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Discrepancy rates in after-hours preliminary computed tomography reports at Chris Hani Baragwaneth Academic Hospital: a mixed methods study

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DISCREPANCY RATES IN AFTER-HOURS PRELIMINARY COMPUTED TOMOGRAPHY REPORTS AT CHRIS HANI BARAGWANATH ACADEMIC HOSPITAL: A mixed methods study

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29 April 2019

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DECLARATION

I, Pearl Gugu Mjoli, declare that this thesis is my own work. It is being submitted for the degree of Master of Medicine in Diagnostic Radiology at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at this or any other university.



……

Dr. PG Mjoli

On this, the 29th day of April 2019

ABSTRACT

Title: DISCREPANCY RATES IN AFTER-HOURS PRELIMINARY COMPUTED TOMOGRAPHY REPORTS AT CHRIS HANI BARAGWANATH ACADEMIC HOSPITAL: A mixed methods study

Investigators: Pearl Gugu Mjoli**,** Marianne Kuehnast, and Kathleen Jacobs

Background: Teaching hospitals rely heavily on preliminary radiology reports issued by registrars. In 2012, research identified a 17.1% error rate in preliminary reports at two academic hospitals in Johannesburg, South Africa. Chris Hani Baragwanath Academic Hospital (CHBAH) being the largest academic teaching hospital in South Africa, has a high workload. There is also an increasing and high demand for radiological services. Given that the empirical evidence suggests that diagnostic errors may have an adverse impact on patient outcomes, it was necessary to review the error rates of preliminary after-hours reporting.

Purpose: To review the discrepancy rates of preliminary after-hours reporting and to explore the perceived causes thereof.

Methods: Secondary analysis was conducted on a cross-section of preliminary radiology reports to identify the error rate, qualify the error type (major vs. minor), and to benchmark against published data in South Africa and internationally. Semi-structured interviews were conducted with registrars at CHBAH and thematically analysed to explore potential causes of errors.

Results: 2982 cases were evaluated. The error rate was found to be 18.48%, with a major error rate of 9.96% and a minor error rate of 8.52%. The error rate was comparable to Sub-Saharan African and international literature of 0.9% to 25 %. The average workload had increased by 94% with registrars reporting an average of 34 scans per shift compared to the previously published 18.5 per shift in the previous study. There was a statistically significant association between body region and error. The “head region” preliminary reports contributed 53.36 % to the error rate followed by followed by “abdomino-pelvic” region (25.95%) preliminary reports.

The interviews highlighted the challenges incurred by registrars when reporting as well as possible solutions to change reporting procedures in an attempt to reduce error rates. The key challenges for registrars included workload, shift work, lack of experience, body region scanned, lack of feedback, interruptions from colleagues, uncertainty and fear of disappointing others.

Conclusions: This study demonstrates that despite technological advances, there has been no improvement in error rates at CHBAH. The results from this study highlight why certain errors may still be occurring, and by understanding this, registrars (both present and future) and ultimately the patients - will benefit from any action taken towards error reduction. This research puts forward suggested options for guiding policy to influence the further reduction of the discrepancy in the after-hours preliminary reporting at CHBAH, including an intervention to reduce call hours.

Keywords: Preliminary registrar reports, error rates, radiology, South Africa, workload

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ABBREVIATIONS

Abbreviation	Full Name
CHBAH	Chris Hani Baragwanath Academic Hospital
CT	Computed Tomography
HMICs	High and Middle Income Countries
LMICs	Low and Middle Income Countries
MR	Magnetic resonance
PACS	Picture Archiving and Communication system
PI	Principal Investigator
SSA	Sub Saharan Africa
SSIs	Semi-structured Interviews

CHAPTER 1: INTRODUCTION

The increasing utilization of radiology services globally, predominantly in emergency medicine, has been documented in a number of studies (1,2). The majority of teaching hospitals provide 24-hour service with heavy reliance on preliminary reports issued by registrars after-hours (3). Studies have demonstrated and quantified the discrepancy rate in preliminary radiology reports, which has been documented to range between 0.9%-25% (4-7), consisting of both minor and major discrepancies.

Due to the increased need for radiology services in the diagnosis and further management of patients, it would be expected that there would be an increase in the reporting workload of radiologists and therefore likely an increased error rate (8). The major discrepancy rate has been established to range between 0.6 % and 2 % (8-10). Studies found Computed Tomography (CT) and Magnetic Resonance (MR) imaging were the modalities most associated with major error-rate that would have led to delayed treatment, misdiagnosis and morbidity.

Whilst the percentage of adverse patient outcomes is small, it is critical that as part of patient safety and quality management (4) the error rates are reviewed, documented and potential improvement strategies are implemented. As a result of the increasing demand on radiology services, a large number of studies have emerged, focusing on the rate and impact of errors in the preliminary reports issued by registrars during their after-hours, unsupervised calls (10). Although these studies are largely conducted within High and Middle Income Settings (HMICs), a study conducted in Sub-Saharan Africa in 2012 identified a 17% error rate in preliminary reports issued by registrars at two academic hospitals in South Africa (4). This was found to be comparable with the 0.9%-25% error rate that has been reported globally (4-8). This study explored potential causes similar to those cited in studies conducted in HMICs such as workload, shift length, region of body scanned, training level and time of reporting.

Despite the causes identified, it is widely accepted that teaching hospitals rely on after-hours calls and furthermore, these form part of radiology registrar training, allowing for registrars to build confidence for reporting independently. Although some studies have suggested that registrars may benefit from increased consultant support in order to improve patient

outcomes (11), it is largely agreed that registrars reporting autonomously continues to be seen as a critical part of radiology training. It is therefore critical that a balance between service delivery, academic development and quality assurance is maintained.

1.1 Research Focus

There is limited literature on benchmarks in the African context when it comes to error rate in preliminary reporting. This study focuses on Chris Hani Baragwanath Academic Hospital (CHBAH) which is the largest academic teaching hospital in South Africa, with approximately 2300 CT scans (patients) scanned in CHBAH every month; an estimated 40% (920) of these patients are scanned after-hours (CHBAH departmental records). Since Terreblanche's (2012) study at CHBAH, the average scans per night have increased from 18.5 scans per call to an estimated 33.3 scans per call, according to the departmental monthly CT-statistics (4). Additionally, a Picture Archiving and Communication System (PACS) has since been installed at CHBAH to streamline the reporting process. In light of the above changes within the CHBAH radiology department over the last eight years and given that the empirical evidence suggests that diagnostic errors may have an adverse impact on patient outcomes, it is necessary to review the error rates of preliminary after-hours reporting.

This thesis illustrates the findings of a mixed method, cross-sectional study undertaken to review and determine the error rates of preliminary after-hours reports by registrars within the radiology department at CHBAH in Johannesburg. Findings from the study illustrate the current error-rate and furthermore, highlight why certain errors may be occurring. By understanding this, registrars (both present and future) will benefit from any action taken (e.g. further training, reduced workload) to decrease errors. This study suggests recommendations that will guide policy initiative to influence the further reduction of the discrepancy in the after-hours preliminary reporting at CHBAH.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

The impact of medical errors in morbidity and mortality has been demonstrated in a number of studies (12-13). Medical errors now rank as the third leading cause of death in the United States, with 10% of all deaths attributed to error (13). As radiological imaging is increasingly becoming an integral part of the diagnostic and patient management process, it is important that error in radiology reporting specifically is monitored, reviewed and managed. Bruno reported that most radiology errors are attributable to image interpretations by the radiologist (14). Recent statistics indicate that the average diagnostic error rate in radiology is estimated to range between 3% and 5% for qualified radiologists (14-16).

This demand for "quick and reliable" reporting in emergency settings has been well documented (17). Empirical evidence demonstrates that timely availability and accuracy of reporting is critical to clinical decision-making (9). Error can lead to patient-care complications such as missed diagnosis, missed opportunity for treatment, delayed treatment, over-investigation and increased health-care costs. Itri et al demonstrated that implementing processes to review and learn from diagnostic errors is critical in radiology quality assurance (16).

2.2 Definitions

"Error" in radiology can be assigned to two broad categories: perceptual and cognitive errors. Cognitive errors are when an abnormality is identified but its significance is not reported or it is poorly understood. Perceptual errors occur when an abnormality is not identified in the first place, but is recognised in retrospect. Perceptual errors are reported to account for 60-80% of radiological errors and cognitive errors 20-40% (18).

