT

Indications for a CT head comprises of both trauma and non-trauma related pathology. Trauma, suspected stroke and seizures are common indications for CT brain requests from the ED.(93) In Chapter 3 it was identified that the three most common indications for CT head imaging were stroke (32%), trauma (30%), and seizures (16%). Due to the frequency of these indications it is justified to explore in more detail the demographics, comorbidities and pathology identified in these patients. A clear understanding of the factors associated with these common indications for CT head studies will help map the type of patient, type of signs and symptoms and type of pathology identified per indication of imaging.

4.2 AIM AND OBJECTIVES

The aim of this chapter was to perform a detailed subgroup analysis of the three most common indications for CT head studies, including the associated clinical signs and comorbidities.

4.3 RESULTS

Stroke (32%), trauma (30%) and seizures (16%) accounted for 78% of the indications for CT head studies in the MPH ED between 1st of June 2018 and 31st of May 2019 (one year). For ease of reference trauma indicated imaging will be discussed first and then non-trauma indicated imaging.

4.3.1 Trauma as an indication for CT head imaging

A total of 217 (32%) patients requiring CT head imaging during the study period, had trauma as the primary indication. The mean age of these patients was 41 years (± 17), and approximately half (47%) of these patients were aged 26-45 years old. The distribution by age of patients obtaining CT head imaging for trauma was different to that for patients with a non-trauma indication (Figure 4), with trauma indicated imaging occurring in younger patients. The majority of trauma indicated imaging occurred in the male population (73%).

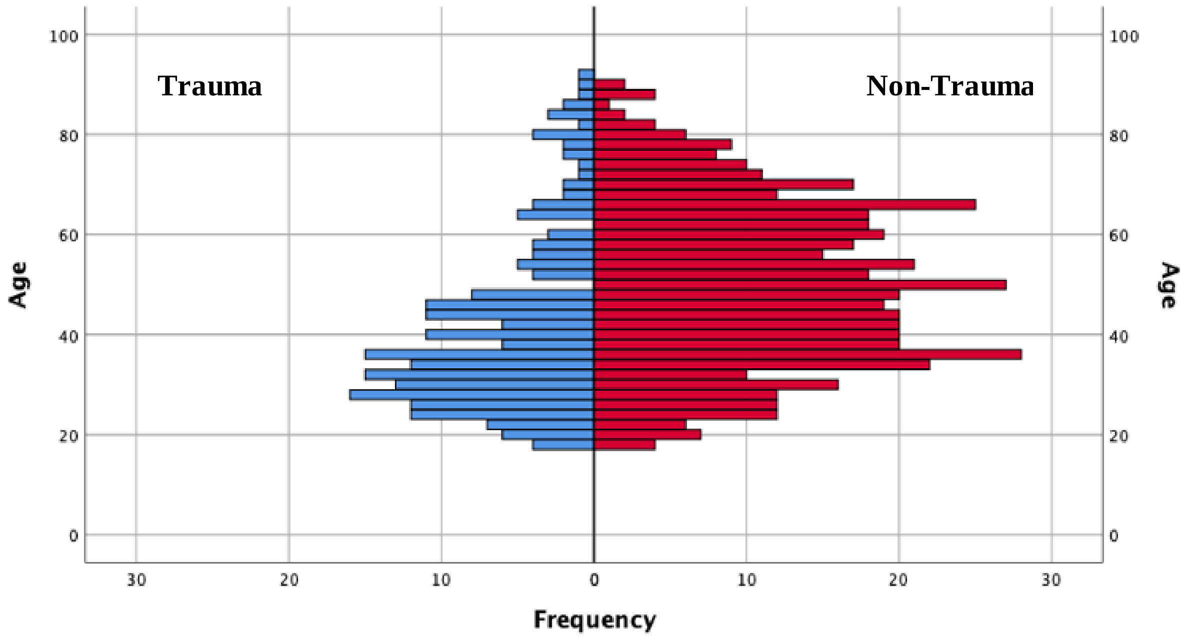

Figure 3: The age group distribution of imaging indicated for trauma and non-trauma CT head imaging

The comorbidities demonstrated in trauma patients are depicted in Table 8. The most common comorbidity is HIV (28%) and then hypertension (26%). Patients with existing pathology had a statistically significantly lower proportion of patient with HPT than those with new pathology on CT brain ($p<0.05$). Epilepsy (12%) and diabetes mellitus (10%) are the next most common comorbidities with similar proportions between the groups of patients demonstrating new pathology, existing pathology and no pathology.

Table 8: The comorbidities of patients with regards to CT imaging for the indication of trauma

N, row%	Total n=165 (100%)	New Pathology n=79 (48%)	Existing pathology n=17 (10%)	No pathology n=69 (41%)	P Value
HIV	46 (28%)	19 (41%)	3 (7%)	24 (52%)	0.294
Hypertension	43 (26%)	22 (51%)	8 (19%)[A]	13 (30%)	**0.041**
Epilepsy	20 (12%)	10 (50%)	1 (5%)	9 (45%)	0.758
Diabetes Mellitus	16 (10%)	8 (50%)	2 (13%)	6 (38%)	0.880
Current Tuberculosis infection	10 (6%)	5 (50%)	0 (0%)	5 (50%)	0.558
Dyslipidaemia	9 (5%)	7 (78%)	1 (11%)	1 (11%)	0.140
Smoking	8 (5%)	3 (38%)	1 (13%)	4 (50%)	0.831
Mental health care user	7 (4%)	4 (57%)	1 (14%)	2 (29%)	0.736
Malignancy	2 (1%)	1 (50%)	0 (0%)	1 (50%)	0.894
Atrial fibrillation	2 (1%)	0 (0%)	0 (0%)	2 (100%)	0.254
Valvopathy on warfarin	1 (1%)	0 (0%)	0 (0%)	1 (100%)	0.505

A Statistically significant difference with no pathology category ($p<0.05$)

The most common clinical signs of patients that were indicated for trauma imaging were altered mental status (21%), motor nerve loss (14%), headache (13%), generalised seizures (12%) and loss of consciousness (6%) (Table 9). However, with regards to new pathology identified on imaging the most common clinical signs in descending order were altered mental state (22%), headache (14%), motor nerve loss (14%), generalised seizures (12%), loss of consciousness (6%) and cranial nerve palsy (6%).

