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Effective radiation dose received by severely injured trauma patients during emergency investigations

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Effective Radiation Dose Received by Severely Injured Trauma Patients During Emergency Investigations

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Submission Date

29/10/2018

Declaration

I Zuko Booi (Student number: 9706217G) am a student registered for MMed Surgery in the year 2018. I hereby declare the following:

- **I am aware that plagiarism (the use of someone else's work without their permission and/or without acknowledging the original source) is wrong.**
- **I confirm that ALL the work submitted for assessment for the above course is my own unaided work except where I have explicitly indicated otherwise.**
- **I have followed the required conventions in referencing the thoughts and ideas of others.**
- **I understand that the University of the Witwatersrand may take disciplinary action against me if there is a belief that this in not my own unaided work or that I have failed to acknowledge the source of the ideas or words in my writing.**

Signature: _____ Date: 22 October 2018

ABSTRACT

Effective Radiation Dose Received by Severely Injured Trauma Patients During Emergency Investigations

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Background

Assessment of severely injured (P1) trauma patients include extensive investigation of all the injuries sustained. The reason for this is to reach proper diagnosis and minimise the risk of missing injuries, some of which might have grave outcomes. As a result a battery of tests are ordered during their admission to the emergency department (ED). Amongst the investigations conducted are radiological studies that invariably expose these patients to radiation with its possible complications. In our setting these include Lodox, X-rays & Computed tomography (CT) scans. In this study we quantitatively estimated the amount of radiation received by P1 trauma patients during their admission to ED.

Materials and Methods

A retrospective, HREC approved study was conducted. The data collected included P1 patients, over the age of eighteen, admitted to CMJAH trauma ED over a period of six months. The primary end point was to estimate the amount of radiation received by these patients during radiological investigations. The amount of radiation received was also compared according to mode of injury sustained.

Results

Out of the 6623 patients seen in CMJAH ED during the six month period of the study, only 1173 patients met all the inclusion criteria. P1 trauma patients received a considerable amount of radiation during their admission to ED. CT scans were responsible for most of the radiation received. On the other hand Lodox exposed patients to the least amount of radiation. Patients with blunt trauma received more radiation compared with patients with penetrating trauma.

Conclusion

Radiological investigations expose P1 trauma patients to considerable amount of radiation. Requesting these investigations, critical as they may be in the management of severely injured trauma patients, must be done with full cognizance of the amount of radiation they impose on these patients.

Lodox, because of its low radiation and its ability to scan the whole body, makes it a favourable equipment to have in an emergency department. Focused X-rays can then be done as suggested by findings from the lodox, collarating this with the clinical picture of the patient.

Dedication

In memory of my late father

Cyril Jonguxolo Booi

1938 – 2012

Acknowledgements

A lot of people have made a great input over the span of my career to ensure that I fulfil my desired goals

To my mother, my brother and all my siblings, thank you for your unwavering support.

To my Supervisors, Dr Maeane Moeng and Prof Geoffrey Candy thank you very much for the support and guidance.

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CHAPTER ONE: INTRODUCTION

Acute trauma patients are exposed to considerable amount of radiation from radiological investigations carried out for diagnostic purposes during their stay in the emergency department (ED). This cumulative exposure to radiation may be associated with a significant increased risk of cancer. Tien et al in Toronto, Canada conducted a prospective study in 2007 to measure the radiation doses trauma patients receive from diagnostic imaging using a dosimeter (1). Also Tjiang et al in Canberra hospital, Australia conducted a retrospective study looking at radiation exposure from diagnostic imaging in trauma patients presenting to emergency department (2).

Our trauma (ED) in Charlotte Maxeke Johannesburg academic hospital (CMJAH) treats approximately thirty thousand individuals annually and two thousand five hundred of these are severely injured (P1) patients. No local studies have been carried out to estimate the accumulated radiation exposure to acute trauma P1 patients during their stay in ED at the Charlotte Maxeke Johannesburg Academic Hospital.

The aim of this study was to estimate the amount of radiation received by trauma P1 patients presenting to CMJAH trauma ED.

The objectives were to estimate the cumulative amount of radiation received by each P1 patient. To compare the amount of radiation received by subjects with blunt trauma to those with penetrating trauma and also to compare amount of radiation received by subjects with stab wounds to those with gunshot wounds.

CHAPTER TWO: LITERATURE REVIEW

Radiological investigations remain the commonest used modality to evaluate subjects in emergency trauma. They offer essential information during evaluation of the integrity of bones, soft tissues and blood vessels. Unfortunately, radiation exposure remains a major concern with these investigations. It is widely accepted that ionising radiation may have harmful effects (3). All subjects are at risk of developing complications associated with exposure to radiation. Subjects with a pre-existing medical condition sensitive to radiation, children, pregnant women and young adults are more vulnerable to radiation and hence have increased rate of complications (4). These complications are as a result of high energy released by photons during X-ray and computed tomography (CT) scan investigations. These can ionize atoms and disrupt molecular bonds, and this is the process by which ionizing radiation damages living cells (5).

Wilhelm Conrad Roentgen, a Rector in the University of Wüzburg, discovered X-Rays in 1895 (6). In February 3, 1896 Edwin Frost performed the first pathologic X-ray in America, which also was the earliest medical X-ray (7,8). X-rays are a form of electromagnetic radiation with a wavelength ranging from 0.03 to 3 nanometres.

To obtain an X-ray photograph, a body part of the subject to be studied is positioned between the X-ray machine and the X-ray detector. Radiation from the X-ray machine is focused and released through the part of the body being studied unto the X-ray detector. A photographic impression is then formed on the X-ray detector based on absorption differences of the tissues. Bones absorb more X-rays compared to soft tissues and this results in less X-rays reaching the detector through bones, hence bones form a lighter impression and are more visible on X-rays than soft tissues (9).

A British engineer Godfrey Hounsfield invented CT in 1972, and Allan Cormack a South African born physicist of Tufts University, Massachusetts also invented it independently. From its invention CT has made great improvements in speed and resolution (10).

Compared with an X-ray a CT offers a more detailed photograph. Tissues being studied on X-ray films are superimposed, CT on the other hand takes thinner slices that can be viewed two-dimensionally, or can be put together and viewed three-dimensionally (11). However, radiation required to perform a CT is much greater than that required for an X-ray.

Lodox is a digital X-ray equipment that is used to obtain X-ray scans at significantly lower doses than conventional X-rays. It utilizes a linear slit scanning method that delivers about a third of radiation compared with that of a conventional X-ray (12). Though Lodox can be used to obtain X-ray scans of different body parts, it can also be used to obtain a full body scan. Lodox settings are usually adjusted according to the size of the person being scanned (Appendix 2) (13). With Lodox the whole body of a patient is scanned at once and therefore it saves time taken for resuscitation while not prejudicing diagnostic radiation (14). Using Lodox one can screen the whole body for injuries or to identify foreign bodies like bullets. Depending on Lodox findings, more focused conventional X-rays of the area of interest may be taken.