In this study "**major errors**" are those that may affect short-term patient clinical management, lead to changes in clinical management or have the potential to result in adverse patient events e.g. a missed pulmonary embolus (19-20).

"**Minor error**" refers to errors that will not immediately change patient management. This includes anatomical variants, incidental findings etc.

The term "**registrar**" is synonymous to "**resident**" and refers to post graduate medical professional registered in an academic institution for radiology speciality training. For the purposes of this study, the term "**registrar**" will be used.

2.3 Medical Imaging

Diagnostic imaging is an area of rapid growth in the emergency setting, particularly cross-sectional imaging with CT and MRI.

CT has been described as "the single most important diagnostic modality in the emergency department for both traumatic and non-traumatic conditions" (21). The use of CT imaging has increased exponentially in emergency medicine with a recent study quoting an 80% increase in the utilization of CT in emergency units (21). Pandharipande et al in a 2015 study, demonstrated the benefit of CT imaging as positively influencing diagnostic confidence and admission decisions in the emergency department (17).

There is a paucity of studies quantifying the use of CT and the diagnostic yield in the South Africa emergency setting. Swartberg and Goldstein demonstrated improved patient outcomes with the use of CT in the emergency medicine setting in one of the Witwatersrand academic hospitals (22). This has also been demonstrated globally.

2.4 Preliminary radiology reporting

The provision of after-hours radiological reporting services by registrars and issuing of "preliminary" reports remains a prevalent practice in academic institutions worldwide. The preliminary reports are most often reviewed the following morning by a consultant radiologist. This is seen as an essential part of registrar training, allowing independent decision-making.

A large number of studies on preliminary reporting have demonstrated error rates of 0.9%-25% with major error-rates of 0.1% to 2.6 % in preliminary reports. This is comparable to the major error-rate between general radiologists, which ranges between 0.8% to 2.6% (23-24). The causes of errors are generally multifactorial and have been attributed to volume of work, experience of registrars, time of reporting and body-region scanned, among others (4, 5, 8-10).

Work hours

There has been a call from the international community for the reduction of work hours for registrars. This is as studies across different specialities have demonstrated that extended work-hours have a negative impact on alertness, patient care, education and thus lead to increased medical-error (25-26).

This has further been demonstrated in radiology, by a number of studies, including those by Ruutiainen (8) who found that the radiology error increased significantly during the final two hours, when registrars covered more than 10 consecutive overnight hours. This was assumed to be related to fatigue-related cognitive decline.

Case loads

The increased reliance on medical imaging, specifically in emergency medicine, coupled with the popularity of 24-hour emergency radiology-imaging, has globally led to increased workload for radiologists. This has also meant increased workloads for registrars. A relationship between high volume and error rates has been proven (5).

Registrars' experience

The existing literature indicates that the likelihood of error decreases with increasing knowledge (27). It has been suggested to delay registrars doing independent calls until they are in their 3rd year of radiology training (28). This suggestion has arisen as studies continue to demonstrate decreased errors with increasing experience (9). A cross-sectional study demonstrated that junior residents were associated with a higher error-rate (5).

Body-region scanned

It is not surprising that more complex studies such as CT-abdomen studies result in a higher error-rate. This had been demonstrated in a plethora of studies where preliminary CT-abdomen reports generated higher error rates, than when compared to other body regions (24-30). Wildman-Tobriner demonstrated a 3.1 % rate of error that could affect clinical management in abdominal CT (15).

2.5. Errors in preliminary radiology reporting in South Africa

There is paucity of studies published on preliminary error-rates in South Africa. In 2012, Terreblanche (4) documented a 17.2% discrepancy between registrars and consultants in two academic hospitals in Johannesburg, Gauteng. Furthermore, De Witt (5) documented an error rate of 8 % in Tygerberg Academic Hospital, a similar training institution in Stellenbosch, Western Cape, South Africa, and a major error-rate of 4% which was comparable to published data. The causes of errors were thought to be due to various factors such as volume, experience, time of reporting (8) and body-region scanned (4, 5, 8-10). With reference to Terreblanche and De Witt's studies, errors in two academic training institutions in the South African context were linked to the time of reporting and the body-region scanned (4,5). These studies did not focus on establishing the cause of these imaging errors and neither on ways of correcting them through qualitative exploration. The factors contributing to these errors within the South African setting, therefore deserve a more in-depth investigation.

2.6. Addressing errors in preliminary radiology reporting

Although much of the focus on the literature has been on establishing error rates in preliminary reporting, some attention has been paid to ways in which errors may be reduced. This has included increased supervision of registrars during night calls. However, the major errors, that have potential to affect patient management, have been cited as not significant enough to reduce registrars' autonomy and thus the learning opportunity afforded, when being "on call". Whilst increased coverage by consultants was linked to reduced report-time turnaround, it is argued that this may come at the expense of registrar training (30).

Within the context of South Africa, the evidence has been limited to suggest pragmatic and sustainable solutions to reducing errors. As a result of Terreblanche's study, however, CHBAH changed the registrar call system. From 2014, there was no longer a single registrar on call, but a senior registrar was paired with a junior registrar, up until 22:00 in the evenings.

2.7. Summary

Based on the evidence presented in this literature review, the accuracy of reporting is critical to clinical decision-making, and errors may lead to patient- care complications. There is a large volume of literature analysing errors in reporting within HMICs, however, little is known about error rates within resource-poor countries such as South Africa, with a very low CT-scanner to patient ratio- 5 CT scanners per million patients (22). The last study conducted was over six years ago and there has been no follow-up to determine if error-rates have improved within the context of South Africa and the largest academic, teaching hospital in the country.

CHAPTER 3: METHODOLOGY

3.1 Study Aim and Objectives

The primary aim of this study was to guide policy initiatives to reduce the error rate in the after-hours preliminary reporting at CHBAH.

To achieve this aim, the study put forward the following research objectives:

Primary Objective

1. To **identify** the error rate in registrar after-hours preliminary reports at CHBAH.

Secondary objectives

2. To **qualify** the error type i.e. major vs. minor.
3. To **compare** the error rate against published data at teaching hospitals in South Africa as well as against international standards.
4. To **explore** the potential causes of errors.

3.2 Research design

The aims and objectives of this study determined that a cross-sectional retrospective research design using mixed methods would be the most appropriate research strategy. This included quantitative analysis of secondary data (preliminary radiology reports) of up to 3000 studies over a 3-month period (Jan 2018-March 2018) to answer the primary objective of the study, as well as secondary objectives 2 and 3. Of the 3000 studies analysed 18 were found to be incomplete. Exploratory, semi-structured qualitative interviews were conducted with registrars to answer objective 4 of the study. These interviews took place over a one-month period.

3.2 Context and current practice

CHBAH is one of four academic teaching hospitals of the University of the Witwatersrand. These hospitals include CHBAH, Charlotte Maxeke Johannesburg Academic Hospital, Helen Joseph Hospital, Rahima Moosa Mother and Child hospital. CHBAH is not only the largest

of the four hospitals within Johannesburg but it is the third largest hospital in the world, with approximately 3200 beds, 150 000 inpatient and 500 000 outpatient cases registered every year (36).

Approximately 2300 CT scans (patients) are performed in CHBAH every month; an estimated 40% (920) of these patients are scanned after-hours according to the departmental monthly statistics. As is common in the majority of academic teaching hospitals, after-hours scans are interpreted by registrars and issued as "preliminary reports" on the PACS. A consultant radiologist then reviews the preliminary reports within 24 hours after the preliminary report has been done. Any errors are then noted under the "comments" sections of the PACS. The department requires that referring doctors are then informed of major errors, likely to affect patient management.

The CHBAH radiology department has 17 consultants, 2 medical officers and approximately 32 registrars at various level of training. In the first 6 months of the registrar training program, the junior registrars are supervised by senior registrars after hours and they are discouraged from issuing reports independently. After 6 months in the registrar program, registrars may issue reports independently, however, it is mandatory for a senior registrar to be onsite to offer experienced support. Registrars start independent radiology after-hours calls after 9 months in the radiology registrar program.

The calls extend from 16h00 to 08h00 of the following day on weekdays. Between 16h00 and 22h00, two additional registrars are allocated to assist with reporting. From 22h00 to 08h00, there is one registrar allocated for reporting with support of an offsite consultant radiologist, who can assist telephonically. The "on call registrar" continues with the normal day shift from 08h00 to 12h00 the following morning, where they are encouraged to learn from any major errors. This forms part of their on-going learning.