Table 9: The clinical signs observed in patients requiring trauma related CT head imaging

n row %)	Total (n= 347; 100%)	New Pathology (n=170; 49%)	Existing pathology (n=33; 10%)	No pathology (n=144; 41%)	P Value
Altered mental state	74 (21%)	37 (50%)	6 (8%)	31 (42%)	0.821
Motor nerve loss	50 (14%)	23 (46%)	5 (10%)	22 (44%)	0.953
Headache	46 (13%)	24 (52%)	5 (11%)	17 (37%)	0.700
Seizures-generalised	41 (12%)	21 (51%)	3 (7%)	17 (41%)	0.812
Cranial nerve palsy	25 (7%)	10 (40%)	0 (0%)	15 (60%)	0.075
Loss of consciousness	22 (6%)	10 (45%)	2 (9%)	10 (45%)	0.954
Vomiting	19 (5%)	5 (26%)	3 (16%)	11 (58%)	0.134
Cerebellar nerve loss	17 (5%)	9 (53%)	3 (18%)	5 (29%)	0.360
Psychosis	14 (4%)	8(57%)	1 (7%)	5 (36%)	0.770
Skull fracture	12 (3%)	5 (42%)	3 (25%)	4 (33%)	0.180
Seizures-focal	9 (3%)	5 (56%)	1 (11%)	3 (33%)	0.854
Soft tissue injury	6 (2%)	5 (83%)	0 (0%)	1 (17%)	0.204
Sensory nerve loss	4 (1%)	3 (75%)	0 (0%)	1 (25%)	0.520
Aphasia	4 (1%)	3 (75%)	0 (0%)	1 (25%)	0.520
Gaze palsy	3 (1%)	1 (33%)	1 (33%)	1 (33%)	0.377
Racoon eyes	1 (0%)	1 (100%)	0 (0%)	0 (0%)	0.579

Table 10 demonstrates the trauma indicated CT head imaging yield to be 58% (48% new pathology and 10% existing pathology). Of the total CT head imaging for indicated trauma 51% of patients are admitted (39% district health care admission and 12% transferred to higher level of care). This demonstrates a high proportion of patients with trauma indicated scans require admission. In all subcategories, 94-100% of imaging is performed in the emergency setting. Of all patients imaged for trauma indicated CT head imaging the highest proportions of pathology were ischaemic stroke (13%), fracture (9%), traumatic haemorrhage (8%) and soft tissue injury (7%).

Table 10: The yield of pathology identified on CT head imaging for the indication of trauma

N (row %)	Sub-criteria	Total n= 217 (100%)	Emergency imaging n=217 (96%)	Outpatient-urgent imaging n=6 (3%)	Outpatient-routine imaging n= 2 (1%)	P Value
Yield	**Existing pathology**	21 (10%)	20 (95%)	1 (5%)	0 (0%)	0.926
	New Pathology)	104 (48%)	101 (97%)	2 (2%)	1 (1%)	
	No pathology	92 (42%)	88 (96%)	3 (3%)	1 (1%)	
Disposal	**Discharge**	98 (44%)	95 (97%)	1 (1%)	2 (2%)	0.761
	Admission	85 (39%)	81 (95%)	4 (5%)	0 (0%)	
	Transfer out	27 (12%)	26 (96%)	1 (4%)	0 (0%)	
	Death	1 (0%)	1 (100%)	0 (0%)	0 (0%)	
	Other	6 (3%)	6 (100%)	0 (0%)	0 (0%)	
Pathology	**Stroke-Infarction**	30 (13%)	29 (97%)	1 (3%)	0 (0%)	0.834
	Fracture	20 (9%)	19 (95%)	1 (5%)	0 (0%)	0.739
	Traumatic intracranial haemorrhage	19 (8%)	19 (100%)	0 (0%)	0 (0%)	0.671
	Soft tissue injury	16 (7%)	15 (94%)	0 (0%)	1 (6%)	0.735
	Space occupying lesion	9 (0%)	9 (100%)	0 (0%)	0 (0%)	0.836
	Hydrocephalus (n=8)	8 (4%)	8 (100%)	0 (0%)	0 (0%)	0.853
	Stroke-Haemorrhage	5 (2%)	5 (100%)	0 (0%)	0 (0%)	0.907
	Cerebral oedema	1 (0%)	1 (100%)	0 (0%)	0 (0%)	0.981
	Aneurysm-non-ruptured	1 (0%)	1 (100%)	0 (0%)	0 (0%)	0.981

4.3.2 Stroke as an indication for CT head imaging

A total of 244 (33%) patients requiring CT head imaging during the study period, had stroke as the primary indication. The mean age of these patients was 55 years (± 15), and the majority (54%) of patients in this sub-category were female. The most common comorbidity of patients that were indicated for stroke imaging were hypertension (38%), HIV (17%), diabetes mellitus (15%), smoking (9%) and dyslipidaemia (7%) (Table 11). With a focus on new pathology identified on imaging the most common comorbidities in descending order were hypertension (36%), diabetes mellitus (18%), HIV (18%), smoking (8%) and dyslipidaemia (7%).

