Computed Tomography imaging of traumatic injuries at Chris Hani Baragwanath Academic Hospital

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A dissertation submitted to the Faculty of Health Sciences, University of the Witwatersrand, Johannesburg, in fulfilment of the requirements for the degree of Master of Medicine in Radiology

Johannesburg, 2021

Declaration

I, Shabina Dawadi, declare that this research report is my own work. The research report is submitted for the degree of Master of Medicine – Radiology, at the University of the Witwatersrand. It is submitted in the submissable format with my protocol and an extended literature review and has not been submitted before for any degree or examination at this or any other institution.

DR. SHABINA DAWADI

On this 21st day of August 2021.

Student's contribution to article

- Principal investigator.
- Study concept and design.
- Primary compilation of the protocol and extended literature review.
- Collection and analysis of data.
- Construction of the database.
- Primary compilation of the manuscript.
- Submission of the manuscript to the publishing journal.
- Corresponding author in the editing process of the published article.
- Primary author of the published article.

Declaration: Student's contribution to article(s) and agreement of co-author(s)

I, Shabina Dawadi, student number 300936, declare that this Dissertation is my own work and that I contributed adequately towards research findings published in the article stated below which are included in the dissertation .

Signature of Student ..... **Date:** 13/06/2021

Name of Primary Supervisor: Dr. Ilana Viljoen

Signature of Primary Supervisor: .....**Date:** 13/06/2021

Agreement by co-authors: By signing this declaration, the co-authors listed below agree to the use of the article(s) by the student as part of her Dissertation. In cases where the student is not the 1st author of a published article, the primary supervisor must explain (under comments) why the student is entitled to use the paper for his/her degree purposes.

Article 1: Title: Trauma in Soweto: The radiology side of the story.

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Comments by primary supervisor:

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Dedication

To my parents, for their endless encouragement and support.

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Thank you to Maryn Viljoen for her assistance with the statistical analysis.

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Authors guidelines for SAMJ

Research
Guideline word limit: 4 000 words

Research articles describe the background, methods, results and conclusions of an original research study. The article should contain the following sections: introduction, methods, results, discussion and conclusion, and should include a structured abstract (see below). The introduction should be concise – no more than three paragraphs – on the background to the research question, and must include references to other relevant published studies that clearly lay out the rationale for conducting the study. Some common reasons for conducting a study are: to fill a gap in the literature, a logical extension of previous work, or to answer an important clinical question. If other papers related to the same study have been published previously, please make sure to refer to them specifically. Describe the study methods in as much detail as possible so that others would be able to replicate the study should they need to. Results should describe the study sample as well as the findings from the study itself, but all interpretation of findings must be kept in the discussion section, which should consider primary outcomes first before any secondary or tertiary findings or post-hoc analyses. The conclusion should briefly summarise the main message of the paper and provide recommendations for further study.

Select figures and tables for your paper carefully and sparingly. Use only those figures that provided added value to the paper, over and above what is written in the text.
Do not replicate data in tables and in text.

Structured abstract

- This should be 250-400 words, with the following recommended headings:
    - **Background:** why the study is being done and how it relates to other published work.
    - **Objectives:** what the study intends to find out

    - **Methods:** must include study design, number of participants, description of the intervention, primary and secondary outcomes, any specific analyses that were done on the data.
    - **Results:** first sentence must be brief population and sample description; outline the results according to the methods described. Primary outcomes must be described first, even if they are not the most significant findings of the study.
    - **Conclusion:** must be supported by the data, include recommendations for further study/actions.
- Please ensure that the structured abstract is complete, accurate and clear and has been approved by all authors.
- Do not include any references in the abstracts.

Main article

All articles are to include the following main sections: Introduction/Background, Methods, Results, Discussion, Conclusions.

The following are additional heading or section options that may appear within these:

- Objectives (within Introduction/Background): a clear statement of the main aim of the study and the major hypothesis tested or research question posed
- Design (within Methods): including factors such as prospective, randomisation, blinding, placebo control, case control, crossover, criterion standards for diagnostic tests, etc.
- Setting (within Methods): level of care, e.g. primary, secondary, number of participating centres.
- Participants (instead of patients or subjects; within Methods): numbers entering and completing the study, sex, age and any other biological, behavioural, social or cultural factors (e.g. smoking status, socioeconomic group, educational attainment, co-existing disease indicators, etc)that may have an impact on the study results. Clearly define how participants were enrolled, and describe selection and exclusion criteria.
- Interventions (within Methods): what, how, when and for how long. Typically for randomised controlled trials, crossover trials, and before and after studies.
- Main outcome measures (within Methods): those as planned in the protocol, and those ultimately measured. Explain differences, if any.

Results

- Start with description of the population and sample. Include key characteristics of comparison groups.
- Main results with (for quantitative studies) 95% confidence intervals and, where appropriate, the exact level of statistical significance and the number need to treat/harm. Whenever possible, state absolute rather than relative risks.
- Do not replicate data in tables and in text.
- If presenting mean and standard deviations, specify this clearly. Our house style is to present this as follows:
- E.g.: The mean (SD) birth weight was 2 500 (1 210) g. Do not use the ± symbol for mean (SD).

- Leave interpretation to the Discussion section. The Results section should just report the findings as per the Methods section.

Discussion
Please ensure that the discussion is concise and follows this overall structure – sub-headings are not needed:

- Statement of principal findings
- Strengths and weaknesses of the study
- Contribution to the body of knowledge
- Strengths and weaknesses in relation to other studies
- The meaning of the study – e.g. what this study means to clinicians and policymakers
- Unanswered questions and recommendations for future research

Conclusions
This may be the only section readers look at, therefore write it carefully. Include primary conclusions and their implications, suggesting areas for further research if appropriate. Do not go beyond the data in the article.

Abbreviations

CT	Computed Tomography
ED	Emergency Department
PACS	Picture Archiving and Communication System
SA	South Africa
MVC/PVC	Motor Vehicle Collision/Pedestrian Vehicle Collision
CTA	CT Angiography
HIV/AIDS	Human Immunodeficiency Virus/Acquired Immunodeficiency Syndrome
USA	United States of America

CIN	Contrast Induced Nephropathy
CHBAH	Chris Hani Baragwanath Academic Hospital

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The following article was submitted to SAMJ on 12 June 2021

Trauma in Soweto: The radiology side of the story.

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None

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SD and IV conceived and designed the study. SD collected the data, conducted the analysis and drafted the original manuscript. IV and LG contributed to the interpretation of the data. All authors contributed to the composition of the final manuscript as well as the review and final approval thereof.