The "day shift" of the weekend calls extends from 08h00 to 20h00 and then the "night shift" 20h00 to 08h00 the following morning.

3.3 Data Collection

The quantitative data was obtained by the PI from the CT reports stored on the PACS in the radiology department in CHBAH. Consent was obtained from the hospital Chief Executive Officer (CEO) and the Head of the Department (HOD) of radiology. The data was obtained from the reporting and "comments section" of the PACS. In order to try and understand the cause of errors, qualitative data was obtained by means of a series of semi-structured interviews with radiology registrars of all training levels.

3.3.1 Inclusion and exclusion criteria

Inclusion criteria

The sample will include:

- Preliminary reports issued by registrars after-hours.
- CT scans reported on the PACS.
- Registrars covering calls in CHBAH.

Exclusion criteria

The exclusion criteria are defined as follows:

- Reports by senior registrars who have obtained their Fellowship of College of Radiologists exit exam.
- Hand-written preliminary reports.

3.3.2 Sample and participant recruitment

Quantitative

The study included analysis of secondary data (preliminary radiology reports) of 3000 studies, of which 18 studies were excluded. All registrars who provided preliminary reports during the said period were grouped according to the level of training in the department. Each registrar was assigned a unique identifier to protect their anonymity. The preliminary reports of the registrar radiologists were compared with the corrections made by the reviewing consultant radiologist. The PI did not reread the scans and the amendments.

Qualitative

For the semi-structured interviews (SSI), a total of six participants were interviewed. The number was sufficient to reach theoretical saturation and was feasible, based on the time permitted to complete the MMED and on the availability of registrars within the department. Participants interviewed were provided with a detailed "Participant information leaflet" and the PI obtained written informed consent from the participant (Appendix 4). Participants were informed that they had the right to withdraw consent at any time during the study.

3.3 Data collection tools

3.3.1 CT reports review (quantitative secondary analysis)

All data was recorded on an excel spreadsheet (see appendix 1) with provision for the years of training, study date, time of the week, acquisition time, study region, scan series, reporting time, error, type of error (i.e. minor/major).

Examples of errors



Figure 3.1: Major error on CT angiography neck in lung windows: tension pneumothorax not reported.

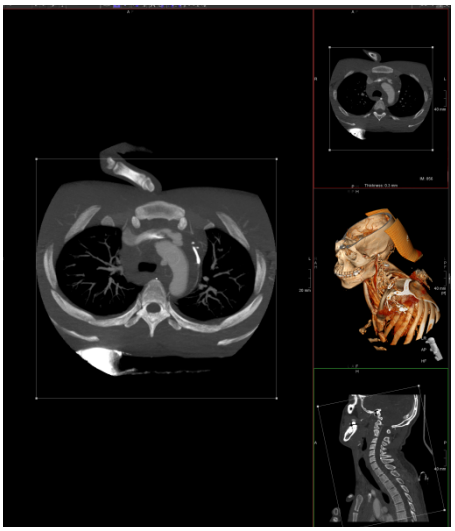


Figure 3.2: Major error on CT angiography to exclude a vascular injury: aortic injury not reported. Scan reported as "normal".



Figure 3.3: Major error on CT abdomen: liver laceration not reported.



Figure 3.4 Minor error on CT of the C-spine: spinous process fracture missed.

3.3.2 Semi-structured interviews (qualitative primary analysis)

The interviews took place at a time and location convenient to the registrar, in the radiology department. The interviews were conducted in English and lasted between 20 to 45 minutes. The interviews were recorded electronically using a dictaphone and then transcribed verbatim by the researcher. The names of participants were omitted and unique participant identities (IDs) were assigned to ensure anonymity. All participants were offered access to the transcript of their audio recordings.

3.4 Data analysis

Quantitative

Quantitative data in a Microsoft Office Excel spreadsheet was imported to *STATA software version 14*, cleaned and coded. Descriptive analysis was done using descriptive statistics, while inferential analysis applied correlations (bivariate), and multivariate regression analysis. The data was analysed at 95% confidence intervals, and at 5% significance level (31).

The following quantitative analyses were conducted:

Univariate and bivariate analyses: Univariate analysis was conducted with table of frequencies for each variable produced. Where applicable, figures were used. To qualify the error-type i.e. major vs. minor, a Chi-square analysis was conducted in order to determine if there were significant differences between major and minor errors for the various variables of interest.

Pearson's correlation: Correlations measure the strength and direction of the linear relationship between the two variables. The correlation coefficient can range from -1 to +1, with -1 indicating a perfect negative correlation, +1 indicating a perfect positive correlation, and 0 indicating no correlation at all. A variable correlated with itself will always have a correlation coefficient of 1 (32). A total of 550 observations were used in this analysis, i.e. only those who experienced a discrepancy (error).

Qualitative

Thematic analysis was employed as a method for identifying, analysing, and reporting patterns (themes) within data (34). This is a flexible form of analysis that includes themes that are generated through the researcher's review of the literature as well as themes that emerge inductively (35). The PI continuously reviewed the raw data and conceptualisation throughout data collection (35). The researcher followed *Braun & Clarke's* guidelines when conducting thematic analysis, which included listening to the audios and rereading the transcripts several times, generating codes and collating into themes. These were then illustrated with relevant data extracts.

3.5 Ethical considerations

This study received ethical approval from the Human Research Ethics Committee at the University of Witwatersrand (see appendix 2). Letters of approval were obtained from the CEO of CHBAH and the HOD of Radiology (see appendix 3). Participants were assigned personal identifiers to ensure anonymity and the key was stored separately from the main data. Data collected including the audio recordings and transcripts were encrypted and maintained on a password-protected computer with access limited to the researcher.

CHAPTER 4: RESULTS and ANALYSIS

This chapter presents both the quantitative and qualitative results of the study. The results will be structured according to the primary and secondary data analyses. Section 4.1 will outline the results from the registrar reports (related to objectives 1-3). Section 4.2 focuses on objective 4, and illustrates the findings and analyses from the qualitative interviews.

4.1 Quantitative analysis

This section provides results of the study on the discrepancy rates in after-hours preliminary computed tomography reports at CHBAH. Out of 3000 studies, 2982 were deemed eligible for inclusion. Descriptive statistics are outlined in the form of tables and figures, followed by bivariate analysis which looks at associations between variables of interest and error type.

4.1.1 Descriptive statistics

Year of training

Sixty-eight percent of the studies in the sample were reported by registrars in YEAR 2 (34.1%) and YEAR 3 (34.1%). A smaller proportion was reported by senior registrars i.e. YEAR 4 (19.9 %) with the most junior registrars responsible for reporting only 9.3% of the study sample (See Figure 4.1).

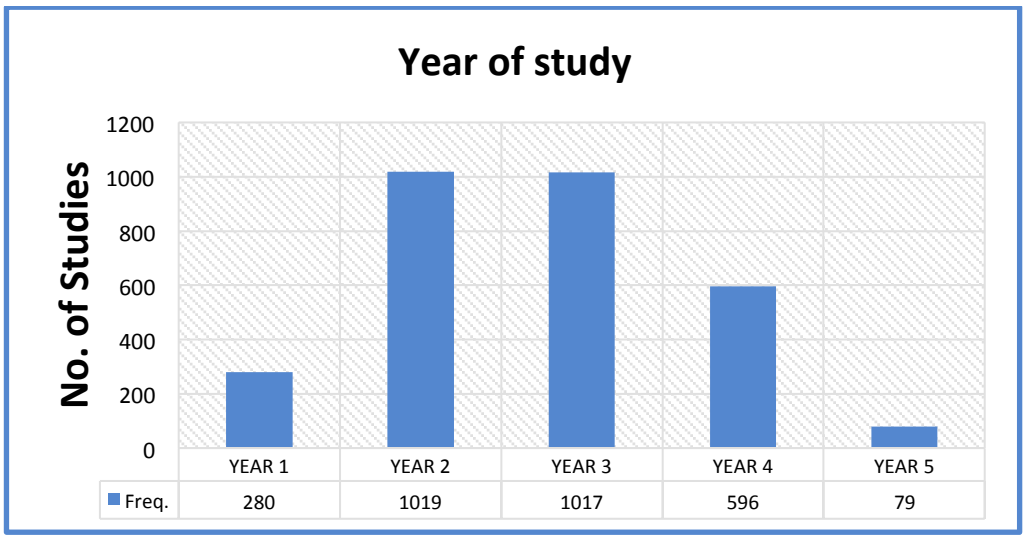


Figure 4.1: CT reporting by year of training.