Table 11: The comorbidities of patients requiring CT head imaging for the indication of stroke

n (row%)	Total (n= 244; 100%)	New Pathology (n=121; 50%)	Existing pathology (n= 49; 20%)	No pathology (n=74; 30%)	P Value
Hypertension	92 (38%)	43 (47%)	21 (23%)	28 (30%)	0.499
HIV	42 (17%)	21 (50%)	5 (12%)	16 (38%)	0.254
Diabetes Mellitus	37 (15%)	22 (59%)	7 (19%)	8 (22%)	0.449
Smoking	21 (9%)	9 (43%)	5 (24%)	7 (33%)	0.735
Dyslipidaemia	16 (7%)	8 (50%)	4 (25%)	4(25%)	0.821
Epilepsy	10 (4%)	6 (60%)	2 (20%)	2 (20%)	0.778
Current Tuberculosis infection	8 (3%)	5 (63%)	2 (25%)	1 (13%)	0.556
Mental health care user	6 (2%)	2 (33%)	1 (17%)	3 (50%)	0.534
Malignancy	6 (2%)	3 (50%)	1 (17%)	2(33%)	0.973
Obese	3 (1%)	2 (67%)	0 (0%)	1 (33%)	0.685
Valvopathy on warfarin	1 (0%)	0 (0%)	0 (0%)	1 (100%)	0.304
Atrial fibrillation	1 (0%)	0 (0%)	1 (100%)	0 (0%)	0.126
Rheumatoid arthritis	1 (0%)	0 (0%)	0 (0%)	1(100%)	0.304

The most common clinical sign of patients that was indicated for stroke imaging were altered mental status (24%), motor nerve loss (17%), cranial nerve palsy (11%), headache and (11%) generalised seizures (10%) (Table 12). However, with regards to new pathology identified on imaging, the most common clinical sign in descending order were altered mental status (22%), motor nerve loss (16%), cranial nerve palsy (14%) headache (12%) and seizures-generalised (10%). Patients who had a cranial nerve palsy that demonstrated new pathology on CT brain, was proportionally higher than in the no pathology category ($p < 0.05$).

Table 12: The clinical signs in the patient with stroke with regards to yield

n (row %)	Total	New Pathology	Existing	No Pathology	P Value
Altered mental state	95 (24%)	46 (48%)	15 (16%)	34 (36%)	0.191
Motor nerve loss	68 (17%)	34 (50%)	14 (21%)	20 (29%)	0.963
Cranial nerve palsy	45 (11%)	30 (67%) [A]	9 (20%)	6 (13%)	**0.021**
Headache	43 (11%)	24 (56%)	9 (21%)	10 (23%)	0.595
Seizures-generalised	40 (10%)	20 (50%)	5 (13%)	15 (37%)	0.331
Cerebellar nerve loss	20 (5%)	9 (45%)	7 (35%%)	4 (20%)	0.171
Loss of consciousness	15 (4%)	6 (40%)	4 (27%)	5 (33%)	0.648
Vomiting	15 (4%)	8(53%)	4 (27%)	3 (20%)	0.623
Skull fracture	15 (4%)	7 (47%)	4 (27%)	4 (27%)	0.769
Seizures-focal	12 (3%)	6(50%)	3 (25%)	3 (25%)	0.865
Psychosis	7 (2%)	4 (57%)	1 (14%)	2 (29%)	0.923
Aphasia	9 (2%)	5 (56%)	2 (22%)	2 (22%)	0.882
Soft tissue injury	6 (1%)	3 (50%)	2 (33%)	1 (17%)	0.620
Sensory nerve loss	6 (1%)	4 (67%)	1 (17%)	1 (17%)	0.712
Gaze palsy	4 (1%)	1(25%)	2 (50%)	1 (25%)	0.285
Racoon eyes	1 (0%)	0 (0%)	0 (0%)	1 (100%)	0.304

A: Statistically significant with no pathology category ($p < 0.05$)

Table 13 demonstrates the stroke indicated CT head imaging yield to be 70% (51% new pathology and 19% existing pathology). Of the total, 66% of patients are admitted (58% district health care admission and 8% transferred to higher level of care). Of all patients imaged for a suspected stroke, the most prevalent pathology on CT brain were ischaemic stroke (19%), space occupying lesion (6%), soft tissue injury (6%) and fracture (5%). Haemorrhagic strokes were identified in 3% of all stroke indicated CT head imaging. Significant differences were noted in the proportions of patients who were discharged and admitted: a significantly higher proportion of patients requiring emergency imaging were admitted ($p<0.05$) and a higher proportion of patients who received outpatient imaging were discharged ($p<0.05$).

Table 13: The yield of pathology identified on CT head imaging for the indication of stroke

Criteria n, row %	Sub-criteria	Total n=236 (100%)	Emergency imaging n=185 (78%)	Outpatient-urgent imaging n=15 (6%)	Outpatient-routine imaging n=36 (16%)	P Value
Yield	**Existing pathology**	46 (19%)	31 (67%)	4 (9%)	11 (23%)	0.268
	New Pathology	120 (51%)	100 (83%)	6 (5%)	14 (12%)	
	No pathology	70 (30%)	54 (77%)	5 (7%)	11 (16%)	
Disposal	**Discharge**	79 (33%)	43 (54%)	2 (3%)	34 (43%) [A,B]	**<0.001**
	Admission	136 (58%)	122 (90%) [C]	12 (9%) [C]	2 (1%)	
	Transfer out	18 (8%)	17 (94%)	1 (6%)	0 (0%)	
	Death	2 (1%)	2 (100%)	0 (0%)	0 (0%)	
	Other	1 (0%)	1 (100%)	0 (0%)	0 (0%)	
Pathology	**Stroke-Infarction**	44 (19%)	35 (80%)	2(5%)	7 (16%)	0.859
	Space occupying lesion	13 (6%)	10 (77%)	2 (15%)	1 (7%)	0.319
	Soft tissue injury	13 (6%)	10 (77%)	1 (7%)	2 (15%)	0.979
	Fracture	11 (5%)	8 (73%)	1 (9%)	2 (18%)	0.883
	Traumatic intracranial haemorrhage	8 (3%)	6 (75%)	0 (0%)	2 (25%)	0.590
	Stroke-Haemorrhage	6 (3%)	5 (83%)	0 (0%)	1 (17%)	0.811
	Cerebral oedema	5 (2%)	3 (60%)	0 (0%)	2 (40%)	0.273
	Hydrocephalus	5 (2%)	3 (60%)	0 (0%)	2 (40%)	0.273
	Intracranial infection	1 (0%)	0 (0%)	1 (100%)	0 (0%)	**0.001**
	Metastasis	1 (0%)	1 (100%)	0 (0%)	0 (0%)	0.871

A: Statistically significant with emergency imaging category (p value< 0.05)
B: Statistically significant with outpatient urgent imaging category (p value< 0.05)
C: Statistically significant with outpatient elective imaging category (p value< 0.05)

4.3.3 Seizures as an indication for CT head imaging

A total of 118 (16%) patients that required CT head imaging during the study period, had seizures as the primary indication. The mean age of these patients was 44 years (± 16), and the majority (58%) of patients in this sub-category were male. Of the total gender category, 71% of males and 71% of females were imaged in an emergency setting.