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ABSTRACT

Background

Computed Tomography (CT) imaging forms an important component in the evaluation and management of patients with traumatic injuries. Many South African emergency departments (EDs) have a significant trauma-related workload, especially in the public sector, where there are limitations in resources relating to CT scanners. It is important to gauge the impact of traumatic injuries on CT utilisation.

Objectives

The primary objectives were to quantify the amount and type of CT imaging studies trauma patients received, as well as to determine the amount of radiologically significant findings in a level 1 trauma centre. The secondary objectives were to determine the trauma unit's CT utilisation rate and describe the demographics of patients who received imaging.

Methods

This was a retrospective, quantitative, descriptive, cross-sectional study undertaken over a two-month period at the radiology and trauma units of a tertiary, academic, teaching hospital in Johannesburg, South Africa. The radiology department's Picture Archiving and Communication System (PACS) was used to evaluate the reports of patients who were referred for a CT scan from the level 1 trauma unit. The trauma unit register was used to calculate the CT utilisation rate.

Results

A total of 1277 CT scans were performed on 843 patients. CT brain accounted for 52% of all scans performed. Out of the 1277 CT scans, 407 scans (354 patients) demonstrated radiologically significant findings i.e. 31.9% of scans and 42% of patients. CT chest and peripheral angiogram demonstrated radiologically significant findings in 60.5% and 50.9% of scans respectively. Assault accounted for 55.8% of the injuries sustained and motor/pedestrian vehicle collisions 33.2%. The trauma unit's CT utilisation rate was 16.7%.

Conclusions

South Africa suffers from a significant trauma-related injury burden mainly related to assault and motor vehicle/pedestrian collisions. This trauma pandemic has a great impact on the limited CT imaging services available. Worldwide there is a broad range of described CT utilisation rates and the findings of this study fall within that range, indicating acceptable usage of CT in this level 1 trauma centre. ED decision makers are encouraged to continue carefully using CT in the trauma setting.

INTRODUCTION

Trauma is a worldwide pandemic.[1] It remains one of the foremost causes of death and disability. According to the Global Burden of Disease study of 2013, injuries accounted for 10.1% of the global burden.[2] The majority of injury-related deaths being from road injury, self-harm, falls and interpersonal violence.[1,2] South Africa (SA) is no exception with trauma-related mortality rates previously being found to be six times the global rate and the motor vehicle/pedestrian collision (MVC/PVC) injury rates found to be double the global average.[3]

Imaging forms a crucial component in the management chain of trauma patients. Computed tomography (CT) scanning, in particular, has become a vital part of the diagnostic process. CT is a highly sophisticated resource which can quickly and effectively demonstrate multiple injuries in a patient.[4] For this reason, CT utilisation in the Emergency Department (ED) has increased significantly worldwide.[5,6]

CT remains a finite and costly resource.[7] In SA, forty-five million people utilise public healthcare services where there are 5 CT scanning machines available per one million population.[8,9] A 2018 study from a level 2 trauma centre hospital in Johannesburg found that 36% of all CTs done by the radiology department were referrals from the ED. Traumatic injuries accounted for 57% of the usage.[8] It is important to ensure that a CT scanning service is utilised judiciously in the management of trauma patients. The result of the CT scan, whether positive or negative, ultimately needs to aid in the present clinical decision-making process and be weighed against the possible future risks of patient harm from the radiation.[7]

Therefore, the primary objectives of this study were to quantify the amount and type of CT imaging studies trauma patients received at a level 1 trauma centre, as well as to determine the amount of radiologically significant findings. The secondary objectives were to determine the trauma unit's CT utilisation rate and describe the patient demographics.

METHODS

This was a retrospective, quantitative, descriptive, cross-sectional study undertaken over a two-month period at the radiology and trauma units of a tertiary, academic, teaching hospital in Johannesburg, South Africa.

All patients, with a history of trauma, who presented to the Chris Hani Baragwanath Academic Hospital level 1 trauma centre during the study period, and who were referred for a CT scan, were included in the study. All the reports along with the necessary clinical information contained within them were available for review on the Picture Archiving and Communication System (PACS). If there was lack of a trauma history on the CT report, an incomplete CT report, lack of a CT report attached to the patient's name or a patient hospital number/name and image mismatch, the reports were excluded from evaluation. As data was collected retrospectively and patients were scanned as per the standard quality of care, this study did not require the use of informed consent. Ethics approval was obtained from the Human Research Ethics Committee of the University of the Witwatersrand (M191070).

All CT findings were considered to be radiologically significant except skin lacerations, subcutaneous soft tissue injuries, chronic pathology and any pathology obviously not related to the sustained trauma. The CT utilisation rate was calculated by tallying the number of trauma patients who received a CT scan against the total number of patients seen in the trauma unit during the study period.

All data was captured electronically by a single abstractor in Microsoft® Excel (Microsoft Office 2019, Microsoft Corporation). Patient characteristics and scan results were evaluated using appropriate statistics to create descriptive summaries. Analysis was

performed using SAS (version 9.2 for Windows, SAS Institute, Cary NC, USA) and Microsoft® Excel (Microsoft Office 2019, Microsoft Corporation).

RESULTS

A total of 843 patients, both adult and paediatric, were included in the study. There were 44 reports excluded from evaluation due to missing information.

Males comprised 80.7% and females 18.5% of the study population. Sex was not documented in 0.8% of patients.

The median age was 32 years (Interquartile Range [IQR] 25 – 41). Patients older than 65 years comprised 3.2% of the population and patients younger than 18 years comprised 7.6% of the study population. Age was not documented in 10.9% of patients.

The total number of CT scans performed was 1277, the breakdown of which is demonstrated in Table 1. Out of the 1277 CT scans, 407 (31.9%) demonstrated radiologically significant findings. This was in 354 patients (42.0%).

Table 1. Breakdown of total scans performed

Scan type	n (%)
Brain	664 (52.0)
Cervical spine	274 (21.5)
Abdomen/pelvis	110 (8.6)
Chest	86 (6.7)
Peripheral angiogram	57 (4.4)
Neck angiogram	52 (4.1)
Whole spine	28 (2.2)
Miscellaneous	6 (0.5)

A panscan (which included a non-contrast CT brain and cervical spine as well as a contrast-enhanced CT of the chest, abdomen and pelvis) was performed in 6.5% of patients.

Figure 1 demonstrates the mechanism of injury as percentage of patients and Figure 2 demonstrates a breakdown of the scans with radiologically significant findings.