Categorization of workload

The workload ranged from 8 to 55 CT reports per call, with a mean of 34 reports per call. The workload was classified into low (0-30 reports), medium (31-45 reports) and high (45-55 reports). At least half i.e. 56.53% (n=1687) of the reports were generated during periods of medium workload, 36. 66% (1094) (see figure 4.2).

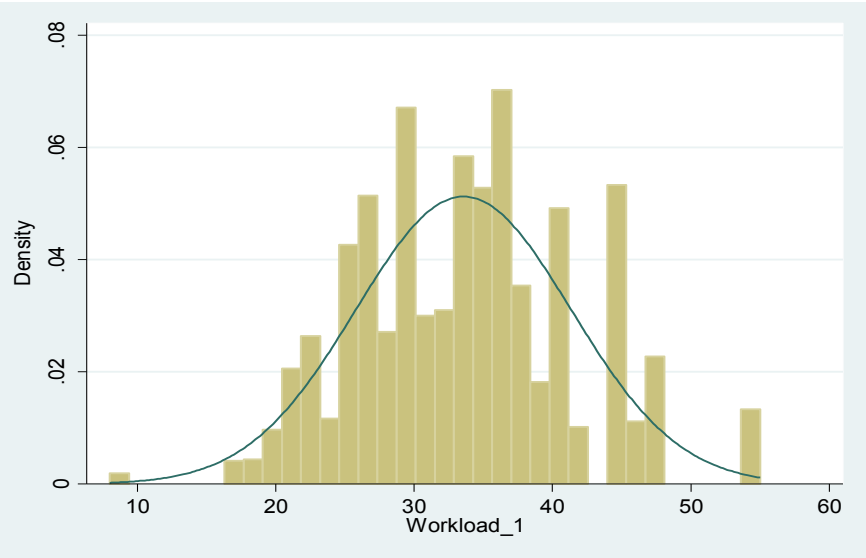


Figure 4.2: Analysis of workload

Workload relating to the day of the week

The weekends generated the largest workload with 58.42% of the study sample reported on Saturday and Sundays. Wednesday and Thursdays generated the lowest workload with only 10.66% and 10.72% of the study sample reported on these days respectively (see figure 4.3).

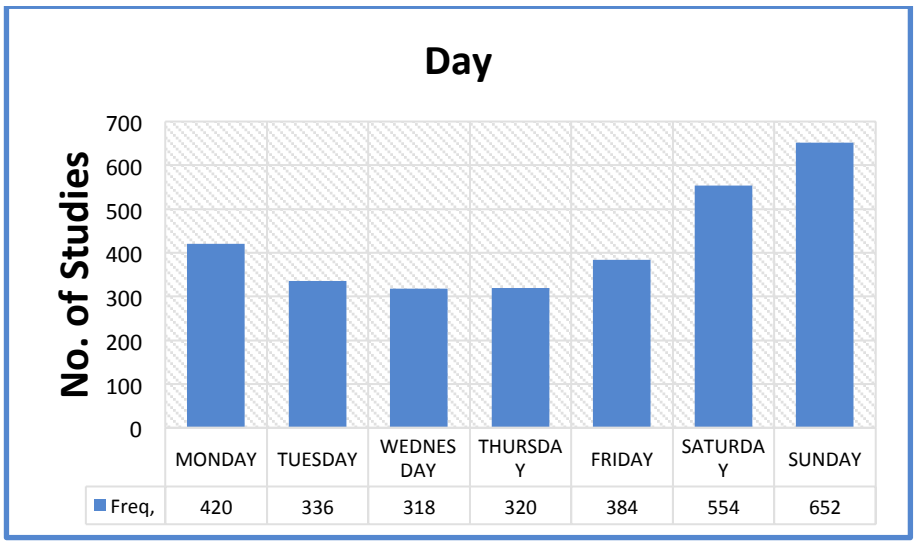


Figure 4.3: Workload by day of the week

Reporting and acquisition time

There was a minimal difference between the acquisition time and the reporting times. The majority (28.5%) of the scans were acquired/performed between 20h00-24h00, 25.8% between 16h00-20h00 and 21% between 00h00-04h00. Only 8.9%, 8.2% and 7.1% were reported between 12h00-16h00, 04h00-08h00 and 08h00-12h00 respectively.

A quarter of the scans were reported between 00h00-04h00 (25.6%), 26.5%3 between 20h00-00h00, 13.3% 04h00 and 08h00. Only 8.4% and 5.3% were reported between 12h00-16h00 and 08h00-12h00 respectively.

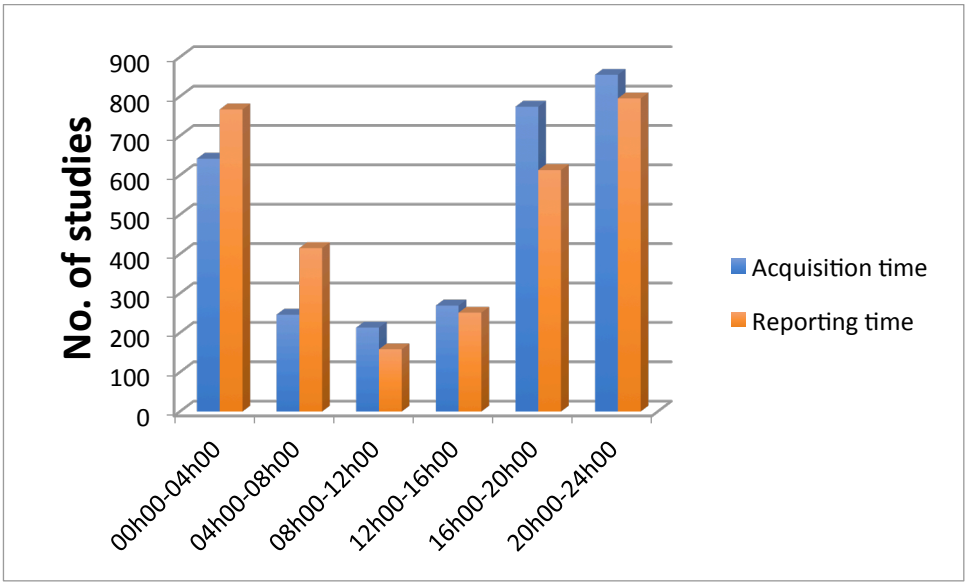


Figure 4.4: Reporting and acquisition time (weekday and weekends).

Body-region scanned

The "head region" accounted for 57.8% of the body regions scanned, followed by "abdomino-pelvic" (14.8%), "cervical/thoracic/lumbar spine region" (13.5%), "vascular" (7.6%), with the "chest region" accounting for only 5.1% (see table 4.1).

Table 4.1: Body-region scanned

BODY REGION	Freq(n)	Percent (%)
Abdomino-pelvic	442	14,8
C/T/L Spine	405	13,5
Chest	153	5,1
Head	1724	57,8
Musculoskeletal	12	0,4
Neck	21	0,77
Vascular	225	7,5
TOTAL	2982	100

4.2 Error/discrepancy

Analysis of error: major/minor

The overall error/discrepancy rate was 18.48% for all included studies. The errors were further categorised as "minor" N=503 (16.68%) and "major" N= 48 (1.6%). These categories form the outcome variables of this study, as it seeks to determine if there are relationships between predictor variables (see table 4.3).

Table 4.3: Error type

ERROR TYPE	Freq (n)	Percent (%)
Minor	503	16,86
Major	48	1.60
NO	2431	81,52
Total	2982	100

Analysis of error with respect to "years of training"

The $\chi(4) = 1.18, p = 0.881$ indicates that there is no statistically significant association between "error type" and "year of training". The minor and major discrepancies were equally likely to occur with no major differences in terms of "the year of training" (see table 4.4).

Table 4.4 Error type with respect to "year of training"

	ERROR TYPE		
	Minor	Major	Total
Year of study	N (%)	N (%)	N (%)
YEAR 1	54 (10.74)	6 (12.77)	60(10.91)
YEAR 2	181 (35.98)	19 (40.43)	200 (36.36)
YEAR 3	177 (35.19)	13 (27.66)	190 (34.55)
YEAR 4	83 (16.50)	9 (17.02)	91 (16.55)
YEAR 5	8 (1.59)	1 (2.13)	9 (1.64)
Total	503 (100)	48 (100)	551 (100)

Analysis of error with respect to" body region"

The "head region" reports contained the most errors (53.36%), followed by "abdomino-pelvic region" (25.95%). The "neck region" scans (0.73%) contributed the least number of errors, followed by "musculoskeletal" (0.91%), "C/T/L spine" (4.90%), "vascular" (7.44%) and "chest" (6.71%).