The most common comorbidities of patients that were indicated for seizure imaging were hypertension (32%), HIV (19%), diabetes mellitus (14%) and smoking (10%) (Table 14). With a focus on new pathology identified on imaging the most common comorbidities in descending order were hypertension and HIV both (33%) and smoking and epilepsy both (9%). The proportion of patients with hypertension was higher in the existing pathology group, than in those with new pathology ($p<0.05$). Similarly so for the patients with diabetes having a higher representation in the existing pathology group than in the no pathology group ($p<0.05$).

Table 14: The comorbidities of patients requiring CT head imaging for the indication of seizures

n, row %	Total n=118 (100%)	New Pathology n=10 (8%)	Existing pathology n=58 (49%)	No pathology n= 50 (43%)	P Value
Hypertension	38 (32%)	3 (8%)	19 (50%) [A]	16 (42%)	**0.037**
HIV	23 (19%)	3 (13%)	10 (43%)	10 (43%)	0.627
Diabetes Mellitus	16 (14%)	0 (0%)	11 (69%) [C]	5 (31%)	**0.007**
Smoking	12 (10%)	2 (17%)	4 (33%)	6 (50%)	0.945
Epilepsy	7 (6%)	2 (29%)	3 (43%)	2 (29%)	0.603
Current Tuberculosis infection	6 (5%)	0 (0%)	2 (33%)	4 (67%)	0.413
Dyslipidaemia	5 (4%)	0 (0%)	2 (40%)	3 (60%)	0.546
Mental health care user	5 (4%)	0 (0%)	4 (80%)	1 (20%)	0.102
Malignancy	3 (3%)	0 (0%)	1 (33%)	2 (67%)	0.650
Deep vein thrombosis on warfarin	3 (3%)	0 (0%)	2 (67%)	1 (33%)	0.476

A: Statistically significant with new pathology category (p value< 0.05)
C: Statistically significant with no pathology category (p value< 0.05)

The most common clinical sign of patients that was indicated for seizure imaging were altered mental status (26%), motor nerve loss (18%), headache and (15%) seizures-generalised (12%) and cranial nerve palsy (9%) However with regards to new pathology identified on imaging, the most common clinical sign in descending order were altered mental status (26%), headache (26%), seizures- generalised (17%) and motor nerve loss (11%). Of the patients obtaining CT head imaging for seizure indication the patients with headache that had new pathology were statistically significant to the patients with no pathology ($p<0.05$).

Table 15: The clinical signs of patients requiring CT head imaging for the indication of seizures

n, row %	Total n=191 (100%)	New Pathology n=35 (18%)	Existing pathology n=75 (39%)	No pathology n=81 (43%)	P Value
Altered mental state	50 (26%)	9 (18%)	18 (39%)	23 (46%)	0.997
Motor nerve loss	34 (18%)	4 (13%)	11 (32%)	19 (56%)	0.313
Headache	29 (15%)	9 (31%) [A]	12 (41%)	8 (28%)	**0.039**
Seizures-generalised	22 (12%)	6 (27%)	11 (50%)	5 (23%)	0.054
Cranial nerve palsy	17 (9%)	0 (0%)	10 (59%)	7 (41%)	**0.036**
Cerebellar nerve loss	10 (5%)	1 (10%)	5 (50%)	4 (40%)	0.575
Psychosis	6 (3%)	1 (17%)	1 (17%)	4 (67%)	0.534
Vomiting	6 (3%)	1 (17%)	2 (29%)	3 (43%)	0.978
Seizures-focal	6 (3%)	1 (17%)	1 (17%)	4 (67%)	0.534
Skull fracture	3 (2%)	1 (33%)	1 (33%)	1 (33%)	0.784
Aphasia	2 (1%)	0 (0%)	0 (0%)	2 (100%)	0.301
Soft tissue injury	2 (1%)	1 (50%)	1 (50%)	0 (0%)	0.340
Loss of consciousness	2 (1%)	1 (50%)	1 (50%)	0 (0%)	0.340
Sensory nerve loss	1 (1%)	0 (0%)	0 (0%)	1 (100%)	0.551
Gaze palsy	1 (1%)	0 (0%)	1 (100%)	0 (0%)	0.405

A: Statistically significant with no pathology category (p value< 0.05)

The yield of pathology for seizure indicated CT head imaging was 54% (18% new pathology and 36% existing pathology). New pathology yield was noted at 5% in the outpatient urgent imaging and 18% in the outpatient elective setting. Of the patients imaged in the emergency setting with seizures as indication, 45% were discharged, 47% were admitted to the district health care facility and 9% were transferred out to higher facilities. Of note 50% of the patients with new pathology identified on urgent outpatient imagine were admitted and the other 50% discharged. Most (92%) patients receiving outpatient-elective imaging were discharged however 4% were admitted and 4% were transferred to a higher level of care.

The most common pathology identified on seizure indicated CT head imaging were ischaemic strokes (21%), traumatic brain haemorrhage (5%) and soft tissue injury (5%). The most common pathology identified on emergency CT head imaging for trauma was stroke-infarct (26%), soft tissue injury (5%), space occupying lesion and fracture both (4%) traumatic intracranial haemorrhage both (2%) and hydrocephalus (1%). Of the patients obtaining CT head imaging for seizure indication the patients with ischaemic strokes that had no pathology were statistically significant to the patients with new pathology (p-value<0.05).

The distribution of patients who were discharged and admitted was significantly different between the three groups (p=0.001).