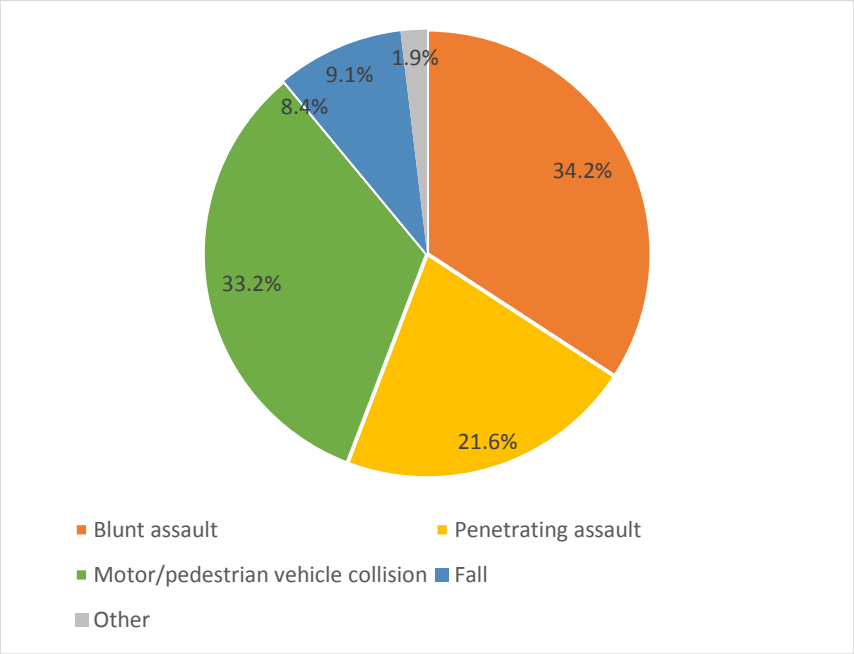

Figure 1 Mechanism of injury as percentage of patients

Gunshot wounds account for 8.4% of all penetrating assault.

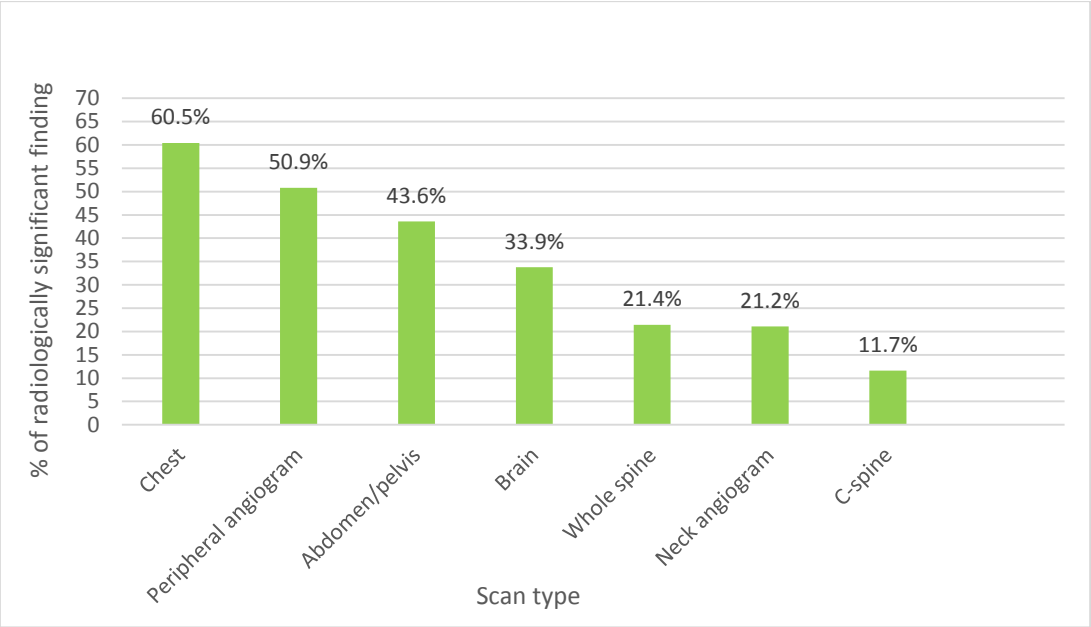

Figure 2 Percentage of scans with a radiologically significant finding

Table 2 shows the frequency of the commonest injuries for each CT scan type.

Table 2. Frequency of injuries per scan type in decreasing order

Scan type	Injury (%)
Brain	Skull fracture (32.4)
	Subarachnoid haemorrhage (30.2)
	Contusion (30.2)
	Facial fracture (24.4)
	Orbit injury (23.1)
C-spine	C7 fracture (37.5)
	C6 fracture (31.2)
Chest	Rib fracture (63.4)
	Pulmonary contusion (48.0)
	Haemopneumothorax (36.5)

Abdomen/pelvis	Liver injury (29.1)
	Pneumoperitoneum (22.9)
	Pelvis fracture (22.9)
	Renal injury (14.5)
	Spleen injury (12.5)
	Haemoperitoneum (12.5)
Peripheral angiogram	Brachial artery (63.6)
	Superficial femoral artery (11.7)
Neck angiogram	Vertebral artery (18.1)

Over the study period, 5058 patients were seen in the trauma unit. The CT utilisation rate was therefore 16.7%.

DISCUSSION

The use of CT scanning in medicine has increased dramatically over the last few decades and this increase is happening at a higher rate in the ED which is the frontline of the hospital.[4] SA has one of the largest burdens of traumatic injuries in the world and unfortunately SA hospitals have a low CT scanner to patient ratio making it a limited resource.[3, 8]

In KwaZulu-Natal, greater than 124 000 patients were managed in government hospitals for traumatic injuries in 2010.[10] Extrapolating this to the national population means more than 750 000 trauma cases per annum that would need treatment in a hospital.[11] These numbers have only increased over the past decade as highlighted by Morris *et al* who found that the number of patients who presented to their ED in a single month of 2018 and 2019 was 2375 and 2695 patients respectively.[12]

In this study, there were 4.3 times more males than females who sustained trauma that required CT imaging. This is consistent with other studies which show that men present to hospital more commonly with traumatic injuries.[8,13,14] The median age of patients in this

study mirrors the general SA trend with a younger patient population presenting to the ED with traumatic injuries.[15]

Interpersonal violence is globally recognized as an important public health issue with low- and middle-income countries being particularly afflicted.[14] SA is atypical when comparing mechanism of injury patterns to worldwide trends.[3] Usually MVC/PVC and other accidental injuries predominate. However, as in this study, assault was the mechanism of injury in more than half of the patients seen.[3] This is also in keeping with known local trends.[7]

The ordering of panscans and combination scans resulted in there being more scans than patients. A patient could have had more than one anatomic region scanned depending on their mechanism of injury, clinical presentation, and imaging requirements. It is often debated whether to use panscan or selective CT scanning in the management of trauma patients. Panscan is particularly helpful in the setting of blunt polytrauma. It can quickly localise multiple injuries and aid in triaging the management of patients.[16] It can guide the conservative management of patients with solid organ injuries and help to differentiate patients who need intensive care or ward admission.[16] Panscan showed clinical utility in the vast majority of patients in a level 1 trauma centre study from Pietermaritzburg.[16] In this study, 140 patients received a panscan over a period of one year. A study conducted at a metropolitan trauma centre in Germany over a two and a half year period resulted in 982 patients receiving a panscan.[17] When extrapolated to a year, the local rate of panscan use is comparatively much less.