The unit used to measure the biologically active dose of radiation, also known as the effective dose, is the milliSievert (mSv). According to the International Basic Safety Standards (BSS) of the International Atomic Energy Agency (IAEA), there is no consensus on the dose limit applicable to medical radiation exposure for patients, but any practice involving exposure to radiation should only be carried out if the benefits of exposure outweigh the risks. However, the dose of radiation must be kept to the minimum dose required for any particular investigation. The dose limit for the public is 1mSv annually, or 5mSv annually under special circumstances provided the average dose remain less than 1mSv per year in a period of five consecutive years (15).

On average a person receives approximately 3mSv of radiation per year from natural background radiation. A single chest X-ray exposes a person to a radiation dose that is equivalent to 10 days exposure to natural background radiation, whereas a single CT scan of the chest is equivalent to 2 years of natural background radiation exposure. A dose of radiation an individual receives from each radiological study can be measured directly using a dosimeter, and this is a more accurate form of determining the amount of radiation received by an individual. Another way of establishing the amount of radiation received by an individual is by estimating a dose of radiation received with each type of investigation performed on an individual. These estimations can be calculated using the standard values for each type of investigation. Though this latter method does not give values as accurate as those obtained when using direct dosimeter readings it still gives a good estimation of radiation received(Appendix 1). These estimated values may differ depending on the type of machine used, the amount of activity administered to the patient and the patient's metabolism (16).

Exposure of patients to radiation is associated with complications. Effects of radiation exposure can be explained using theoretical dose-response models. These models suggest that there are different possibilities of response to radiation exposure. There are several such models and amongst these, linear–no threshold model appears to be one of the extensively debated in literature.

Linear–no threshold (NLT) model suggests that cancer can be induced by exposure to any level of radiation, however no clinically effects are seen below 500 mSv. Above this level, clinical symptoms may start appearing. Doses above this great level are also association with the development of leukemia. According to the LNT extrapolation the relationship between effective radiation dose and cancer risk is linear for effective dose of 100 mSv or more. There are no direct measurements for doses less than 100 mSv, and risks at these levels are extrapolated from higher doses. Based on this there is no level of exposure to radiation that does not correspond to increased risk of developing cancer. There is also supporting data from lower exposures for more sensitive population like fetuses and children and presence of rare types of cancer.

Currently the accepted approach used to estimate the risk of low-dose radiation, which is at the same level as that of radiological investigations, is by using Linear–no threshold extrapolation of the risk of cancer from high-dose radiation data Fig 1. This was approved by both Biological Effects of Ionizing radiation (BIER) VII reports of the United States National Academy of Sciences and the International Commission on Radiological Protection (ICRP). Also the International Commission of Radiological Protection concludes that the LNT model, combined with a dose and dose-rate effectiveness (reduction) factor (DDREF) of 2 for extrapolation from high doses, should be used (2,17). However there are opponents to this model like French Academies report, stating that its use for assessing risks associated with exposure to low doses of radiation is not based on scientific evidence. The NLT model was also introduced as a concept to facilitate radiation protection (18).

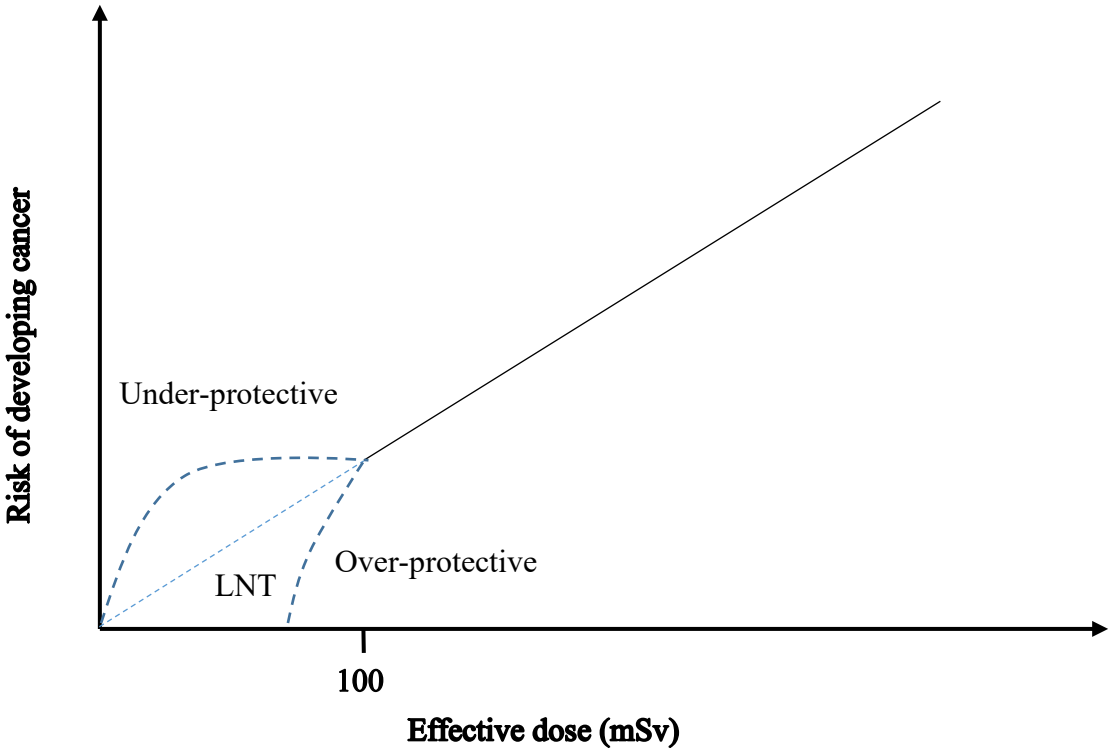

Figure 1: Linear–no threshold (LNT) extrapolation

The risks associated with ionizing radiation generally falls into two categories of effects. These effects depend on the dose of radiation given. Acute exposure effects, also known as 'radiation sickness', result from exposure to high doses of radiation within a short space of time. This is usually doses above 750 mSv(19). Acute exposure effects are measured in Grays/GY. 1 Gray is equivalent to 1 Sievert. Chronic exposure effects result from exposure to low doses of radiation and are measured in miliSieverts/mSv. Radiological investigations, because they expose individuals to low doses of radiation, increase the risk of developing chronic exposure effects.