Table 16: The yield of pathology identified in the CT head imaging for indicated seizures

n, row %	Sub-criteria	Total n=120 (100%)	Emergency imaging n=85 (71%)	Outpatient-urgent imaging n=10 (8%)	Outpatient-routine imaging n=25 (20%)	P Value
Yield	**Existing pathology**	43 (36%)	31 (72%)	4 (9%)	8 (19%)	0.896
	New Pathology	22 (18%)	17 (77%)	1 (5%)	4 (18%)	
	No pathology	55 (46%)	37 (67%)	5 (9%)	13 (23%)	
Disposal	**Discharge**	66 (55%)	38 (58%)	5 (8%)	23 (35%)^{AB}	**0.001**
	Admission	45 (38%)	39 (87%) C	5 (11%) C	1 (2%)	
	Transfer out	9 (8%)	8 (89%)	0 (0%)	1 (11%)	
	Death	0 (0%)	0 (0%)	0 (0%)	0 (0%)	
	Other	0 (0%)	0 (0%)	0 (0%)	0 (0%)	

Pathology	**Stroke-Infarction**	25 (21%)	22 (88%)	0 (0%)	3 (12%)	0.077
	Traumatic intracranial haemorrhage	6 (5%)	2 (33%)	0 (0%)	4 (67%) [A]	**0.017**
	Soft tissue injury	6 (5%)	4 (67%)	1(17%)	1 (17%)	0.743
	Fracture	5 (4%)	3 (60%)	0 (0%)	2 (40%)	0.486
	Space occupying lesion	4 (3%)	3 (75%)	1 (25%)	0 (0%)	0.324
	Stroke-Haemorrhage	2 (2%)	0 (0%)	0 (0%)	2 (100%)	**0.021**
	Cerebral oedema	2 (2%)	0 (0%)	0 (0%)	2 (100%)	**0.021**
	Hydrocephalus	1 (1%)	1 (100%)	0 (0%)	0 (0%)	0.813

A: Statistically significant with emergency imaging category (p value< 0.05)
B: Statistically significant with outpatient urgent imaging category (p value< 0.05)
C: Statistically significant with outpatient elective imaging category (p value< 0.05)

4.4 DISCUSSION

4.4.1 Trauma as an indication for CT head imaging

Of the 729 patients accessed in the ED for CT head imaging 217 (30%) were indicated due to trauma. This cements trauma and injuries as one of the four aspects of South Africa's quadruple burden of disease model.(94) Patients who required a trauma CT head imaging were predominantly male with an almost 3:1 dominance.(78,95) A total of 55% of all trauma CT head studies were noted in the age group of 26-45 years of age. In LMICs, the literature shows a high trauma burden from age 15-24 years of age.(95) In South Africa it appears that the bulk of trauma imaging occurs at a later stage when compared to other LMICs however still considered in the younger population. CT head imaging utilisation is higher in the younger population which is congruent with the literature.(96) The cumulative yield of pathology for trauma indicated imaging was 58% (new pathology= 48% and existing pathology=10%). There is a second peak in trauma imaging in the elderly which according to Pan et al is in keeping with increased chance of falling and subdural haemorrhage formation.(96) It is of value to note a third of patients >75years olds require imaging secondary to trauma. The elderly patients are also a population at risk. It has been noticed in a recent study that 25.6% of trauma to the elderly was due to assault by a known assailant.(97) Non-accidental injury is a further burden of disease that needs to be considered in this age group. In summary the indications for CT head imaging utilisation have a higher prevalence for trauma in the younger population and less utilisation in the olderpopulation which aligns with LMICs and HICs.

The categorical peak age of patients requiring CT head imaging shows noticeable fewer comorbidities. Hypertension is noted to be significantly more prevalent in this subgroup. (98) There is a noticeably low (10%) number of patients with existing pathology that have comorbidities when compared to the population who have new pathology (48%). This could also be related to the fact that if patients are younger, but also could be due to the fact that patients could be confused on presentation and an accurate history may not be obtained, therefore, documentation of comorbidities may be poor adding to confounding bias. However, if one considers that ischaemic stroke is the most common pathology (14%) identified on a CT scan, comorbidities contributing to a vasculopathy (hypertension, HIV, diabetes mellitus, TB and smoking to name a few) is expected. It is noted that 22.7% of trauma adult patients have three or more comorbidities when being imaged for traumatic head injury.(98) The top three comorbidities demonstrated are hypertension, HIV and epilepsy 40% of patients have one or more comorbidity when confronted with acute trauma (99) and patients with comorbidities have a worse prognosis.(99) This is of importance to ensure blood pressure control in the hypertensive patient that may require permissively higher blood pressure control. It is also of value to note that when the health care worker manages the trauma patient that good protective personal equipment is used to prevent body fluid contact with the HIV infected patient. A further comorbidity to note is that of epilepsy and one can ask the question if the trauma was secondary to epilepsy or was it an incidental comorbidity.

Patients requiring anticoagulation therapy due to an array of comorbidities (valvopathy, pulmonary emboli, clotting disorders) need to access the ED safely. When focusing on anticoagulation therapy risk in trauma it is of value to note that the patient showed no new pathology. This 'blanket statement' cannot bedrawn due to the low study sample however it is an area of interest. A recent HIC study stated that there is a significantly higher chance of patients developing post-traumatic haemorrhage when on antiplatelet therapy than when patients are on anticoagulation therapy.(53) This is an area to consider in the research of this South African population as the population show comorbidities in keeping with metabolic syndrome and the likelihood of antiplatelet use. With regards to anticoagulation therapy *Uccella et al* further confirms that the risk of haemorrhage in the patient on anticoagulation therapy is the same as that of the general population which is confirmed in this study.(53)

Patients with new pathology on trauma imaging had indications for imaging based on altered mental state, headache, motor nerve loss as the top three clinical features. This signs and symptom profile does not align with the high-risk signs and symptom profiled identified in the ATLS and Canadian head CT rule clinical decision tools.(17,19) Those with no pathology on trauma CT head imaging had the following clinical signs most commonly as indication: altered mental state, seizures-generalised and headaches. Considering that the most common finding on a trauma indicated CT head imaging study was a stroke (14%), these clinical signs are well aligned for stroke symptoms (41), therefore, confirming that these common signs are not specific for trauma. The history is often difficult to distinguish between a stroke and neurology secondary to a fall, resulting in an intracranial bleed. Patients often present with a vague history of a fall with subsequent localising signs – more often than not, they had a stroke and then fell – instead of the symptoms being caused by a fall. These details are often not easily extracted from the history and, therefore, many CT scans with a trauma indication, end up demonstrating radiological findings of an ischaemic stroke.