The χ (6) = 27.5, p = 0.000 indicates that there is statistically significant association between error type and "body region." Errors were most likely to be identified in the "head region" scan, however these errors contributed mainly to minor errors (55.8%), with only 27.7% contributing to major errors.

The "abdomino-pelvic" region errors were more likely to be major errors (51.1%), compared to minor errors (23.6%). Although a small proportion, total "vascular" region errors were twice as likely to be major errors (14.9%), compared to minor errors (6.8%). "Chest" errors (6.71%) were equally likely to be major or minor errors, while C/T/L spine (4.90%) and "musculoskeletal" (0.91%), were predominantly minor errors (1%) (see table 4.5).

Table 4.5: Error with respect to "body region"

	ERROR TYPE		Total
	Major	**Minor**	
BODY REGION	N (%)	N (%)	N (%)
ABDOMINOPELVIC	24(51.10)	119 (23.61)	143 (25.95)
C/T/L SPINE	0	27 (5.36)	27 (4.90)
CHEST	34.26)	35 (6.94)	38 (6.71)
HEAD	13 (27.66)	281 (55.75)	294 (53.36)
MUSCULOSKELETAL	0	5 (0.99)	5 (0.91)
NECK	1 (2.13)	3 (0.60)	4 (0.73)
VASCULAR	7 (14.89)	34 (6.75)	41 (7.44)
Total	48 (100)	503 (100)	551 (100)

Analysis of error with respect to "workload"

The χ (2) = 46.6, p = 0.001 indicates that there was statistically significant association between "error type" and "workload". The average workload (scans per shift) was 33.3 scans, with a maximum of 55 and a minimum of 8 scans. No errors were identified when less than 15 reports were issued. There were more minor errors (39.36%) compared to major errors (34.04%) during calls of medium workload i.e. 16-30 reports. Major errors (59.57%) were more likely to have occurred during medium workload calls where 31-45 reports were issued, compared to minor errors (54.47%), There was no difference between the rate of major and minor errors during high workload calls (see table 4.6).

Table 4.6: Error with respect to workload

Workload	**Minor**	**Major**	**Total**
	N (%)	**N (%)**	**N (%)**
16 to 30	198 (39.36)	16 (34.04)	214 (38.91)
31 to 45	274 (54.47)	29 (59.57)	303 (54.91)
45 to 60	31 (6.16)	3 (6.38)	34 (6.18)
Total	503	48	551
	100.00	100.00	100.00

Pearson chi2 (2) = 0.5199 Pr = 0.771

Analysis of error with respect to "the day of the week"

The χ (2) = 1.11, p = 0.573 indicates that there is no statistically significant association between "error type" and "day of the week". Minor and major errors were almost equally likely to occur with no major differences in terms of the "day of the week". There were very slight differences between errors during weekdays; major errors (68.1%) seem to occur more on weekdays compared to minor errors (60.24%). Another slight difference can be observed between errors during weekends; major errors (29.8%) seem to occur less on weekends compared to minor errors (36.98%) (see table 4.7).

Table 4.7 Error with respect to "day of the week"

	Major	**Minor**	**Total**
DAY TYPE	**N (%)**	**N (%)**	**N (%)**
WEEKDAY	33 (68.09)	303 (60.24)	336 (60.91)
PUBLIC HOL	1 (2.13)	14 (2.78)	15 (2.73)
WEEKEND	14 (29.79)	186 (36.98)	200 (36.36)
Total	48 (100)	503 (100)	551 (100)

Analysis of error with respect to" reporting time"

The χ (2) = 1.33, p = 0.723 indicates that there is no statistically significant association between "error type" and "reporting times". Minor and major errors occurred with no differences in reporting times. It is only between 00h00 and 04h00, that a slight difference is observed between major (19.15%) and minor (26.79%) errors. Comparing different time periods, errors were more likely to occur between 04h00 and 08h00, followed by the period between 08h00 and 12h00. This could imply that minor errors were more likely to be reported between 00h00 and 04h00 (see table 4.8).

Table 4.8: Error with respect to "reporting time"

	Reporting times		
	MAJOR N(%)	**MINOR N(%)**	**Total N(%)**
00h00-04h00	13(27.08)	130(25.84)	143(25.95)
04h00-08h00	2(4.17)	60(11.93)	62(11.25)
08h00-12h00	3(6.25)	21(4.17)	24(4.36)
12h00-16h00	5(10.42)	44(8.75)	49(8.89)
16h00-20h00	13(27.08)	116(23.06)	129(23.41)
20h00-24h00	13(25.00)	132(26.24)	145(26.13)
Total	48(100)	503(100)	551(100)
Pearson chi2(5)	Pr = 0.658		

Analysis of error with respect to "acquisition time"

The χ (2) = 2.42, p = 0.971 indicates that there is no statistically significant association between "error type" and "acquisition time". Those demonstrating minor and major errors were equally likely to demonstrate no differences in acquisition times (see table 4.9).

Table 4.9 Error with respect to "acquisition times"

	Acquisition time		
	MAJOR N(%)	**MINOR N(%)**	**Total N(%)**
00h00-4h00	11(22.92)	110(21.87)	121(21.96)
04h00-08h00	0(0.00)	34(6.76)	34(6.17)
08h00-12h00	4(8.33)	32(6.36)	36(6.53)
12h00-16h00	4(8.33)	50(9.94)	54(9.80)
16h00-20h00	19(37.50)	143(28.43)	126(29.22)
20h00-12h00	11(22.92)	134(26.64)	145(26.32)
Total	48(100)	503(100)	551(100)
Pearson chi2(5)	Pr = 0.405		

4.3 Qualitative results

4.3.1 Semi-structured interviews (SSIs)

Six participants took part in SSIs. All participants had been doing afterhours calls during the period of the study. The analysis of the interviews produced two dominant themes, with other sub-themes, as highlighted in **Table 4.10.** These will be outlined below and supported by direct quotes from the interview transcripts. The registrars remain anonymous and the quotes are identified by the Participant number and Page number of the transcript. For example, a quote from "participant one" and taken from page 3 of the transcript will appear after the quote as 'P1, p3'.

Table 4.10: Themes & Sub-Themes from SSIs

Theme	Sub-Theme
1. Challenges with reporting	Lack of feedback/supervision/training
	Workload
	Shift work and fatigue
	Interruptions
	Lack of knowledge/experience
	Uncertainty
	Body region scanned
	Fear of disappointing and overburdening colleagues
2. Suggestions to reduce error rates	Improving channels of communication
	Increasing level and quality of supervision
	Reducing call hours
	Increasing staff numbers
	Improving approaches to learning

4.3.2 Contextual information on registrars and reporting

All of the registrars had experience of doing calls, ranging from 6 months- 2 years. The registrars explained that templates are used at CHBAH for reporting and most of the registrars were familiar with the templates but some had issues with how to edit the template on PACS. Otherwise, the templates were considered to be quite useful. One registrar noted that he/she tries to report "according to pathology" first before relying on the templates. All the registrars explained that they review and check amendments on reports afterwards, usually during the course of the week or when they are next on duty. If, when reporting, registrars are unsure of something and cannot consult with anyone, the most common source of help is the internet or books, or sometimes a fellow colleague (with more experience). Although the majority of registrars thought that the rate of errors decreased with increased experience, one registrar stated that increased knowledge and studying may paradoxically impact on error rates for registrars as they may begin to "overcall" pathology.

4.3.3 Theme 1: Challenges with reporting

A number of sub-themes emerged when discussing errors in reporting. Many of the participants attributed such errors to potential causes as outlined below:

Lack of feedback/supervision/training

Although registrars were sometimes hesitant to elaborate, there was agreement on a lack of feedback, inadequate supervision and limited on-going training: For example, with regards to feedback, registrars explained that although they may try to check for errors, their reports have not always been reviewed or at times when they are reviewed, *"I don't even see what they are talking about*" (sic) (P6, p1)

Furthermore:

"Sometimes consultants make corrections on the request form but not on PACS and then you don't get to know what mistakes were made and what corrections were done on your reports if it's not on PACS" (sic) (P2, p3).