Analysis based on data from nuclear workers focussed on risks of leukemia and cause-specific cancer mortality as a result of exposure to chronic, low-dose radiation. The study had a mean cumulative dose of 19.4mSv and showed a non-significant linear association between radiation exposure and mortality from leukemia excluding chronic lymphocytic leukemia (CLL). An increased risk was observed for chronic myeloid leukaemia mortality. There was also a significant elevated risk for all-cause mortality, all cancer mortality, and lung cancer mortality.

The risks for solid cancer mortality was also elevated. Therefore occupational radiation exposure was significantly associated with solid cancer and leukaemia incidence(20).

Acute trauma patients are subjected to clinically significant amount of radiation during their stay in the ED. A mean of 22mSv of mean effective dose from diagnostic imaging can result in little but measurable risk of cancer (1). About 1.9% of patients undergoing a repeat CT scan in the ED have increased risk of developing cancer due to cumulative exposure (21).

A balance between the benefits of radiological investigations against the complications resulting from exposure to radiation needs to be established without compromising patient care. In selected cases, other radiological modalities of investigation may be used. These include ultrasonography and Magnetic resonance imaging (MRI) (22).

CHAPTER 3 – METHODOLOGY AND MATERIALS

3.1 Study Methods

The study was conducted in CMJAH trauma ED, area 165. All trauma patients attended at CMJAH are first seen in this area. This is where they are stratified according to the severity of their injuries. P1 patients are looked after in the separate area in 165 called resuscitation bays. In this area, each patient has a dedicated nurse looking after him/her.

A trauma data form is completed for each P1 patient admitted to the trauma ED. This form documents all investigations, including radiological investigations conducted on each patient while in the ED. The data on these forms is ultimately compiled in the trauma data bank. Using these forms and the trauma data bank a number of radiological investigations conducted on each adult patient will be determined.

References from the literature were used to determine the average effective dose from Lodox, X-rays and CT scans (Appendix 1 & 2) (16). These are the same values used at CMJAH radiology department.

Effective dose from radiological investigations conducted on each individual was summed up to determine the cumulative radiation dose received by that particular individual.

Cumulative dose of radiation was also compared according to the mode of injury, i.e. blunt vs penetrating trauma and stab wounds vs gunshot wounds.

We currently do not have similar studies conducted locally and hence we do not have data on how much radiation is being received by trauma P1 patients during their admission to ED. Therefore, this study will give us the data on the amount of radiation received by these patients.

3.2 Study Design

This was a retrospective study to estimate the amount of radiation received by severely injured (P1) trauma patients admitted to the CMJAH trauma ED.

3.3 Setting

The study was conducted in CMJAH trauma ED, area 165.

3.4 Study Population

The study included both adult male and adult female trauma P1 patients during their admission in trauma ED.

3.5 Study Period

The study period extended from the 1st July 2013 to 31st December 2013.

3.6 Sample Size

Approximately two thousand patients are seen and treated in our ED every month and approximately ten percent of these are P1 patients.

The study sample comprised 1173 patients. This is significantly bigger compared to a similar study conducted in Canberra hospital, Australia in 2008, which consisted 118 patients (2).

3.7 Inclusion and Exclusion Criteria

The study only includes male and female patients eighteen years and older, who have been admitted at the trauma resuscitation bays as P1 patients.

Patients with incomplete clinical data and pregnant patients were excluded from the study. Also, patients who had CT angiograms as part of their investigation were excluded from the study as there were no standard references of radiation dose from CT angiograms found in the literature.

3.8 Data Collection

Trauma bank data and clinician notes were used. Radiological and X-ray data sheet were used to estimate radiation dose (Appendix 1). Names of patient were not used and a data sheet with all patient details was completed (Appendix 3).

3.9 Data Analysis

Data was recorded in EXCEL and analysed using Statistica. Results have been presented in Tables and graphs. Data was grouped by mode of injury, either blunt and penetrating injuries. These groups were compared by t-test or non-parametric test (Mann-Whitney test). For categorical data a Chi-squared test was used.

3.10 Ethical Clearance

Ethics clearance for this study was obtained from the University of the Witwatersrand Human Research Ethics Committee (HREC).

The clearance certificate number is M151006 (Appendix 4).

CHAPTER 4 - RESULTS AND DISCUSSION

4.1 Results

Between July and December 2013, 6623 patients were seen in the CMJAH Trauma Emergency Department. Of these 1341 patients were assessed as severely injured trauma (P1) patients. The total number of P1 patients comprised of 58 patients under the age of eighteen, and 1283 patients aged eighteen years and older. As there is no standard estimation of the mean effective radiation dose for CT angiogram a further 110 patients of the 1283 patients who had CT angiograms had to be excluded from the study, 42 patients did not have recorded Lodox, X-rays, and CT, leaving 1131 patients included in the study (Table 1), leaving 1173 patients eligible for inclusion in the study population. The Consort diagram (Fig 1) shows the breakdown of the patients and exclusion.