CT of the brain was the most commonly ordered investigation. This is similar to previous studies conducted in both Johannesburg and Cape Town. [8,18] In the Cape Town study, 90% of the assault victims needed a brain CT. [18] In contrast, our study included other mechanisms of injury in addition to assault and still resulted in a CT of the brain being commonly performed. This may be due to the fact that, despite the mechanism of injury, head trauma is commonly sustained and can have devastating consequences. Imaging is often necessary to evaluate for lesions which may require neurosurgical intervention.[19]

Our study also found that c-spine CT scans had a lower positive yield compared to CTs of the brain. This might be because often c-spine CTs are ordered coupled together with a CT of the brain. These combination scans are usually ordered due to the known increased risk of cervical spine injuries in head trauma.[20] Kulvatunyou *et al*. noted a positive yield of 0.7% if a CT cervical spine was done for isolated, direct blunt head trauma.[21] Owing to the risk of potential cervical spine injury, c-spine CTs may be requested as part of institutional protocols or doctor preference and would be a contributing factor to the lower yield rate.[8] Although it is a low-yield investigation, one needs to consider the cost of a potentially missed spinal cord injury from not ordering a CT of the c-spine. These costs range from patient-related morbidity and mortality to litigation expenses.

Neck and peripheral CT angiography (CTA) are effective imaging modalities to evaluate for vascular trauma. [22,23] In a prior SA study, the most common reasons for performing peripheral CTA were gunshot wounds.[24] This was also the major mechanism of injury contributing toward peripheral CTA being performed in the current study and may account for the more significant injuries noted in this group. Another major trauma centre in Pietermaritzburg evaluated the use of neck CTA in penetrating trauma and found 19.5% of their patients had a vascular injury.[22] A Cape Town study found that 66% of patients with extremity trauma had a normal CTA. This contrasts with our study which found that almost half of the patients had a vascular injury on peripheral CTA. This may be because comparatively fewer patients were imaged or may alternatively reflect the clinical acumen of the referring ED doctors who carefully selected patients on the appropriate clinical grounds for evaluation by CT.

Significant imaging findings were noted in almost half of the patients in this study, more so for blunt than penetrating trauma. Both yields were lower, however, than those noted in a previous local Johannesburg study.[8] This discrepancy may be related to our study being conducted at a level one trauma centre compared to the Johannesburg study which was at a level two trauma centre. This highlights the principle that a lower positive yield is likely related to increased CT utilisation.[8] One could perhaps then infer that it is according to this principle that our level one trauma centre study yielded a lower incidence of positive findings.

There are multiple international studies which evaluate the patterns of CT scan utilisation in EDs, however, in SA, studies which describe utilisation and yield rates are minimal especially in a level 1 trauma centre.[8] There are variable ED CT utilisation rates throughout the world. These range from anywhere between 2.8% to 33%.[6] Our CT utilisation rate was in the middle of this range. A direct local comparison could not be made as, to the best of our knowledge, local utilisation rates specific to trauma units have not previously been described. A level two trauma centre in Johannesburg showed a CT utilisation rate of 4.6%. This finding however was for both traumatic and non-traumatic conditions. Beyond the utilisation rate of CT, one also needs to consider the appropriateness with which an imaging investigation is performed. Referring clinicians need to be aware of which imaging modality would be most suited to answer their clinical question. A study conducted in the Eden and Central Karoo districts of SA looked at the appropriateness of CT and MRI scans performed in relation to the requesting department and clinician. Both state and private sector referrals were included. The majority (63.5%) of their scans were deemed to be appropriately performed.[25] This information was not gathered for our study as it was outside the intended scope. It could possibly form part of future additional research which would allow for a provincial comparison.

Factors which may contribute to increased CT utilisation in the ED include ease of access to radiology services, utilisation in order to increase patient throughput, cost-saving from improved diagnoses, the risk of malpractice lawsuits and the advantages of CT compared to traditional (more invasive) methods.[26] Many ways to improve positive yields have been proposed including using clinically-based guidelines.[27] Although there is a strong argument for decreasing CT usage, it is important to note that there are benefits to current utilisation patterns. A study conducted by Salim et al. at a level one academic trauma centre, over a period of 18 months found that 189 of their patients without obvious signs of injury, who had a panscan, required a change in management based on abnormal CT findings.[28] A negative scan in the trauma setting should not be discounted as it can allow for prompt discharge of the patient. [29]

Conversely, the increasing utilisation of CT can lead to the increasing cost of healthcare.[4] In SA, the provincial Departments of Health showed the second highest expenditure of all government departments in the 2015-2016 fiscal year.[30] A study conducted in Bloemfontein in 2017 measured the imaging component cost of violence-related injuries. Over a period of 6 months, of the patients imaged for violence-related injuries, CT scans contributed 83.8% to the total bill.[30] This emphasises the financial constraints endured by our already burdened healthcare departments due to intentional traumatic injuries. The financial implications represent only a single facet – the direct cost – of a multi-faceted process. A study on missed injuries in trauma patients noted around 15 to 22.3% of patients had clinically significant missed injuries.[31] More recently, patients who received CT scans were shown to have less likelihood of being hospitalised. [32] This would ultimately save money. One therefore also needs to consider the impact of each of these various perspectives.

Although the benefits of CT imaging for traumatic injuries generally outweigh the risks, it is worthwhile to note the associated health risks of imaging. Radiation exposure as a result of medical imaging is associated with carcinogenesis.[33] Trauma patients form part of a subset of patients who are more likely to receive CT scans due to the nature of their injuries. These patients' radiation doses have also been higher than other hospital-based populations.[33] The younger a patient is at the time of receiving a CT scan, the greater the time available for any potential effects from ionizing radiation to occur.[33] Although only 7.6% of patients in this study were younger than 18 years old, adult patients still have potential carcinogenic risk related to the CT radiation. With such a large number of patients requiring CT scans following trauma in SA, it is important for the decision makers in EDs to use imaging prudently.[33]

The study is strengthened by the size of the study population and because it was carried out in a level 1 trauma centre. Limitations include the fact that data was collected retrospectively and only over two months which could have resulted in seasonal variations in trauma being missed. Furthermore, it is difficult to extrapolate findings from only one facility suggesting the need for further larger trauma-based imaging research. This would preferably be from a country-wide database from all hospitals and not just

level 1 trauma centres. The lack of electronic medical records for the CT scan report documentation as well as the registration records may mean that some data could have been inadvertently omitted.