It was felt that there is "*no standard approach"* to reporting and training has focused on procedures but is rather lacking when it comes to teaching registrars how to actually identify and report pathological findings:

"[The lectures] don't tell you what to report and what to look for" (sic) (P3, p3).

In relation to training, one registrar expressed a concern about the lack of support from the consultants:

"I feel like I'm not really getting much out of the consultants. I feel like I'm just pushing the queue" (sic) (P5, p3).

The importance of "reviews" to registrars' learning was strongly emphasised with one participant stating:

"The reviews help me to know what to look for next time because there are some mistakes I've made and I'm like "no, no, don't ever do this mistake again" (sic) (P1, p2)
One registrar stated that sometimes *"there are times where I am too tired to care"* (sic) (P4, p2). Therefore they did not actively seek feedback.

Workload
Workload was a very dominant sub-theme in the interviews. Registrars cited CHBAH as the busiest hospital that they have worked in, and their perception was that there is an association between the high volume of workload they experience and subsequent errors. When asked in which hospital, on the Wits circuit, registrars make more mistakes, comments were:

"CHBAH, I think it's because of the exhaustion…there are too many cases to be reported and many ultrasound studies to be done in between the CT cases" (sic) *(P2, p3)*

"*CHBAH, most mistakes are made because of the volume of work after hours*" (sic) (P5, p3)

Regarding how busy the hospital is and how this relates to errors:

"Ideally you would have to go and look through the scan you did through the night and check the reviews. I would love to do that because that's how you learn and that's how you become a better doctor. But in the swing of things, I think we are in quite a big circuit. I've never been able to do that." (sic) (P3, p1)

"It's the workload because the department accepts everything that the surgeons request." (sic) (P1, p2)

"I don't concentrate well because of the emotional stress of how busy our circuit is" (sic) (P3, p2)

"If there was time to actually sit and review each and every case you would know [your errors]. Which is sad, because you then think "ok. Let's wing it again" and then you wing it" (sic) (P4, p3)

Shift work and fatigue

Some registrars explained that most of their errors probably occur during their night shifts as this is when they are at their most tired, working long hours and often alone:

"*I think on call the mistakes that are made are due to tiredness. If you come to work from 12 PM the previous day and then you are left overnight to report urgent cases alone, you get up exhausted and if you are tired you make mistakes*" (sic) (P2, p2)

"Another second thing is long hours, long shift for the number of patients" (sic) (P5, p2)

One registrar stated that after-hours reporting is not a time for learning as reports are *'mass produced… and definitely not like what happens in the daytime. After-hours reporting isn't about learning. It's about service delivery"* (sic) *(P3, p1)*

The time of day also played a part in the likelihood of reporting errors being made. For example, one registrar said:

"*Around 2am, I'm tired and then I make mistakes because I'm not fully concentrating on what I'm doing or I'm hungry. Also between 6 am and 8am, there's a lot of scans being done before 6am so you try faster before 8am because now you have to start new work or a new day. So, you tend to report faster than you normally would."* (sic) (P4, p2)

Another registrar explained that sometimes there is just too much to do for one person:
"In-between you're doing so many modalities at one time. You could be doing pneumatic reduction, ultrasound, screening cases. So what makes it more complex is going in-between different imaging modalities in one night" (sic) (P5, p2)

There were many complaints about interruptions by clinicians and claims that such interruptions "*probably contribute to the mistakes we make"* (sic) (P6, p3) as registrars may lose track of what they had been evaluating on the scan:

"If the interruptions were not there I would make less mistakes" (sic) (p6, p3)

One registrar described such interruptions in detail:

"I get easily distracted. Especially if there's a junior because they keep asking you questions that you don't know. And then you get bookings, the last minute bookings from clinicians. They come in and out and they distract you. You leave reports half done. I've reported and forgot to go back to them because then you close, you open something else, you give contrast and then somebody talks to you and you forget about your report" (sic) *(*P4, p1)

Lack of knowledge/experience

Registrars associated the making of errors with their length of experience but that experience and "being on the floor" helps to reduce errors:

"*I would say the error rate…is less now…[when] I check the amendments now I find that not much has changed compared to how it was when I first started*" (sic) (P2, p2)

Uncertainty

When asked what registrars do when they are unsure of something, one participant stated that they may consult a friend:

"Basically, I will try and call a friend but if they are sleeping I will basically report for the sake of reporting" (sic) *(P6, p2)*

Others said:

"You just write whatever you see and send it out knowing that the following day it'll be reviewed." (P2, p1)

"*What I do is I l look at the scan and if I see something, I write about it even if I don't understand. I'll write that I've seen this and submit.*" (sic) (P5, p2)

Body region scanned

Some registrars stated that they did not struggle to report one particular "body region" but "the neck" was mentioned as taking longer to report on. Angiography and abdominal scans were cited as being "quite tough" (P3, p1) as well as facial fractures by another registrar.

Fear of disappointing and overburdening colleagues

The registrars expressed that they sometimes rushed through scans in order to avoid being judged or avoid disappointing colleagues by leaving work unfinished:

"*I don't want to get behind with my scans. I don't take breaks. So I push, push, push and then I get so fatigued but I don't stop I still continue…. I start emotionally collapsing when I think there's a possibility that I would have to hand over work to my colleagues. I am afraid I would be perceived as a lazy registrar who hands over work.*" (sic) (P3, p2)

4.3.4 Theme 2: Suggestions to reduce errors

The interview participants suggested possible ways to improve reporting procedures. They also came up with potential solutions on how to reduce errors rates. The sub-themes are discussed below:

Improving channels of communication

All registrars agreed that more feedback was needed:

"I would prefer to get feedback." (sic) *(P6, p1)*

The importance of feedback was recognised as way of learning and developing:
"*It needs improvement because if I make a mistake and it's corrected but I don't see the correction, I will make the same mistake again tomorrow and this will go on forever and we'll be sending out reports that are wrong. You don't grow as well as a registrar; you become a senior but report and think like a junior.*" (sic) (P2, p3)

With regards to improving general communication, one registrar suggested that:
"The onus should be on us because this is our career, our academic program. It's not really anything to do with the consultants but I would love a photo and a WhatsApp of the corrections so that I'm prompted to look at that scan." (sic) (P3, p1)

Another said:
"*Here it would also be nice if they were to book over the phone. I don't know if it would mean less or more bookings but I guess you would be less annoyed.*" (sic) (P4, p3)

Increasing level and quality of supervision

Although feedback regarding reports was deemed to be useful, one participant found the most effective way of learning was for a consultant to physically sit with the registrar and go through the cases with errors:

"*The best way was for the consultant to sit with me and actually show. For me that worked. Then it could be explained*" (sic) (P6, p2)

"*Reviews and sitting with consultants would help, even if it's not a one- on- one session but if you know that certain registrars were on call that week and then we go through mistakes we've made. Maybe even as a group, maybe if it was a CT brain. There are so many pathologies we could cover. Especially if we did for example brain pathologies you could encounter on call."* (sic) (P4, p2)

Some comments that were directed at the consultants improving their own practice included the following:

"*Consultants need to read more, gain more experience and exposure to many cases so that they are able to correct the mistakes that registrars make.*" (sic) (P2, p3)

"*You have the registrar's reports, then you have another tab that is often closed and this contains the amendment by the consultant. I don't think it's a logical pairing and I think that consultants should generate a new report. Copy the whole thing and then amend it to one succinct summary. So you have the original report and the amended one.*" (sic) (P3, p3)

Reducing call hours

It was suggested that the call hours be reduced so that the after-hours worked are in line with those worked by registrars in other parts of the country. There was some scepticism as to how it would help for registrars to try to rest before going "on call". This option was regarded as favourable and it was suggested that registrars must "*at least rest in between*" (sic) (P1, p3), if it were not to be "feasible" to reduce hours or, alternatively, a "shift type" system could be considered:

"Perhaps like, you put on 2 people and you each do six hours" (sic) *(*P1, p3)

"*I think what can be done to help with this is perhaps time to rest, maybe two hours during the call at night. Not many mistakes are made during the day because you're still fresh.*" (sic) (P2, p3)

Increasing staff numbers

A number of registrars mentioned the idea of increasing staff numbers. This was however thought not to be as attractive as the other options:

"If there were more persons on call, especially here at Bara. I think it would be better." (sic) *(P1, p2)*

"*I absolutely would not want this to be done but if more than one person could be on call*" (sic) (P3, p3)

"It would need a lot of time and manpower. I feel, maybe it's too ideal that we have a regular sit with a particular consultant to go through the cases" (sic) (P4, p3)

Improve approaches to learning

There were several suggestions as to how training and learning could be improved. Overall, registrars felt that lectures should be more didactic, also that tutorials should be more focused on each intake/ group of registrars, depending on their experience etc. for example, focusing on emergencies for the junior registrars.