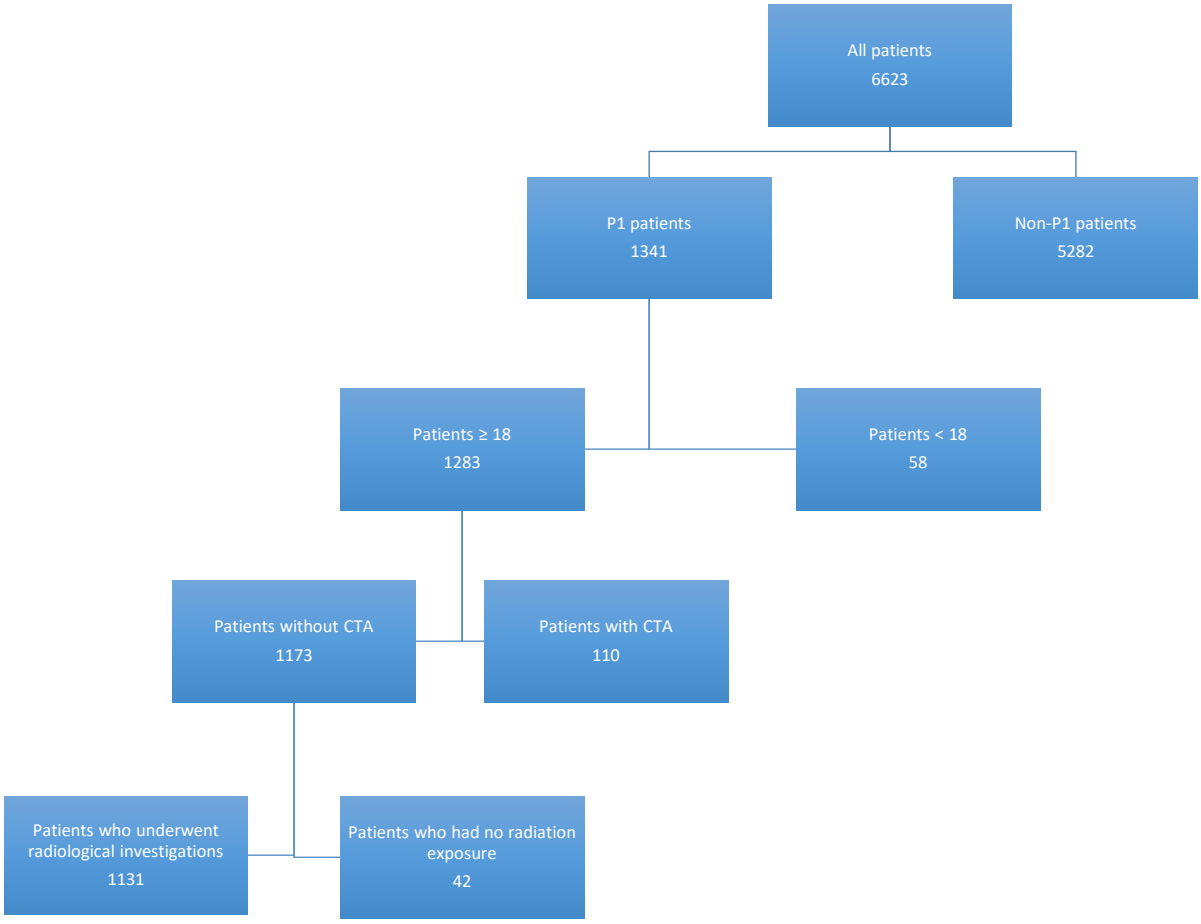

Figure 2: Study Population. SEVERAL PATIENTS (42) HAD Dose = 0 for LODOX/X-ray & CT AND WERE EXCLUDED = TOTAL PATIENTS = 1131 Investigations = 2144

The study comprised of 1017 males and 114 females. Of the 1017 males in the study the majority, 48.2% sustained penetrating injuries, followed by blunt injuries at 29.6% and other injuries at 22.2%. The average age of the individuals in the study was 30 years (range 18-92). Individuals sustaining penetrating injuries were significantly younger, median age of 29 years, compared to those sustaining blunt injuries, median age of 32, with the standard deviation of 0.0005 (Table 3).

The mechanisms of injury were divided into 8 categories; motor vehicle accidents (MVA), motor bike accidents (MBA), pedestrian vehicle accidents (PVA), burns, gun shot wounds (GSW), stab, fall from height (FFH) and uncategorized (comprising patients not falling under any of these categories).

These categories were further classed into blunt injuries (MVA, MBA, PDA, FFH), penetrating injuries (GSW, Stab) and other (burns, uncategorized).

Table 1 shows the number of patients according to mechanism of injury. Of the 1131 patients included in the study, 46.3% of patients had penetrating trauma and 31.7% sustained blunt trauma, with the remaining 22% constituting the rest of the patients categorized as neither blunt nor penetrating.

Table 1: Number of patients: according to the mechanism of injury.

MVA	**MBA**	**PVA**	**FFH**	**Stabs**	**GSW**	**Burns**	**Uncategorized**
122	20	143	73	387	137	12	237
BLUNT				**PENETRATING**		**OTHER**	
358				524		249	

The right panel of Table 2 outlines the different types of modalities underwent by each group of patients. It further shows that the majority of patients on each group had at least two forms of modalities of investigation performed. 71.7% of patients had more than 1 type of modality carried out.

A total of 2144 investigations were performed on these 1131 patients. The majority of these investigations, 42.3% (907), were performed on patients sustaining penetrating trauma. Patients with blunt trauma underwent 34.6% (742), and the remaining 23.1% (495) investigations were carried out on the group of patients who neither were categorized as blunt nor penetrating (Table 2).

For all the three categories of injury most patients underwent two modalities of radiological investigations. Patients with penetrating trauma constituted the majority of patients who underwent a single modality of radiological investigations, whereas the majority of patients with blunt and other injuries had two investigations performed on them(Figure 3).

Lodox constituted the majority of the total number of investigations performed, 36.1% compared to CT scans 32.5% and Xrays 31.3%. For penetrating injuries the Lodox constituted the majority of investigations 40.7% as opposed to patients with blunt and other injuries, who underwent more CT scans 38.1% and 41.6% respectively, compared to Lodox 32.9% and 32.7% respectively(Table 2 & Figure 4). The mean effective dose from Lodox was 0.007 for all categories of trauma and this was lower than radiation dose received from both X-Rays and CT scan (Tables 3 & 4).

Most patients underwent two investigation modalities. Also, patients who had all three modalities of investigation were exposed to more radiation compared to those who either underwent one or two modalities, with the mean effective dose of 8.027 mSv (Table 5 & Figure 5).

Table 2. Number of modalities per patient (left panel) and number of each modality undertaken for 1131 patients (right panel).

	Number of modalities							modalities				
Injury	1	**2**	**3**	**Total Patients/ injury type**	p		**Injury**	**Lodox**	**X-ray**	**CT-Scan**	**Total Procedures/ injury type**	p
Blunt (n; %)	63 17.8%	206 57.5%	89 24.9%	358 31.7			**Blunt (n; %)**	244 32.9%	215 29.0%	283 38.1%	742	
Penetrating (n; %)	205 39.1%	255 48.7%	64 12.2%	524 46.3%	***		**Penetrating (n; %)**	369 40.7%	331 36.5%	207 22.8%	907	***
Other (n; %)	52 20.9%	148 59.4%	49 19.7%	249 22.0%	ns/ ǂ ǂ ǂ		**Other (n; %)**	162 32.7%	127 25.7%	206 41.6%	495	ns/ǂ ǂ ǂ
Totals (patients/ procedure numbers)	320 28.3%	609 53.8%	202 17.9%	1131			**Totals (Number of procedures)**	775 36.1%	673 31.3%	696 32.5%	2144	