Conclusion

South Africa has a substantial assault and MVC/PVC related injury burden. This translates to imaging as noted in the number of CTs performed and the imaging patterns of traumatic injury. Our study corroborates the principle that a decreased positive CT yield is likely related to increased CT utilisation. Worldwide there is a broad range of described CT utilisation rates and the findings of this study fall within that range, indicating acceptable usage of CT in this level 1 trauma centre. Locally, further studies are required, however, in order to make an accurate comparison. With such a large number of trauma patients in SA needing CT imaging as well as the known health risks of CT, it is important for ED doctors to continue using CT judiciously.

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Chapter 2: Protocol with extended literature review

1. Rationale

Trauma represents a worldwide pandemic. It is one of the foremost causes of death and disability and according to the global burden of disease study of 2013, traumatic injuries accounted for 10.1% of the global burden (1, 2). Imaging as a whole forms an integral part of the management chain of trauma patients. Computed tomography (CT) scan in particular, has become a vital part of the diagnostic process as this is a highly sophisticated resource which is readily available and can quickly and effectively demonstrate multiple injuries in a patient (3). For this reason CT utilisation in the Emergency Department (ED) has increased significantly worldwide (4, 5). CT however remains a finite and costly resource with multiple other associated risks (6). South Africa (SA), a country with a high traumatic injury burden is also a country where approximately 45 million people rely on public health resources and with regard to imaging, where there are only 5 CT scanners available for one million people of the general population (7, 8) (9). It is therefore important to make sure that a CT scanning service, a constrained resource,

is carefully utilised in the management of ED patients, where the radiological outcome, whether positive or negative aids in clinical decision making (8).

2. Introduction

The Global Burden of Disease Study is a thorough regional and global assessment of mortality and disability from major diseases and injuries, as well as their risk factors. According to the Global burden of diseases 2013, injuries accounted for 10.1% of the global burden of disease. An estimated 973 million people suffered injuries that warranted healthcare of which 56.2 million (5.8%) warranted inpatient care and 4.8 million people died. Major causes of injury death were road injury (29.1%), self-harm (17.6%), falls (11.6%) and interpersonal violence (8.5%). Worldwide the impact of injuries is disproportionately felt by low to middle income countries and in particular on all regions of the African continent (1). In the 15-49 year age group in Southern Sub Saharan Africa, interpersonal violence is the major contributing factor to injury rates followed by collective road injury (2). Globally over 90% of trauma deaths occur in low to middle income countries with almost one fifth occurring in Africa (10). Trauma accounts for 1.7 times the cumulative mortality from malaria, tuberculosis, and HIV/AIDS combined (11).

2.1 Epidemiology of traumatic injuries in SA

The injury burden profile for SA differs from most regions of the world. Intentional injuries far exceed unintentional injuries with interpersonal violence contributing significantly to the burden (10).

A study conducted at Tygerberg Hospital, using data from the Cape Metropole study, found that in SA, in the year 2000, 59 935 injury-related deaths were recorded. Forty-six per cent of these deaths were homicides, 26.7% road traffic related and 9.1% due to self-inflicted injuries (10). In contrast to other regions worldwide, in South Africa there were more homicides than road traffic injuries and suicides.

Traumatic injuries form a significant component of the ED workload at state hospitals in SA. In KwaZulu-Natal in 2010, more than 124 000 people were treated in state hospitals for motor vehicle, violence and domestic/work related injuries. Of note is that almost 80% of these injuries were considered critical. These rates far surpass the comparative international incidence (7). Similar patterns were noted in Mpumalanga and the Eastern Cape. Mnguni et al. studied abdominal injuries over a seven year period at King Edward VIII Hospital in Durban and found that 488 cases were admitted to a single surgical unit (out of 6 units in total) with penetrating traumatic injuries, outnumbering blunt traumatic injuries by 9:1 (7).

Moodley and associates, in a study related to trauma mortality in Pietermaritzburg, over the period of 1 January 2010 - 31 December 2011, found that the three principal causes of death were head injuries, polytrauma and chest injuries. The polytrauma and head injury-related deaths were mostly caused by blunt trauma whereas the chest injury deaths were overpoweringly caused by penetrating trauma (12).

2.2 CT utilisation and yield rates

The use of CT scanning has dramatically increased over the last few decades. This increase is happening at a higher rate in the ED as compared to anywhere else (3). There were

various increasing rates of CT utilisation noted, ranging from an increase of 2.8 -13.9% in the US from 1995-2007, 12.4-33% in South Korea from 2001-2010 and 9.8-13.9% in China from 2005-2008 (5). The Davis Medical Centre associated with the University of California, performed a record review over the period 1998-2005 to evaluate the patterns of CT utilisation at their centre, which is a level one trauma unit, and one of the busiest units in the United States of America (USA). This study noted that 286 753 CT scans were performed during this time. The utilisation rate for the ED increased from 1999-2004 and although ED patients comprised only 9.6% of the total patient visits in 2004, almost half (49.5%) of the CT scans were performed on them (13).

A national study on the trends of the use of advanced radiology in USA emergency departments between 1998-2007 showed that CT utilisation during ED visits for injuries had increased significantly despite there being no equivalent increase in the occurrence of life-threatening conditions or a change in the ultimate disposition of the patients. CT use increased from 6% in 1998 to 15% in 2007. This study also noted that patients who presented to an academic ED were more likely to receive a CT scan than those presenting to non-academic institutions. This was thought to be due to a number of factors such as more severely injured patients presenting to academic EDs, less experienced clinicians (residents) requesting scans at these facilities and an increased availability of CT (14).

South African EDs experience one of the largest burdens of traumatic injuries in the world. It was estimated by the SA Medical Research Council that approximately 1.5 million patients who suffered traumatic injuries were seen at secondary and tertiary level hospitals in 1999 (8). An investigation of South African diagnostic imaging equipment

found there to be only 5 CT scanners for every one million people of the general population. This greatly differs to the 101 CT scanners for every one million of the general population in Japan and almost 41 CT scanners for every one million of the population in the United States of America. In a country such as SA, with a population of 58 million, where approximately 45 million people depend on public health care facilities with limited imaging resources, the utilisation of CT scans needs to be effective and thoughtful (8, 9, 23).