ATLS demonstrate an array of clinical signs suspicious for significant head injury.(19) The clinical sign of racoon eyes showed 0% (n=1) new pathology however this sample was weak, therefore, validation ispoor in this study. Other signs like suspected skull fracture and gaze palsy were equivocal for new, existing and no pathology and further loss of consciousness was further equivocal for new pathology and no pathology. This demonstrates the lack of these clinical signs' specificity for trauma. Taking all the above into account, no clinical sign was more prevalent in those with new pathology and that the clinical signs in this study do not align with expected trauma clinical signs of head injury.

When one considers the urgency of trauma as an acute decompensating process then one can agree that most imaging would be performed in the emergency setting (96%). 97% of new-onset pathology was diagnosed in the emergency setting with a 58% yield (48% new and 10% existing). It is understandable that there was a 46% discharge rate in the emergent setting. Other HIC EDs show an 80% discharge rate however this study encompassed patients being directly discharged from the emergency unit and from the emergency unit observation ward.(100). *Borczuk et al* (2019) further state that of the observed patients 36% were discharged within 24 hours.(100) Patients with a minor head injury and traumatic changes on CT imaging are frequently discharged after a brief observation period (<24hours) without neurosurgical intervention.(101) Safe discharge is always key when regarding patient management and in this study, patients accessing this department are from low to middle income background. If these patients complicate, they may not be able to gain access quick enough if discharged home. Admission to the district setting was noted to be 39%, while transfers out to higher care 12%. Therefore, with these justifications the discharge figure of 46% appears appropriate and aligns with HICs.(100)

Of great interest, the patients presenting to this district care level with trauma in the emergent setting show CT head pathology most commonly of ischaemic stroke (14%). As described above, at the time of presentation, it is often difficult to distinguish whether the symptoms (stroke) resulted in the patient falling or whether the fall (trauma) resulted in the symptoms. Because physicians are unable to rule out a head injury, they often have no choice but to request a CT scan.

The vasculopathy risk factors of stroke due to infarction encompass hypertension and, therefore, the most common comorbidity of hypertension in a trauma patient aligns with the most common finding of stroke on CT head imaging. Further the most common clinical signs of altered mental status, headache and motor nerve deficit align with the patient who could have a stroke. This shows that trauma which initially was thought to be the primary cause of presentation masked the clinical features of stroke. The series of events, therefore, demonstrate that the stroke occurred first and then the trauma was the result of the stroke. CT imaging protocol for trauma would not have depleted the stroke yield of pathology as both suspected stroke and trauma studies are performed initially by non-contrast CT head imaging. The emergency clinician should consider stroke if the neurological findings correlate with stroke in a trauma patient.

As expected, after stroke, the pathology of fracture (9%), traumatic intracranial haemorrhage (9%) and soft tissue injury (7%) are the most common pathology found on all trauma imaging. The type of patient remaining at a district level hospital for work up and management would typically entail the patient with minor head trauma (GCS >12).(19) This aligns with the literature between 6-10% of minor head injury pathology is noted in minor head trauma considering the GCS.(51) 12% of the patients developed cranial nerve palsy when presenting with trauma. Cranial nerves are prone to injury in traumatic brain injury with similar distribution in mild, moderate and severe grade head injury.(52) This study population pathology aligns with those presenting in HIC countries.

This subgroup of patients requiring trauma indicated imaging shows correlation with the literature and highlights that in the different income countries show similarity when encountering the patient with isolated head trauma. Stroke was the most common pathology identified on trauma imaging which is substantiated by the increase in risk factors and clinical signs identified in trauma indicated imaging. Therefore, patients imaged for trauma indications demonstrate trauma as the secondary pathology to the primary stroke pathology.

4.4.2 Stroke as an indication for CT head imaging

In this subgroup 236 patients were imaged due to stroke suggested pathology. There was a female predominance of 54% relating to the previous subgroup demonstrating males are more likely to present for trauma imaging. 78% of imaging was performed in the emergency setting demonstrating the urgent evaluation of this pathology which aligns with a similar South African study.(102) Of the total images, there was an overall 72% yield for pathology (new 51% existing 21%). Yield of pathology for stroke in the emergency setting was noted at 54%.(103) 29% of patients had no pathology, therefore, it is understandable that 23% of patients were discharged from the ED after imaging. Patients who are not at risk of falling or who are able to swallow post brain insult are able to be discharged safely.(104,105) Other patients can be considered patients with transient ischemic attacks or reversible ischaemic neurological deficient and safe for discharge for outpatient work up.(41) A further 66% of patients were admitted to the district hospital while 9% were transferred to a higher care facility. This is likely due to patients requiring intubation or concurrent pathology requiring high care admission which is not available at a district level health facility. Therefore, these study figures correlate with the literature.

The pathology noted commonly in emergency stroke imaging was ischaemic stroke. Ischaemic strokes were identified in 19% of imaging while haemorrhagic strokes were identified in 3% of imaging. Looking at the ratio of ischaemic to haemorrhagic stroke this is 88% and 12% respectively. These figures align with HIC and LMIC in the literature.(48,63) The value in knowing the different pathological process for stroke is paramount in decreasing further morbidity of the patient when considering thrombolytic therapy. New pathology was noted in 40% of outpatient urgent imaging and 39% of outpatient elective imaging. Most significantly these studies showed features of ischaemic stroke. There is a high admission rate (66%) with the lack of knowing if this is a first onset stroke or a subsequent stroke. The management of subsequent strokes is less demanding as supportive measures have previously been put in place as opposed to the management of first onset stroke.(106) Therefore, with the high yield of pathology it is suitable to have a high admission rate to ensure appropriate management of acutely ill patients.