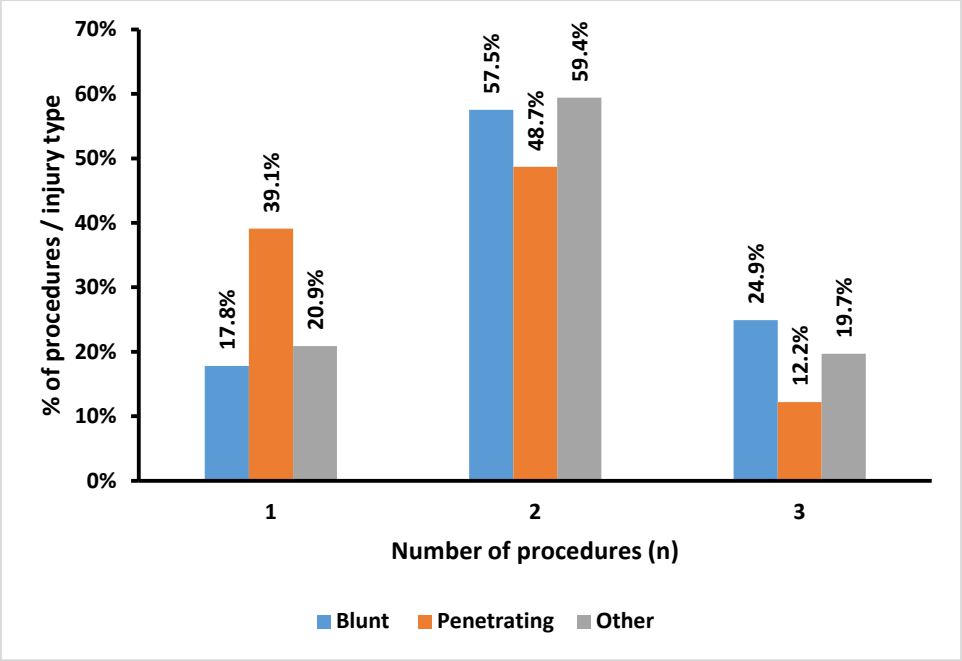

Figure 3. Number of procedures carried out as a percentage of injury type. Procedures carried out for penetrating injuries were significantly different to the number of procedures carried out for blunt ($p<0.0005$) and other ($p<0.0005$) injuries. See Table 2 (left panel).

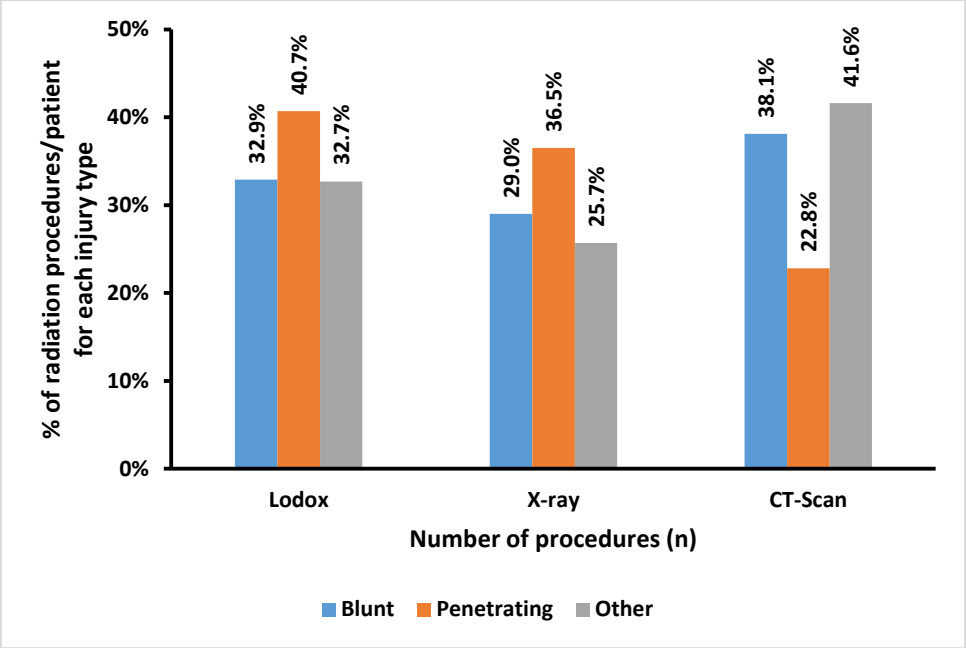

Figure 4. Radiation procedure type as a percentage according to injury type. The percentage of the radiation procedures for carried out for penetrating injuries were significantly different to the number of radiation procedures carried out for blunt ($p<0.0005$) and other ($p<0.0005$) injuries. See Table 1 (right panel).

Table 3: Patient demographics. Data as average and standard deviation with median and range [ ] The number in brackets represents the number in each group or the number in the group who had the procedure. Statistical tests: ANOVA with post-hoc; Chi-squared; Kruskal-Wallis; Abbreviations MVA: motor vehicle accident; MBA: motor bike accident; PVA: pedestrian vehicle accident; FFH: fall from height; GSW: gun shot. Statistical differences : */**/*** p<0.05/0.005/0.0005 respectively for Blunt injury vs other groups; ǂ/ ǂ ǂ/ ǂ ǂ ǂ p<0.05/0.005/0.0005 respectively for Penetrating injury vs other groups

	All (1131)	**Blunt (n=358)**	**Penetrating (n=524)**	**Other (n=249)**	**Overall significance (p)**
Age (years)	32.0±10.2	34.9±12.1	30.0±8.0***	32.2±10.6*/ǂ	<0.0001
	30.0 [18.0-92.0]	32.0 [18.0-88.0]	29.0 [18.0-63.0]	30.0 [18.0 – 92.0]	
Sex (n male; %)	1017 (89.9%)	301 (84.1%)	490 (93.5%)***	226 (90.8%)*/-	0.0005
MVA (n) 1	122	122	-	-	
MBA (n) 2	20	20	-	-	
PVA (n) 3	143	143	-	-	
FFH (n) 5	73	73	-	-	
Stab (n) 6	387	-	287	-	
GSW (n) 7	137	-	137	-	
Burns (n) 4	12	-	-	12	
Other (n) 8	237	-	-	237	
RD Lodox (mSv)	0.005±0.003	0.005±0.003	0.005±0.003	0.005±0.003	0.32
	0.007 [0.000 – 0.007]	0.007 [0.000-0.007]	0.007 [0.000-0.007]	0.007 [0.000–0.007]	
RD X-rays (mSv)	0.193±0.436	0.365±0.618	0.070±0.203***	0.204±0.392***	<0.0001
	0.020 [0.000 – 3.980]	0.020 [0.000-3.980]	0.020 [0.000 – 1.420]	0.020 [0.000- 3.550]	
CT (mSv)	6.0±8.5 (n=696)	9.18±11.26 (283)	3.91±6.02**	5.73±7.11*/ ǂ ǂ ǂ	<0.001
	4.00 [0.00 – 32.00]	4.00 [0.00 – 32.00]	4.00 [0.00 – 32.00]	4.00 [0.00 – 32.00]	
Accumulated dose (mSv)	6.181±8.536	9.554±11.117	3.990±6.024**	5.944±7.136**/ ǂ ǂ ǂ	<0.001
	4.007 [0.007-3284.7]	4.127 [0.007 – 32.847]	0.027 [0.007 – 32.780]	4.007 [0.007-32.787]	

Table 4. Number of radiation procedures and radiation dose to patients per radiological modality. Data as n, percentage of total number of patients, mean ± std, median & range [ ]. Statistical differences : */**/*** p<0.05/0.005/0.0005 respectively for Blunt injury vs other groups; ǂ/ ǂ ǂ/ ǂ ǂ ǂ p<0.05/0.005/0.0005 respectively for Penetrating injury vs other groups