Due to the increased use of CT in trauma and the concerns relating to radiation exposure, pricing, overdiagnosis and incidental lesions, Hansen et al. developed the Negative CT Score, (ΣCT−). It calculates how often CT imaging identifies significant injuries. In their study, of the 2.36 body regions scanned per patient, 2.10 regions found no important CT findings. The intention of this study was to create a clinically useful tool to quantify trends and patterns of CT utilisation and compare these across institutions to allow for optimised CT use (15).

There are multiple studies worldwide which evaluate the patterns of CT scan utilisation in EDs, however, studies which describe utilisation and yield rates in SA are minimal. A study at a public sector, adult tertiary academic ED in Johannesburg looked at CT scan utilisation and positive yield rates over a 4 month period. The ED attended to 65 000 patients annually. Approximately 23% of these patients were trauma related. The diagnostic radiology department performed an average of 700 emergent and non-emergent scans per month. Thirty six percent of the total monthly scans performed were for referrals from the ED. In this study 1010 reports were analysed and 57% of these scans

were performed on patients with traumatic injuries. The CT scanner utilisation rate (total patients from the ED who received a CT scan) was 4.6% and the total positive yield (trauma and non-trauma) was 53.8%. Findings were deemed positive if there was a radiologically significant finding in relation to the indication for the scan. There was a positive yield rate of 47.1% for trauma patients in total, 54.2% yield rate for penetrating trauma and 45.7% yield rate for blunt trauma. A 4.6% utilisation rate in an ED that has more than 5 000 patient visits per month is low (8).

2.3 Impact of CT utilisation

2.3.1 Economic impact

The increasing utilisation of CT leads to increasing costs of healthcare (3). In SA, in the 2015-2016 financial year, the provincial Departments of Health demonstrated the second highest expenditure of all government departments. These departments had spent nearly R150 billion (16). Radiology is a cross-disciplinary resource, which provides support to many different departments and is essential to the contemporary management of many different disease processes. CT scanning forms the cornerstone of the management of blunt polytrauma (6). A study conducted at Bloemfontein's Pelonomi Tertiary Hospital in 2017 measured the cost of imaging violence-related injuries. Over a period of 6 months, 1 380 patients were imaged for violence related injuries accounting for 5 475 imaging investigations. General radiographs were the most commonly performed study. They contributed 11.9% to the total imaging bill. Even though CT scans did not form the bulk of the imaging – they contributed 83.8% (R5 957 280) to the total amount. Of all

investigations performed by the radiology department, violence-related imaging accounted for 14.8% (16).

2.3.2 Radiation exposure

CT scanning makes use of ionizing radiation which is associated with two risk types: deterministic and stochastic. Deterministic risks have a predictable effect directly related to the amount of radiation received. Stochastic risks are those associated with the effects of chance mutations. This means the effects may occur at random but are based on the amount of radiation received. With receiving increasing amounts of radiation the probability of these mutations increases with the possibility of radiation-induced cancers ensuing (17).

Radiation exposure is measured using the effective dose in millisievert (mSv), which describes the overall detrimental biologic effect. Radiation exposure as a result of medical imaging is associated with stochastic i.e. carcinogenic risks. A few examples include leukemia, thyroid and solid organ cancers, cataracts, sterility, and birth defects (17). Below as indicated in table 1 are the typical effective doses of radiation exposure for CT scans (17).

Table 1. Typical effective doses of radiation exposure for CT scans.

Body region scanned	Radiation exposure (mSv)
Brain	2
C-spine	4
CTA neck	4
Facial bones	5
Chest	7
CTA chest	15
Abdomen and pelvis	14

(17)

Radiation dose is cumulative and some trauma patients form part of a subgroup that receive multiple studies during their hospital admission as well as multiphasic studies of which the total effective radiation dose is multiplied by the number of phases. Owing to these risks, CT optimization techniques and careful and appropriate selection of patients for imaging is required (18).

2.3.3 Contrast-Induced Nephropathy

"Contrast-induced nephropathy (CIN) has been defined as an increase in serum creatinine of 0.5mg/dl or 25% from baseline 48 hours after contrast administration" (17). The incidence of CIN is variable and ranges from 3.3–19%. There has even been an incidence range of 50–80% in high-risk patients. CIN is the third major cause of acute acquired renal failure in the hospital setting due to increasing utilisation of intravenous contrast exams. CIN accounts for roughly 11% of these cases. Risk factors for CIN include ?pre-existing renal dysfunction, diabetes mellitus, age older than 75 years, hypovolaemic vascular status, increased volume of contrast, intra – arterial contrast administration and simultaneous administration of other nephrotoxic drugs (19, 20). A study by Hipp et al.

based at Kings County Hospital Centre in Brooklyn New York found an incidence rate of CIN of 5.1% in trauma patients at their level one trauma centre and that trauma injury severity score did not correlate with the degree of CIN. No patients died or required acute or chronic dialysis (19). Colling et al. also based at a level one trauma centre in Minnesota USA, found an incidence rate of CIN of 4% in trauma patients following blunt trauma. In contrast however their study found injury severity score to be an independent risk factor (21). Bashir et al. in Pietermaritzburg SA found an incidence rate of 14.7% in blunt trauma patients. This value falls within the range noted in the literature, but is much higher when compared to the low incidence values of high – income countries. This implicates local systematic factors. The study also found that in our local setting CIN is linked to increased risk of death and need for renal replacement therapy (22). There are multiple contradictory studies on the matter of CIN and for completeness sake, a more recent meta-analysis from 2018 found no notable difference between patients who received a contrasted scan and those who had a non-contrast scan (25).

2.4 This project in context

South Africa is an upper middle-income country with a large traumatic injury burden and limited health resources especially with regards to CT imaging. CT imaging, however, is not without its own associated cost and risks (3, 15, 17, 24). It is therefore imperative to quantify the usage of CT in order to make sure it is being judiciously utilised while at the same time not compromising patient care.

3. Aim

The aim of this study is to quantify and investigate the effect of traumatic injuries on the CT scanning service at Chris Hani Baragwanath Academic Hospital (CHBAH).

4. Study Objectives

Primary:

- To determine the number and site (anatomical region) of CT scans that the radiology department at CHBAH performs related to trauma in a two month period.
- To determine the amount of radiologically relevant findings in CT scans performed for trauma, in total as well as per anatomic region scanned.

Secondary:

- To describe the patient population undergoing CT scans in the Trauma Unit at CHBAH.
- To determine the CT utilisation rate by the CHBAH trauma unit.

5. Methods

5.1. Research paradigm

This is a retrospective quantitative cross-sectional study.

5.2. Sample

The sample population will be all patients (adult and paediatric) who attended the CHBAH trauma unit and received CT scans over the proposed time period 01/05/2019 – 30/06/2019. The estimated sample size will be approximately 720 patients.