The gender demographic of the stroke category shows a female predominance (54%). The reality in South Africa is that rooted in traditional culture the overweight female is considered more beautiful.(107) As noted, the comorbidity of obesity does not stand alone, it is associated with the metabolic syndrome of diabetes mellitus, hypertension and dyslipidaemia.(83) The risk factors for stroke are hypertension, smoking, transient ischaemic attack, heart disease, diabetes mellitus, hypercoagulopathy, high red blood cell count and sickle cell anaemia as well as a carotid bruit. (41,108) The most common comorbidity present in CT's with existing, new and no pathology was hypertension, 46%, 36% and 40% respectively. It was of great value to note that diabetes mellitus and HIV infection show to be the next common comorbidities in new pathology CT imaging. Both these comorbidities result in vasculopathy and, therefore, show to have a good correlation with stroke.(41,109) Smoking was equivocal in the study however of the patients that smoked 62% obtained new CT pathology. Dyslipidaemia is twice more prevalent in patients with new pathology than in patients with existing or no pathology. Obesity appeared low in the study sample however this could be due to the poor data capturing due to the retrospective nature of the study. In conclusion the study showed that patients present with stroke to have a various comorbidities most of which relate to vasculopathy.

The impact of stroke is considered an acute pathology as one can intervene with chemical or mechanical thrombectomy. It is of value to note that in the emergency setting more imaging has been done for this type of patient than at other time intervals (78%). Clinical signs of stroke can be an array of neurology relating to where the pathology in the brain can occur for example motor, sensory, cranial nerve, speech, cerebellar signs. Patients can also present with signs of raised intracranial pressure such as changing neurology, vomiting and headache.(41) In this study it is of value to note that the most common sign of new stroke is altered mental status. Motor neurology and cranial nerve palsy signs were then further noted followed by headache and generalised seizures. All other clinical signs appeared in some patients with stroke showing that stroke can present with a variety of symptoms and signs. When one recalls the pathology in the trauma subgroup the most common new pathology was stroke. It is fitting to note the overlap that there are clinical findings in keeping with trauma when focussing on new stroke pathology.(110)

The stroke patient demonstrates different facades of presentation with multiple risk factors that provoke pathological processes. In this district level emergency department, the ischaemic and haemorrhagic disease process aligns with national and international EDs showing that even with the array of population diversity accessing health in this district health emergency department the pathology is the similar globally. When managing the acute illness, high stroke yield results in high admission rates that could explain the increase in admission rates in this setting resulting in safe management of patients.

4.4.3 Seizures as an indication for CT head imaging

Of the total amount of CT head imaging performed in the emergency department 16% of CT head imaging requested was for indication of seizures. A HIC stated a 46% of patients presenting with seizures receive imaging in the acute setting.(68) Unfortunately we cannot correlate this with our study as this study is focused on the subset of patients presenting with seizures to the ED that received imaging, therefore, this would be of value to assess in future trials. Of all the patients requiring CT imaging 6% of these patients were admitted. This is more significantly higher than the 1.4% in HIC.(111) The South African population has a significantly high prevalence of HIV (54) which predisposes the HIV patient to intracranial opportunistic infections, vascular disease as well as non-benign lesions. Therefore, when considering these types of pathologies, a 6% admission rate could explain an increase in this type of patient. A further limitation of the study is that due to the retrospective nature CT head imaging for seizures was not subcategorised into initial onset seizures or recurrent seizures. These subcategorises are discussed separately in the literature and may account for the difference in result findings.

Imaging ordering timing, when patients present to the ED with seizures, is mostly requested in the emergency setting than the non-emergency period. New pathology was noted in 20% of emergency imaging, 10% in outpatient-urgent and 16% in outpatient-routine. A high proportion of these patients have existing pathology (emergency 47%, outpatient urgency 40% and outpatient elective 32%). *Goldberg et al* advocates for all CT imaging for seizures to be performed in the emergency setting and then further work up can be performed as an outpatient.(71) The majority of ED visits for seizures have been noted in the literature for non-index seizures.(68) This may be inferred from this study as more patients imaged with seizures had existing pathology (36%) than new pathology (18%) identified on CT imaging. The literature state that 3% of patient presenting with non-index seizures had acute change in patient management.(68) New pathology had a high prevalence of HIV, hypertension, smoking or existing epilepsy.(112–114) . This may relate to the study by *Moolla et al* which showed a patient would need to have a CD4 of <50, focal signs, neck stiffness, persistent vomiting or a GCS of less than 15 to predict a space occupying lesion.(12) These comorbidities will be appropriate to investigate in the future if there is an association with seizures. Further research would be of value to trace patients and see if poor outcomes have developed due to timing of imaging as most imaging was performed in the non-emergent time period in this study.

The yield of pathology was noted to be 54% (18% new and 36% existing). It is noted that due to the low yield of new pathology, the discharge of patients at 45% in the acute setting can be considered appropriate. However, 46% were admitted in the acute setting with 9% transferred to a higher level of care. This could relate to defaulting of treatment of existing pathology or adjusting of current prescription to obtain appropriate control of seizures. The type of pathology noted in the acute setting was noted to be ischaemic stroke.(115) Other less frequent pathology were space occupying lesion seen in 4% (3% - 13% in the literature), trauma 6% (2-6% in the literature), hydrocephalus 1% (20-50% of patients with shunts) (116), alcohol abuse (19.8%), intoxication (9.3%), infection n=0,0% (0.9-9.2%), sleep or substance deprivation (3.5%), trauma (2.6%), metabolic aetiology (2.6-4.9%) and multiple sclerosis (1.7%).(67,117) Outpatient imaging in both categories showed no obvious trend. The outpatient elective category showed a prevalence for pathology of traumatic intracranial haemorrhage, haemorrhagic stroke and intracranial oedema ($p = 0.017$, 0.021 and 0.021 respectively). This is a small sample when considered statistical significance.

Seizures are a common presentation to the emergency department requiring imaging. There is a high yield of existing pathology noted on imaging than new pathology. Higher admission rates may be related to the high burden of disease related to HIV and hypertension. Further studies isolating these subgroups may assist in further understanding the pathology.