	All (1131)	**Blunt (n=358)**	**Penetrating (n=524)**	**Other (n=249)**	**Overall significance (p)**
RD Lodox (n)	775 (68.5%)	244 (68.1%)	369 (70.4%)	162 (65.0%)	
Dose (mSv)	0.007±0.000	0.007±0.000	0.007±0.000	0.007±0.000	- [1]
	0.007 [0.000 – 0.007]	0.007 [0.000 – 0.007]	0.007 [0.000 – 0.007]	0.007 [0.000 – 0.007]	
RD X-rays	673 (59.5%)	215 (60.1%)	331 (63.2%)	127 (51.0%)	
Dose (mSv)	0.324±0.526	0.607±0.699	0.111±0.247***	0.401±0.472**/ ǂ ǂ ǂ	<0.0001
	0.020 [0.020 – 3.980]	0.720 [0.020-3.980]	0.020 [0.020-1.420]	0.120 [0.020 – 3.550]	
CT scan	696 (61.5%)	283 (79.1%)	207 (39.5%)	206 (82.7%)	
Dose (mSv)	9.723±9.017 (n=696)	11.618±11.365	9.910±5.679*/ ǂ ǂ ǂ	6.932±7.263***/ ǂ ǂ ǂ	<0.0001
	4.00 [1.40 – 32.00]	4.00 [2.00 – 32.00]	4.00 [1.40 – 32.00]	4.007 [0.007-32.787]	
	1131 (100%)	358 (100%)	524 (100%)	249 (100%)	
Accumulated dose	6.181±8.536	9.554±11.117	3.990±6.024**	5.944±7.136**/ ǂ ǂ ǂ	<0.0001
Dose (mSv)	4.007 [0.007-32.847]	4.127 [0.007 – 32.847]	0.027 [0.007 – 32.780]	4.007 [0.007-32.787]	

[1]Standard deviation = 0 and no comparison between groups is possible.

Table 5. Radiation dose to the patient according to the combination of radiation modalities used. Data as mean±std and median and range. Statistical difference calculated with a Kruskal-Wallis test.

				Statistical difference (p)						
Number of radiation modalities used (n)	**Radiation modalities (n patients)**	**Patients (n)**	**Radiation dose (mSv) Mean±std and Median [range]**	**Lodox vs**	**X-Ray vs**	**CT vs**	**Lodox + X-ray vs**	**Lodox + CT vs**	**X-ray + CT vs**	**Lodox + X-ray + CT vs**
1	Lodox	141	0.007±0.000 0.007 [0.007-0.007]	-	**0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**
	X-ray	128	0.024±0.334 0.020 [0.020-1.420]	**0.0001**	-	**<0.0001**	**ns**	**<0.0001**	**<0.0001**	**<0.0001**
	CT-Scan	51	10.274±9.415 4.0 [2.0-32.0]	**<0.0001**	**<0.0001**	-	**<0.0001**	ns	0.61	0.13
2	Lodox + X-ray	116	0.221±0.5947 0.027 [0.027-3.497]	**<0.0001**	ns	**<0.0001**	**-**	**<0.0001**	**<0.0001**	**<0.0001**
	Lodox + CT-Scan	266	9.488±8.685 4.007 [2.007-32.007]	**<0.0001**	**<0.0001**	ns	**<0.0001**	-	0.15	**0.0057**
	X-ray + CT-Scan	177	9.841±9.396 4.720 [1.420-32.780]	**<0.0001**	**<0.0001**	0.61	**<0.0001**	0.15	-	1.0
3	Lodox + X-ray + CT-Scan	202	10.581±9.034 8.027 [2.027-32.847]	**<0.0001**	**<0.0001**	0.13	**<0.0001**	**0.0057**	1.0	-

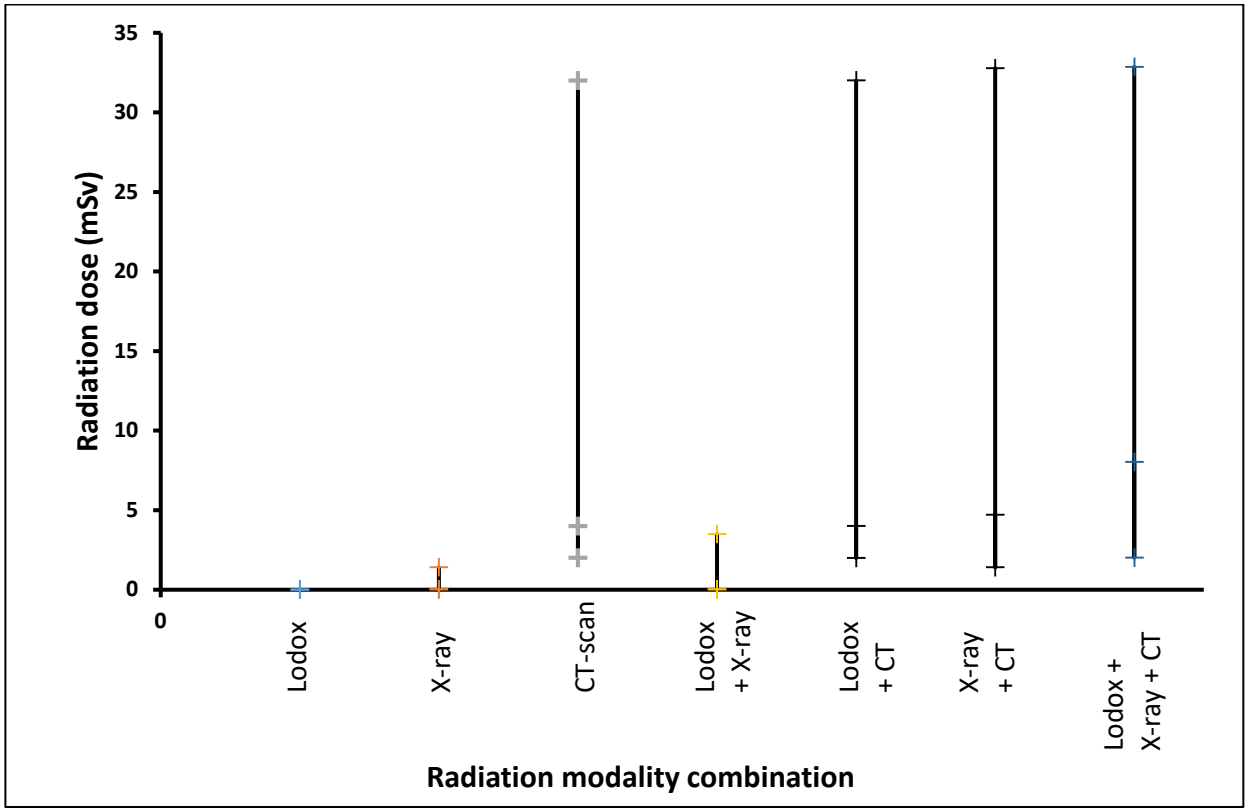

Figure 5. Radiation dose according to the combination of radiation modalities used to illustrate the overwhelming contribution of the radiation dose from CT-scans. Data as median (middle cross) and range. Statistical differences are tabulated in from Table 4.