"When starting the program, the focus should be about emergencies in a manner of a tut. We should be saying that these are the first month registrars, this is the number they are and this is the tut we are giving them. It should be more focused on that in the first 9 months." (sic) (P5, p3)

Regarding the planning of cases:

"I've experienced that not getting used to planning cases is what makes you accept cases that are not relevant. You can't understand which is not important, which one is important and why. So I think this should also be included as a tut." (sic) (P5, p3)

CHAPTER 5: DISCUSSION

5.1 Summary of results

The primary objective of this study was to identify the error rate in registrar after-hours preliminary reports at CHBAH. Following secondary analysis of reports, the error rate was found to be 18.48%.

There were three secondary objectives including:

1. Quantifying the error type i.e. major vs. minor. We found that major errors contributed 1.6 %, whilst minor errors contributed 16.86%.
2. Benchmarking the error rate against published data on teaching hospitals in South Africa and internationally. This appears in table 5.1.

TABLE 5.1: Summary of comparative studies regarding errors in preliminary reporting

	Year	No of studies	Data collection period	Ovarall error rate	Major Error	Minor Error
Our Study	2018	2982	71 days	18.48%	1.60%	16.86%
De Witt (5)	2014	225	28 days	8%	4%	4%%
Terreblanche (4)	2012	1477	80 days	17.1%	7.7%	9.4%
Ruchman (38)	2002-05	11,908	3 years	23,97	2.6%	21.37%

3 The qualitative findings identified two dominant themes emerging from the semi-structured interviews with registrars, including:

a) Challenges with reporting
b) Suggested interventions to reduce error rates.

The key challenges for registrars were consistent with the literature (workload, shift work, lack of experience and body-region scanned), with additional emphasis placed on areas such as lack of feedback, interruptions from colleagues, uncertainty and the fear of disappointing others.

Eight years on from Terreblanche's study within the same department at CHBAH, the error rate remains fairly consistent. The error rate in 2012 was 17.1% with only a marginal increase to 18.48%. The error rate is comparable to published Sub-Saharan Africa benchmarks and internationally published literature of 0.9% to 25 % (2-8). In comparison to Terreblanche's study, the total error rate remains roughly the same. The increase may well be attributed to an increase in the workload (see Table 5.2).

Table 5.2: Comparison of after-hours workload (scans) in 2012 vs 2018

Workload	2012	2018
Low	0-17	0 to 30
Medium	18-23	31 to 44
High	>24	45 to 55

Workload has been implicated in a number of studies as a major contributor to error (5,11). The average workload in CHBAH has increased by 94%, with registrars reporting an average of 34 scans in a 16-hour call, compared to the previously published 18.5 scans for the same hospital. Workload also came up repeatedly in the interviews as a very likely reason for error, with registrars attributing many of their errors to the sheer volume of work which leads to exhaustion, pressure to push through and results in subsequent mistakes being made. CHBAH is one of the busiest hospitals on the Wits circuit, therefore it is not surprising to find this issue being mentioned repeatedly in the interviews.

Together with workload, the length of the call shift at CHBAH, where registrars cover shifts of 12 to 16 hours, may contribute to the increased error rate. This study demonstrates a higher rate of errors between 20h00 and 24h00, similar to Terreblanche's finding. Ruutiainen also demonstrated that there was an increased error-rate after working 10 consecutive hours (8) Registrars also reported this in their interviews, stating that due to being tired and hungry, more errors were being made.

The results indicated a statistically significant association between "body region" and error. The "head region" reports contributed 53.36 % to the error rate; followed by "abdomino-pelvic" scans (25.95%). This is contrary to Terreblanche's findings, where the "abdomino-pelvic" scans contributed 33.9% and the "head" 16.5 % of the errors. These differences may be attributed to interventions implemented after Terreblanche's report. However, the

"abdomino-pelvic region" still contributed the most to **major** errors. Additionally, in this study, "vascular" region scans were twice as likely to generate major errors (14.89%) compared to minor errors (6.75%). Thus, as demonstrated in similar studies, the preliminary reporting of "abdomino-pelvic" and "vascular "scans remains an area of concern. These finding suggests a need for more focused training especially for the reporting of "abdomino-pelvic" and "vascular" scans.

A notable but not statistically significant association was demonstrated with "year of study/registrar experience" and error rate. The lower error-rate in **YEAR 1** with an increase in **YEAR 2** and **YEAR 3**, coupled with a decrease in **YEAR 4** is consistent with literature. This was attributed to pairing of juniors with seniors in the first year and a reduction in the number of calls by senior registrars as they start preparing for radiology exit exams.

When comparing the results of this study with its predecessors, it is important to consider the context in which the study has been conducted. As already pointed out, the majority of such studies have mostly taken place within HMICs. Very little, similar research has been done in LMICs such as Southern Africa. CHBAH is noted as being the busiest hospital in South Africa, therefore it can be expected that the error may be higher. Overall, findings were fairly consistent with studies conducted both in low- and high-income settings. One would speculate that there would be higher case volumes in LMICs because of the scarcity of expensive resources like CT scans.

A unique feature of this study is the qualitative component, which involved anonymous interviews with the registrars. To our knowledge, this is the first published study of its kind in Sub-Saharan Africa. As with all qualitative research, it is the quality of the data rather than the number of participants taking part. The interviews not only confirmed what emerged from the quantitative analysis, but also provided a richness and understanding that one cannot capture by means of quantitative analysis. The data from the interviews provided insight into the perspectives of the registrars.

Suggestions on how to reduce errors from the registrars' perspective

The registrars made valuable suggestions on how to reduce the error rate. Some suggestions were consistent with the existing literature (reducing call hours, increasing staff numbers, increasing level and quality of supervision) however, new suggestions around improving

feedback and “approaches to learning” also emerged. Terreblanche suggested in his 2012 study to change the registrar call system by adding an additional registrar to each shift and pairing a junior together with a senior registrar. This recommendation was only partially implemented. An additional “lates registrar “cover was introduced only until 22h00, and where available also a medical officer. Having calls covered by two registrars would have resulted in the doubling of the number of call per month for registrars. It was thus not implemented.

Overall, the study hopefully demonstrates the value of involving the registrars in such research as it involves them, especially if recommended changes/interventions are put into place to improve practice.

CHAPTER 6: LIMITATIONS OF STUDY & SUGGESTIONS FOR FUTURE RESEARCH

6.1 Limitations of study

Due to the limitation of the time available to collect data, we were not able to demonstrate whether seasonality (in terms of public holidays and disease burden) had any influence on error rate. Unlike Terreblanche's research, the study was retrospective so it was not possible to further classify error type e.g. missed finding, incorrect wording, misinterpretation etc, as this classification is not part of the department's amendment protocol.

While it was very useful interviewing the registrars, the sample size was small due to limitations of availability and time. Only those registrars rotating in CHBAH at the time of the study were eligible for interview. The results may therefore not be representative of all registrars within CHBAH.

6.2 Suggestions for future research

Specific to the evidence presented in this study, further research could be conducted on the following:

1) The direct impact of the preliminary registrar errors.
2) Understanding errors from the perspective of the consultants
3) Tracking registrars through the program to see if error improves with experience
4) Designing an intervention targeted at reducing error rates such as reduction of call hours
5) Quantification of the error rate on finalised reports i.e. reporting error by qualified radiology staff.

More broadly speaking, the methods and approach used in this study could be applied in different contexts to determine how useful they are for determining error rates and establishing potential causes as previously classified in comparative, prospective studies.

CHAPTER 7: CONCLUSION

This study demonstrates that despite quantification of error in 2012 and technological advances since then, there has been no improvement in error rates at CHBAH. The results from this study highlight why certain errors may still be occurring, and by understanding this, registrars (both present and future) and ultimately the patients will benefit from any action taken towards error reduction. This research therefore plays an important role in quality assurance at CHBAH. Radiology plays an ever- increasing role in the clinical-diagnostic and management-pathway and thus contributes to the morbidity and mortality attributed to medical error. Understanding and implementing strategies aimed at error reduction will positively impact on quality and safety of medical care within South Africa's largest academic teaching hospital. This study therefore suggests recommendations that will guide policy initiatives to further reduce the error rate in the after-hours preliminary reporting at CHBAH.