In summary stroke (32%), trauma (30%) and seizures (16%) are common indication for CT head imaging at a district health emergency centre. Trauma imaging demographic demonstrates a male predominance and patients peak age show more commonly a younger patient between the age of 26-45years old. Patients with trauma have variable singular or multiple comorbidities with the most common shown to be hypertension and HIV. Ischaemic stroke is the most common finding in a trauma study demonstratingthat the trauma most likely masked the primary pathology. The proportion of minor head injury pathology identified aligns with HIC literature. Suspected stroke is a common indication for imaging with ischaemic stroke being the most common pathology in the stroke indicated CT head study. Ischaemic to haemorrhagic aetiology ratios align with the literature. This study sample demonstrates multiple comorbidities that add the risk factors for vasculopathy. Seizures are a further common indication for CT head imaging and although a small sample was identified there was a higher existingpathology found on CT head imaging than new pathology. There may be value in identifying patients with first onset seizures as opposed to recurrent seizures when imaging patients in an emergency setting.

CHAPTER 5 | CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSION

When the ED clinician considers acquiring CT head imaging in a resource-limited setting, an appropriate clinical history, examination as well as awareness of the most prevalent disease profile of the community the doctor is treating, is required. High yields of pathology on CT imaging may be related to delayed access to imaging modalities. The fact that the yield is so high (higher than international norms) probably suggests that we are underutilising CT scans – or in other words, missing pathology in patients we do not scan. The delicate balance between resource stewardship and good clinical practice is challenging in a resource limited setting, because most evidence-based advice are from High-income countries. Access to CT scans and delayed presentations due has multiple modifiable and non-modifiable factors that impacts the health-seeking behaviour of a patient, may also affect CT scan yield.

Further, delayed imaging times and ED consultation times are not according to international trends in this district health setting, and this may be due to multiple factors relating to access to health. Longer waiting times in the LMIC EDs compared to the HIC EDs is suggested to be an area to focus improvement on the flow of patients. However, taking this into account the overburdened health system and the supply-demand mismatch, these could be considered acceptable.

There is a predetermination at the district level ED to request CT head imaging for young males and older females. Hypertension is the most common comorbidity in this population which links as a risk factor to the most common CT head finding of an ischaemic stroke. Stroke, trauma and seizures are common indications for imaging in the South African setting with the most common pathology identified as an ischaemic stroke. Discharge of patient figures are considered appropriate for trauma, stroke and seizures when considering the high yield of pathology identified and type of pathology identified in these subgroups.

The demographics of the subgroup of patients requiring trauma indicated imaging show correlation with the literature and highlight that different income countries show similarity when encountering the patient with isolated head trauma. The trauma patient is a younger patient with fewer comorbidities. Trauma pathology can mask primary stroke pathology where stroke was the most common pathology identified on trauma imaging. This statement is substantiated by the increase in risk factors and clinical signs of stroke in trauma indicated imaging. Therefore, patients imaged for trauma indications demonstrate trauma as the secondary pathology to the primary stroke pathology.

The subgroup of patients requiring stroke imaging demonstrate different facades of presentation with multiple risk factors that provoke pathological processes. In this South African district level ED, the ischaemic and haemorrhagic aetiology of stroke aligns with HIC and LMIC Eds. Even with the array of population diversity accessing health in this district health emergency department the pathology is similar globally. When managing the acute illness, high stroke yield results in high admission rates, therefore, this would explain the increase in admission rates in this setting to, therefore, allowing for safe management of patients.

Seizures are a common presentation to the emergency department requiring imaging. There is a high yield of existing pathology noted on imaging than new pathology. Higher admission rates may be related to the high burden of disease related to HIV and hypertension however further subpopulation analysis would need to be considered in these patients. Further studies isolating these subgroups and separating index from non-index seizure work up may assist in further understanding the pathology.

5.2 LIMITATIONS

The study may not represent the true prevalence of patients obtaining CT head imaging at a district level as sampling did not include patients who presented to community health centres or general practitioners and/or those who were discharged/referred from these facilities and subsequently not referred to Mitchells Plain Hospital. Sampling also did not include patients who died before reaching the hospital or those patients who were referred to higher level of care facilities.

This study also was only performed in the public health sector. It was performed in a single hospital and did not include paediatric patients.

Selection bias may influence results if not all patients receive CT head imaging when this may be indicated. This may lead to skewed data. A large sample, therefore, can decrease the chance of this potential source of bias. The diversity of patients accessing public health is significant with approximately 80% of the general population accessing public health centres. The final study sample was smaller than projected (729 participants).

The retrospective data collection model had inherent limitations. The quality of the data, especially the clinical details was subject to good clinical notes and sufficient clinical details. Unfortunately, the clinical records (clinical data) continued too little information to perform regression analysis.

Multivariate regression analysis has the ability to assess the impact that a variable has on the outcome while taking into consideration the interplay between all the variables included, depending on the model. This would have allowed us to understand which variables have the most impact on the outcome at hand (CT scans with new pathology). The information gained from a multivariate regression analysis can even be used to devise a scoring system (clinical decision tool) that can help us to utilise CT scanning more efficiently, especially in our resources challenges setting. An appropriate prospective data collection model will provide sufficient information for this type of analysis.

5.3 FUTURE RECOMMENDATIONS

It is strongly recommended to obtain a multi-centre study to assess all levels or care. Further it is advised to obtain a larger study sample to draw more relevant data from the diverse South African population accessing ECs. Missing data due to patients accessing other facilities or levels or care can therefore be combined into one study to better explain the demographics, indications and pathology identified in the emergency setting when requesting CT head imaging.

Due to the retrograde nature of this study broad questions were asked and investigated. If this study were performed prospectively, less confounding bias would be noted and focused subgroup analysis can assist in clarifying specific indications and pathology identified on CT imaging, for example stroke, trauma and seizures.

It is of value to note that few patients imaged in the ED were under the age of 18. This could be due to patient's being referred to a specialised paediatric level 1 hospital 20km from MPH. It is of value to note that head imaging in the neonatal/paediatric patient can be performed by other modalities (e.g., Ultrasound and MRI) to mitigate radiation risk. Therefore, looking forward this type of study would be limited to the under 18 years of age population.

A focused prospective review of stroke, trauma and seizure patients would be of value. When focusing the review for seizure it will be of value to identify the non-index versus the index stroke presentation. Then further research can be done on these subsets of patients.

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