4.2 Discussion

For effective management of severely injured trauma (P1) patients, early diagnosis of injuries and prompt management is paramount. To accomplish this a patient has to undergo several investigations which include amongst others, radiological investigations. These radiological investigations comprise of Lodox, conventional X-rays and CT scans which in turn expose patients to radiation.

As a result P1 patients are exposed to significant amounts of radiation during their first 24 hours of admission to the emergency department. Also as a result of the nature and severity of injuries sustained by P1 patients most of them are usually admitted for further management. During the period of their admission a series of follow up radiological investigations are usually ordered thereby increasing the radiation dose these individuals are exposed to. Cumulative radiation exposure is known to add incrementally to long-term risk of developing cancer (23). This however should not compromise proper evaluation of the patient's injuries, which if missed might be life-threatening.

Tien et al. prospectively measured the radiation doses to trauma patients from diagnostic imaging using dosimeters. In this study he found out that effective radiation dose estimated by counting radiologic procedures, the same way we did in our study, underestimated effective doses by approximately 25% when compared with dosimeter based results. Using dosimeter results a mean effective dose was 22.7 mSv for trauma patients (1). In our study the mean effective radiation dose for trauma patient was 4.007 mSv, which is almost a quarter of the mean effective dose obtained using a dosimeter by Tien et al. This was however still almost half the mean effective dose from a similar retrospective study conducted in Australia by Tjiang et al (2).

In our study most of the radiation was from CT scans with a mean effective dose of 4.00 mSv, with Lodox exposing patients to least amount of radiation with a mean effective dose of 0.007 mSv (Table 4). For all categories of injury CT scans consistently exposed patients to more radiation than both Lodox and X-rays.

The cumulative mean effective radiation dose received by individuals sustaining blunt trauma was significantly more compared to that received by individuals with penetrating trauma. The mean effective radiation dose from CT scans was also significantly higher for individuals with blunt trauma compared to those with penetrating trauma. Again individuals with blunt trauma

received higher dose of mean effective radiation from X-rays compared to the individuals with penetrating trauma. Lodox on the other hand exposed both individuals with blunt trauma and penetrating trauma to equal amounts of mean effective radiation dose, which was also lower than that of both X-Rays and CT scans (Table 3 & 4). Individuals with penetrating trauma received more radiation from X-rays and this can be attributed to the predictability of injuries associated with this mechanism of trauma. Comparatively, patients with blunt trauma and the group falling under other, usually have complex injuries that necessitate extensive radiological investigations. For this reason they usually get different modalities of investigations and hence more exposure to radiation.

4.3 Study Limitations

The major limitation of this study was the fact that no dosimeters were used. All available data was estimated from standard tables (Appendix 1).

CHAPTER 5 – CONCLUSION

Though our study, by design, underestimates the mean effective radiation dose, we still appear to be exposing our patients to less amounts of radiation compared to other institutions. This however does not imply that there is no long term risk of cancer. Therefore ordering of radiological investigations should be done judiciously.

There is also a need to carry out a similar study in our setting using a dosimeter. This will allow both comparison with the current results we have and also allow for assessment of the absolute values of the mean effective dose of radiation received by patients.

References

1. Tien HC, Tremblay LN, Rizolli SB, Geberg J, Caldwell C, Brenneman FD. 2007. Radiation exposure from diagnostic imaging in severely injured trauma patients. *Journal of trauma-injury infection & critical care*, 62(1):15-156, January 2007.
2. Tjiang HH, Richardson D. 2011. Radiation exposure from diagnostic imaging in trauma patients presenting to emergency department. *MSJA*, 3(2), October 2011.
3. Mazrani W, McHugh K, Marsden PJ. 2007. The radiation burden of radiological investigations. *Archives of disease in childhood, 92(12): 1127-113, December 2007.*
4. The joint commission. August 2011. *Radiation risks of diagnostic imaging.* [Online], Available: http://www.jointcommission.org/assets/1/18/sea_471.pdf. [11 January 2014].
5. Radiation Effects Research Foundation. 2007. *How radiation affects cells*. [Online], Available: http://www.rerf.jp/radefx/basickno_e/radcell.htm. [1 May 2014].
6. Assmus, A. 1995. *Early History of X Rays*. [Online], Available: http://www.slac.stanford.edu/pubs/beamline/25/2/25-2-assmus.pdf [25 January 2014]
7. Spiegel PK. 1995. The First Clinical X-Ray Made in America – 100 Years. *AJR*,164:241-243, January 1995.
8. Reed AB. 2011. The history of radiation use in medicine, *J Vasc Surg,* 53(1 Suppl):3S-5S, Jan 2011.
9. NASA. 2011. *X-Rays*. [Online], Available: https://science.nasa.gov/ems/11_xrays [25 January 2014]
10. Coran AG, Caldamone A, Scott Adzick N, Krummel TM, Laberge J, Shamberger R. 2012. *Pediatric surgery*. [Online],

Available: https://books.google.co.za/books?isbn=032309161X [14 January 2018]

11. Mayfield clinic & spine institute. February 2013. *Computed tomography (CT) and CT angiography.* [Online], Available: https://www.mayfieldclinic.com/PE-CT.htm [14 January 2018]

12. Evangelopoulos DS, Deyle S, Zimmermann H, Exadaktylos AK. 2009. Personal experience with whole-body, low-dosage, digital X-ray scanning (LODOX-Statscan) in trauma. *Scandinavian journal of trauma, resuscitation and emergency medicine*, 17:41, 12 September 2009.

13. Trauernicht C, Rall C, Perks T, Maree G, Hering E, Steiner S. 2012. Dose reduction and image preservation after the introduction of a 0.1 mm Cu Filter into the LODOX Statscan unit above 110 kVp. *IRPA13:Glasgow, 13-18 May 2012.*

14. Boffard KD, Goosen J, Pllani F, Degiannis E, Potgieter H. 2006. The use of low dosage X-ray (Lodox/Statscan) in major trauma: Comparison between low dose X-ray and converntional X-ray techniques. *Journal of trauma-injury infection & critical care*, 60(6):1175-1183, June 2006.

15. IAEA. n.d. *Radiation safety*. [Online], Available: http://www.iaea.org/Publications/Booklets/Radiation/radsafe.html. [11 January 2014].