5.2.1. Inclusion criteria

All patients (adult and paediatric) with a history of trauma who presented to the to the CHBAH trauma unit over the above proposed time period who received a CT scan related to the sustained trauma.

5.2.2. Exclusion criteria

The following criteria will exclude patients from the study:

- Lack of any or trauma history on the CT report
- Incomplete CT reports attached to the patient's name
- Lack of CT report attached to patient's name
- Patient hospital number/name and image mismatch

5.3. Materials and Methods

The primary investigator of this study will review all the radiology reports on the CHBAH PACS system over the proposed time period 01/05/2019 – 30/06/2019 and only trauma related CT reports will retrospectively and serially be evaluated. The reports will be evaluated for any applicable exclusion criteria and if found, these reports will be eliminated from the study.

The CT scanners used at CHBAH radiology department for trauma patients over the proposed time period are Toshiba Aquilion 64 and Toshiba Aquilion CX which are 64 and 128 slice CT scanners respectively.

The PACS system used is Agfa IMPAX 6.5.1.501.

A data collection sheet (see Appendix A) will be used to capture the relevant information from the CT reports. The CT reports which remain after the exclusion criteria have been applied, will be evaluated and the relevant data entered onto the data collection sheet. Following entry of all the applicable reports from the proposed time period the data will be evaluated and the following totals tallied:

- Numbers of all scans performed
- Number of specific scan types performed
- Number of radiologically relevant findings in total
- Number of radiologically relevant findings per scan type

To determine the utilisation rate, the total number of trauma patients who received a CT scan (will be counted from PACS) will be tallied against the total number of patients seen at the trauma unit over the proposed time period. This information can be found in the trauma registry, which is kept in the trauma unit.

5.4. Data collection

Data will be captured by the primary investigator onto a predesigned data collection sheet (see Appendix A) after which data will be transcribed on to a Microsoft Excel spreadsheet for statistical analysis. The data will be captured anonymously by recording data from the CT reports in a serial number format. The data to be collected per report will be the following:

- Age of patient
- Sex of patient
- Mechanism of injury – if available.
- Scan type. PANSCAN and combination scans will be recorded individually.

- Radiologically relevant finding: Yes/No

The types of scans which may be evaluated are the following:

- Brain
- Cervical spine, thoracic spine, lumbar spine, whole spine
- Chest
- Abdomen + pelvis
- CT angiogram neck, peripheries (upper or lower limbs)

Radiologically relevant findings, applicable to all scan types, will be all findings except the following exclusions:

- Skin lacerations
- Soft tissue injuries: subcutaneous oedema or subcutaneous soft tissue haematomas
- Any chronic pathology
- Any pathology obviously not related to sustained trauma

In addition, the total number of patients in the trauma registry for the proposed time period will be collected as this will be required to calculate the utilisation rate; as specified in the materials and methods section.

5.5. Reliability and validity

Reliability:

- The reliability of the study may be compromised by the fact that the total number of reports/patients on PACS may be under represented as CHBAH PACS system intermittently experiences technical difficulties and there is a possibility that not

all patients who were scanned will have reports on the PACS system. This may affect the results to a degree that depends on the amount of studies excluded. To improve the reliability in this regard the proposed time period in which data is collected is extended over 61 days, consequently also increasing the number of patients to be included.

Validity:

- There are doctors being trained both in radiology and in trauma at CHBAH - therefore scans may be requested in different patterns by different referring doctors rotating in the trauma unit.
- There is no global radiological consensus on what constitutes a radiologically relevant injury therefore for the purposes of this study our own pre-defined exclusions will be applied.

5.6. Bias

- CHBAH is a tertiary hospital and the referral centre for a large drainage area. The number of patients treated at the trauma unit is thought to exceed those of smaller surrounding regional hospitals, other tertiary hospitals and private sector hospitals.
- The requesting patterns of doctors working in the trauma unit are variable. This may be influenced by the amount of experience and confidence the doctors have

relative to the management of trauma patients. Thus we won't be assessing individuals, or specific teams. This decreases bias.

- Bias in terms of reporting of CT scans is reduced by the fact that there are multiple different radiologists reviewing and approving them. The fact that there is different levels of experience and seniority amongst the radiologists, may introduce a bias though.
- As above this will be the same with the referring doctors.

6. Data analysis and statistics

All data will be captured electronically by the primary investigator in Microsoft Excel. Further analysis will be done using SAS Version 9.2. Descriptive statistics namely frequencies and percentages will be calculated for categorical data. Means and standard or medians and percentiles will be calculated for numerical data. Analytical statistics namely the Shapiro-Wilk test will be used to investigate the normality of numerical data. A significance level (α) of 0.05 will be used.

The following statistical tests will be used for the following objective:

- To describe the patient population receiving CT scans, a combination of mean, median, frequencies and percentages will be used.
- To determine the number and type (anatomical region) of CT scans that the radiology department at CHBAH performs related to trauma in a two month period – frequencies and percentages.
- To determine the amount of radiological relevant findings in CT scans performed for trauma, in total as well as per anatomic region scanned – frequencies and percentages.

- To determine the CT utilisation rate by the CHBAH trauma unit in a two month period – frequencies and percentages.

7. Ethics

Ethical clearance will be obtained from the Human Research Ethics Committee of the University of the Witwatersrand. Permission will also be obtained from the head of the radiology department at CHBAH as well as from hospital management. Data collection will only commence once all approvals have been granted.

7.1. Consent forms

Data is collected retrospectively and thus this study does not require the use of a consent form.

7.2. Data safety

Data will be collected anonymously by allocating a number code to each patient. The key to this code will only be available to the primary investigator and her supervisors if necessary. The data collection sheets will be stored on the primary investigator's personal computer and external memory device. A backup will be stored on DropBox. This data will only be shared with the supervisors of the study.

8. Timing

Month of the Year	January 2019	February 2019	March 2019	April 2019	May – July 2019	August – Nov 2019	Dec2019-Feb2020	March-April 2020	May – June 2020
Literature search									
Reading literature									
Summarising literature									
Preparing Protocol									
Protocol Assessment									
Ethics application									
Collecting data									
Data analysis									
Writing up thesis									
Submit: marking									
Writing up paper									

9. Budget

Travel costs	R250
Endnote	R500
External memory device	R200
Printing	R500
Total	**R1450**

The principal investigator will cover the expenses.

No applications for funding will be made.