CHAPTER 8: REFERENCES

(1) Arasu VA, Abujudeh HH, Biddinger PD*, et al.* 2015. Diagnostic emergency imaging utilization at an academic trauma center from 1996 to 2012. *Journal of the American College of Radiology : JACR*, 12(5):467-74.

(2) Tung M, Sharma R, Hinson JS*, et al.* 2018. Factors associated with imaging overuse in the emergency department: A systematic review. *The American journal of emergency medicine*, 36(2):301-09.

(3) Bruno MA, Duncan JR, Bierhals AJ*, et al.* 2018. Overnight Resident versus 24-hour Attending Radiologist Coverage in Academic Medical Centers. *Radiology*, 289(3):809-13.

(4) Terreblanche OD. 2012. Statistical review of radiology registrars after-hours computed tomography reporting accuracy. *Acta Radiol*, 53:61-68.

(5) De Witt JF, Griffiths-Richards S, Pitcher RD. 2014. The accuracy of after-hour registrar computed tomography (CT) reporting in a South African tertiary teaching hospital. *South African Journal of Radiology*, 18(1), 3 pages.

(6) Davenport MS, Ellis JH, Khalatbari SH*, et al.* 2010. Effect of work hours, caseload, shift type, and experience on resident call performance. *Acad Radiol*, 17(7):921-7.

(7) Issa G, Taslakian B, Itani M*, et al.* 2015. The discrepancy rate between preliminary and official reports of emergency radiology studies: a performance indicator and quality improvement method. *Acta Radiol*, 56(5):598-604.

(8) Ruutiainen AT, Durand DJ, Scanlon MH*, et al.* 2013. Increased error rates in preliminary reports issued by radiology residents working more than 10 consecutive hours overnight. *Acad Radiol*, 20(3):305-11.

(9) Ruutiainen AT, Scanlon MH, Itri JN. 2011. Identifying benchmarks for discrepancy rates in preliminary interpretations provided by radiology trainees at an academic institution. *J Am Coll Radiol*, 8(9):644-8.

(9) Weinberg BD, Richter MD, Champine JG*, et al.* 2015. Radiology resident preliminary reporting in an independent call environment: multiyear assessment of volume, timeliness, and accuracy. *J Am Coll Radiol*, 12(1):95-100.

(10) Bruni SG, Bartlett E, Yu E. 2012. Factors involved in discrepant preliminary radiology resident interpretations of neuroradiological imaging studies: a retrospective analysis. *AJR Am J Roentgenol*, 198(6):1367-74.

(11) Coleman S, Holalkere NS, O'Malley J*, et al.* 2016. Radiology 24/7 In-House Attending Coverage: Do Benefits Outweigh Cost? *Current Problems in Diagnostic Radiology*, 45(4):241-46.

(12) Brennan TA, Leape LL, Laird NM*, et al.* 1991. Incidence of Adverse Events and Negligence in Hospitalized Patients. *New England Journal of Medicine*, 324(6):370-76.

(13) Schwendimann R, Blatter C, Dhaini S*, et al.* 2018. The occurrence, types, consequences and preventability of in-hospital adverse events – a scoping review. *BMC Health Services Research*, 18(1):521.

(14) Bruno MA, Walker EA, Abujudeh HH. 2015. Understanding and Confronting Our Mistakes: The Epidemiology of Error in Radiology and Strategies for Error Reduction. *RadioGraphics*, 35(6):1668-76.

(15) Wildman-Tobriner B, Cline B, Swenson C*, et al.* 2018. Evaluating Resident On-Call Performance: Does Volume Affect Discrepancy Rate? *Curr Probl Diagn Radiol*.

(16) Itri JN, Tappouni RR, McEachern RO*, et al.* 2018. Fundamentals of Diagnostic Error in Imaging. *RadioGraphics*, 38(6):1845-65.

(17) Pandharipande PV, Reisner AT, Binder WD*, et al.* 2016. CT in the Emergency Department: A Real-Time Study of Changes in Physician Decision Making. *Radiology*, 278(3):812-21.

(18) Brady AP. 2016. Error and discrepancy in radiology: inevitable or avoidable? *Insights into imaging,* 8(1):171-82.

(19) Strub WM, Vagal AA, Tomsick T*, et al.* 2006. Overnight resident preliminary interpretations on CT examinations: should the process continue? *Emerg Radiol*, 13(1):19-23.

(20) Velmahos GC, Fili C, Vassiliu P*, et al.* 2001. Around-the-clock attending radiology coverage is essential to avoid mistakes in the care of trauma patients. *Am Surg*, 67(12):1175-7.

(21) Bellolio MF, Heien HC, Sangaralingham LR*, et al.* 2017. Increased Computed Tomography Utilization in the Emergency Department and Its Association with Hospital Admission. *The western journal of emergency medicine*, 18(5):835-45.

(22) Swartzberg K, Goldstein LN. 2018. High positive computed tomography yields in the emergency department might not be a positive finding. *The South African Medical Journal,* 108(3):230-234.

(23) Branstetter BFt, Morgan MB, Nesbit CE, *et al.* 2007. Preliminary reports in the emergency department: is a subspecialist radiologist more accurate than a radiology resident? *Acad Radiol*, 14(2):201-6.

(24) Cooper VF, Goodhartz LA, Nemcek AA, Jr., *et al.* 2008. Radiology Resident Interpretations of On-call Imaging Studies: The Incidence of Major Discrepancies. *Academic Radiology*, 15(9):1198-204.

(25) Baldwin DC, Jr., Daugherty SR, Tsai R, *et al.* 2003. A national survey of residents' self-reported work hours: thinking beyond specialty. *Acad Med*, 78(11):1154-63.

(26) Veasey S, Rosen R, Barzansky B, *et al.* 2002. Sleep loss and fatigue in residency training: a reappraisal. *Jama*, 288(9):1116-24.

(27) Tung M, Sharma R, Hinson JS, *et al.* 2018. Factors associated with imaging overuse in the emergency department: A systematic review. *The American journal of emergency medicine*, 36(2):301-09.

(28) Bansal A. 2005. Twenty-four-hour attending physician coverage and its impact on resident training. *J Am Coll Radiol*, 2(7):642-4.

(29) Stevens KJ, Griffiths KL, Rosenberg J, *et al.* 2008. Discordance rates between preliminary and final radiology reports on cross-sectional imaging studies at a level 1 trauma center. *Acad Radiol*, 15(10):1217-26.

(30) Wu MZ, McInnes MDF, Blair Macdonald D, *et al.* 2013. CT in Adults: Systematic Review and Meta-Analysis of Interpretation Discrepancy Rates. *Radiology*, 270(3):717-35.

(31) Greenland S, Senn SJ, Rothman KJ, *et al.* 2016. Statistical tests, P values, confidence intervals, and power: a guide to misinterpretations. *European Journal of Epidemiology*, 31(4):337-50.

(32) Hamilton LC. Statistics with Stata, version 12: Brooks/Cole, Cengage Learning; 2013.

(33) Creswell JW. Research design: qualitative, quantitative, and mixed methods approaches. California: Thousand Oaks, California:SAGE; 2014.

(34) Braun V and V Clarke. Using thematic analysis in psychology. 2006.

(35) Pope C MN. Qualitative research in health care: Oxford: Blackwell; 2006.

(36) [No authors listed]. CHRIS HANI BARAGWANATH HOSPITAL; The World's 3rd Biggest Hospital, in South Africa. Available: https://www.chrishanibaragwanathhospital.co.za/contact [Accessed on 10 June 2018].

(37) Tarek N. Hanna, Christine Lamoureux, Elizabeth A. Krupinski, Scott Weber, Jamlik-Omari Johnson. Effect of Shift, Schedule, and Volume on Interpretive Accuracy: A Retrospective Analysis of 2.9 Million Radiologic Examinations. *Radiology* 2008; 287(1): 205-212

(38) Ruchman Richard, Jaeger Joseph, Wiggins Ernest, Seinfeld Syndi, Thakral Vikas, Thakral Vikas . Preliminary Radiology Resident Interpretations Versus Final Attending Radiologist Interpretations and the Impact on Patient Care in a Community Hospital. *American journal of Roentgenology* 2007; 189(3): 523-6