10. Anticipated problems

- Incomplete CT reports attached to patient
- No CT reports attached to patient
- PACS technical difficulties

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12. Appendices

Study ID	
Gender (M/F)	
Age (in years)	
Mechanism of injury	
MVA	
PVA	
Penetrating assault	
Gunshot wound	
Blunt assault	
Fall	
Other	
Scan type	
Brain	
C-spine	
T-spine	
L-spine	
Whole spine	
Chest	

Abdomen/pelvis	
Neck angiogram	
Upper limb angiogram	
Lower limb angiogram	
Other	
Radiologically relevant finding	
Yes	
No	

Chapter 3: Appendices

Appendix A: Ethics Clearance Certificate

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

R14/49 Dr S Dawadi

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)
CLEARANCE CERTIFICATE NO. M191070

NAME: (Principal Investigator)	Dr S Dawadi
DEPARTMENT:	School of Clinical Medicine Department of Radiation Sciences Division of Diagnostic Radiology Chris Hani Baragwanath Academic Hospital
PROJECT TITLE:	Computed tomography imaging of traumatic injuries at Chris Hani Baragwanath Academic Hospital
DATE CONSIDERED:	2019/10/25
DECISION:	Approved unconditionally
CONDITIONS:	
SUPERVISOR:	Professor L Goldstein
APPROVED BY:	CB Penny Dr CB Penny, Chairperson, HREC (Medical)
DATE OF APPROVAL:	2020/01/29

This clearance certificate is valid for 5 years from date of approval. Extension may be applied for.

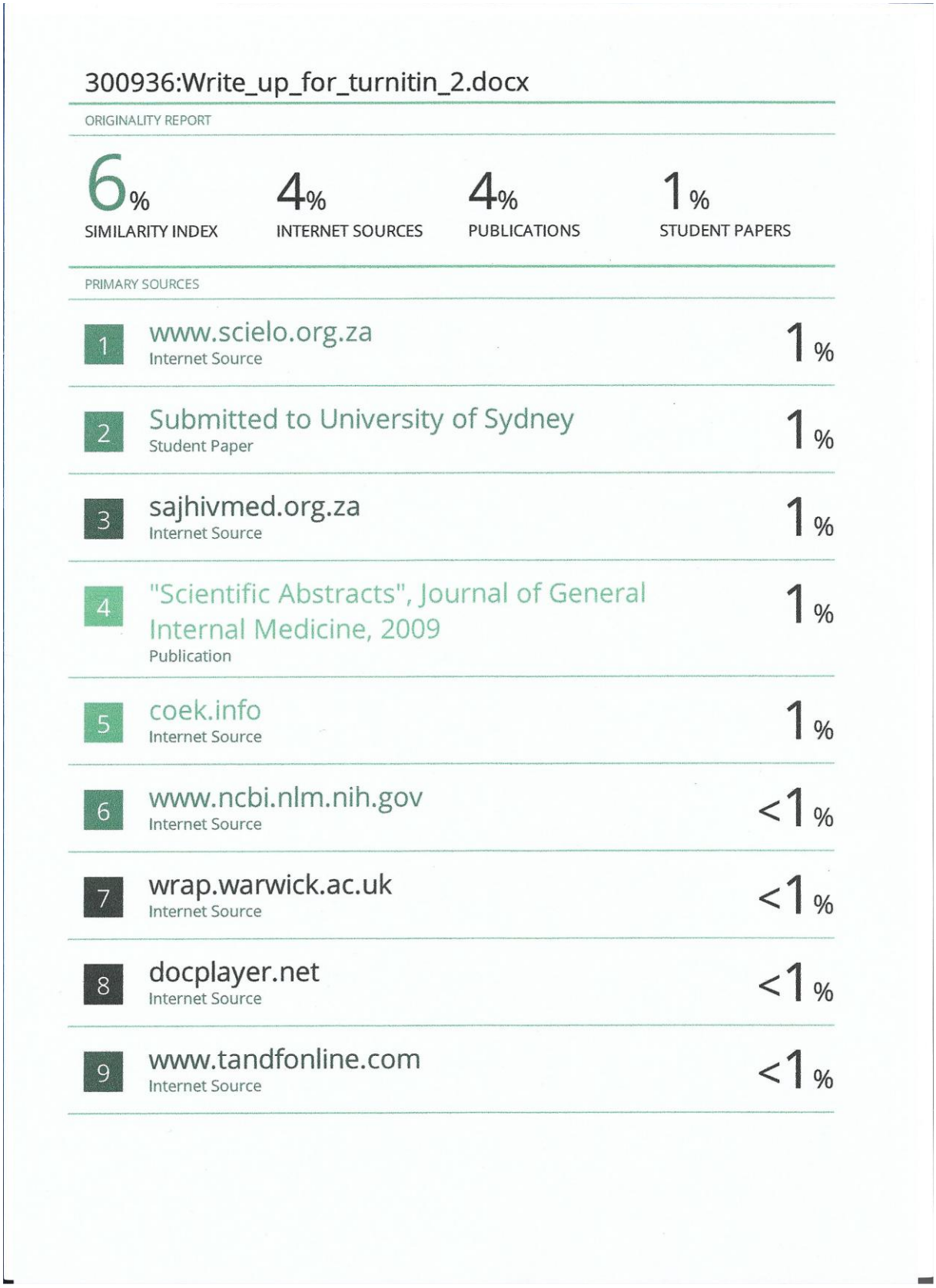
DECLARATION OF INVESTIGATORS

To be completed in duplicate and **ONE COPY** returned to the Research Office Secretary on the 3rd Floor, Phillip Tobias Building, Parktown, University of the Witwatersrand, Johannesburg.
I/we fully understand the conditions under which I am/we are authorized to carry out the above-mentioned research and I/we undertake to ensure compliance with these conditions. Should any departure be contemplated, from the research protocol as approved, I/we undertake to submit details to the Committee. **I agree to submit a yearly progress report**. When a funder requires annual re-certification, the application date will be one year after the date when the study was initially reviewed. In this case, the study was initially reviewed in **October** and will therefore reports and re-certification will be due early in the month of **October** each year. Unreported changes to the application may invalidate the clearance given by the HREC (Medical).

Principal Investigator Signature — Date: 30/01/2020

PLEASE QUOTE THE CLEARANCE CERTIFICATE NUMBER IN ALL ENQUIRIES

Appendix B: Turnitin report



300936:Write_up_for_turnitin_2.docx

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Appendix C: Note on referencing style

Please note that the referencing in the extended literature review and protocol of this thesis is a modification of the Vancouver Referencing style, done according to the Faculty of Health Sciences Style Guide as set out by the Wits Health Sciences Library.

The information on this WHSL Vancouver Citation Style Guide for Theses, Dissertations and Research Reports is available from http://libguides.wits.ac.za/whsl-vancouver updated on 8 August 2017.

The referencing in the article submitted to SAMJ is in the standard Vancouver Referencing style.