16. RadiologyInfo.org. 2013. *Radiation dose in X-ray and CT exams*. [Online], Available: https://www.radiologyinfo.org/en/info.cfm?pg=safety-xray. [1 May 2014].

17. Mattsson S, Nilsson M. 2015. On the estimation of radiation-induced cancer risks from very low doses of radiation and how to communicate these risks. *Radiation Protection Dosimetry.* 165(1-4): 17-21, July 2015.

18. Tubiana M, Feinendegen LE, Yang C, Kaminski JM. 2009. The Linear No-Threshold Relationship Is Inconsistent with Radiation Biologic and Experimental Data. *RSNA Radiology,* 251(1): 13-22, April 2009.

19. United States Environmental Protection Agency. February 2018. *Radiation Protection.* [Online], Available: *https://www.epa.gov/radiation/radiation-health-effects* [1 January 2018].

20. Kitahara CM, Linet MS, Rajaraman P, Ntowe E, Berrington de Gonzalez A. 2015. A New Era of Low-Dose Radiation Epidemiology. *Current Enviromental Health Reports.* 2(3): 236-49, September 2015

21. Griffey RT, Sodickson A. 2009. Cumulative Radiation exposure and cancer risk estimates in emergency department patients undergoing repeat or multiple CT. *American journal of roentgenology*, 192(4), April 2009.

22. Brenner DJ, Hall EJ. 2007. Computed Tomography – An increasing source of radiation exposure. *The new England journal of medicine*, 357:2277-2284, November 2007.

23. Sodickson A, Baeyens PF, Andriole KP, Prevedello LM, Nawfel RD, Hanson R, Khorasani R. 2009. Recurrent CT, Cumulative radiation exposure, and associated radiation-induced cancer risks from CT of adults. *RSNA Radiology*, 251(1), April 2009.

Appendix 1: An estimated dose an individual might receive from each different radiological investigation(1,2).

Estimates of the dose an individual might receive from one x ray.

Single Radiograph	Effective Dose, mrem (mSv)
Skull (PA or AP)[1]	3 (0.03)
Skull (lateral)[1]	1 (0.01)
Chest (PA)[1]	2 (0.02)
Chest (lateral)[1]	4 (0.04)
Chest (PA and lateral)[2]	6 (0.06)
Thoracic spine (AP)[1]	40 (0.4)
Thoracic spine (lateral)[1]	30 (0.3)
Lumbar spine (AP)[1]	70 (0.7)
Lumbar spine (lateral)[1]	30 (0.3)
Abdomen (AP)[1]	70 (0.7)
Abdomen[3]	53 (0.53)
Pelvis (AP)[1]	70 (0.7)
Pelvis or hips[3]	83 (0.83)
Bitewing dental film[3]	0.4 (0.004)
Limbs and joints[3]	6 (0.06)

Estimates of the dose an individual might receive if undergoing an entire procedure (e.g., a lumbar spine series typically consists of five films).

Complete Exams	Effective Dose, mrem (mSv)
Intravenous pyelogram (kidneys, 6 films)[1]	250 (2.5)
Barium swallow (24 images, 106 sec fluoroscopy)[1]	150 (1.5)
Barium meal (11 images, 121 sec fluoroscopy)[1]	300 (3.0)
Barium follow-up (4 images, 78 sec fluoroscopy)[1]	300 (3.0)
Barium enema (10 images, 137 sec fluoroscopy)[1]	700 (7.0)
CT head[1]	200 (2.0)
CT chest[1]	800 (8.0)
CT abdomen[1]	1,000 (10)
CT pelvis[1]	1,000 (10)
CT (head or chest)[2]	1,110 (11.1)
PTCA (heart study)[3]	750–5,700 (7.5–57)
Coronary angiogram[3]	460–1,580 (4.6–15.8)
Mammogram[3]	13 (0.13)
Lumbar spine series[3]	180 (1.8)
Thoracic spine series[3]	140 (1.4)
Cervical spine series[3]	27 (0.27)

Appendix 2: Statscan (Lodox)

Procedure Name and Patient Size	Tube Voltage [kV]	Slit Width [mm]	Focal Spot	Tube Current [mA]	Scan Speed [mm/s]	FSD [cm]	Field Size		Reference Point – Z [cm]	Entrance Dose without 0.1 mm Cu Filter [mGy]	Entrance Dose with 0.1 mm Cu Filter [mGy]	Effective Dose without 0.1 mm Cu Filter [mSv] ICRP 103	Effective Dose with 0.1 mm Cu Filter [mSv] ICRP 103	Percentage Dose Reduction [%]	Image Quality without 0.1 mm Cu Filter				Image Quality with 0.1 mm Cu Filter			
							Beam Width [cm]	Beam Height [cm]							Line Pairs	Contrast			Line Pairs	Contrast		
Chest (lung) AP - XL	140	0.4	S	160	70	99.3	39.5	38.5	60.50	0.315	0.200	0.114	0.084	26.7	2.2	17	5	15	2.2	17	5	15
Full Body (Abdomen) AP - Large	120	0.4	S	160	140	98.0	41.5	188.0	7.03	0.131	0.078	0.106	0.077	27.5	2.0	17	5	16	2.0	17	5	16
Full Body (Abdomen) AP - XL	145	0.4	L	200	140	98.0	45.5	200.0	7.48	0.222	0.147	0.190	0.147	22.7	1.6	17	4	15	1.6	17	4	15
Abdomen AP - XL	120	1.0	L	200	70	98.0	42.0	42.5	19.80	0.891	0.548	0.228	0.176	23.2	2.2	14	5	11	2.2	14	5	11
Pelvis AP – XL	120	1.0	L	200	70	98.0	45.0	32.5	13.80	0.913	0.544	0.159	0.118	25.7	2.2	14	5	11	2.2	14	4	11
Skull AP – XL	120	0.4	S	200	70	93.5	19.6	22.2	96.00	0.329	0.190	0.008	0.006	29.0	2.8	17	5	16	2.8	17	5	16
Chest (lung) Lat – Large	130	0.4	S	160	70	72.4	21.0	32.5	58.00	0.381	0.234	0.042	0.031	26.0	1.2	17	6	15	1.2	17	6	15
Chest (lung) Lat – XL	140	1.0	L	125	70	72.4	23.0	34.5	62.00	0.969	0.627	0.101	0.078	23.2	1.0	13	6	11	1.0	13	6	11
Pelvis / Hip Lat - Large	120	1.0	L	200	70	72.4	19.0	29.0	13.20	1.243	0.744	0.055	0.043	22.5	1.2	13	6	11	1.2	12	6	10
Pelvis / Hip Lat - XL	130	1.0	L	200	70	72.4	20.0	30.0	14.00	1.399	0.876	0.055	0.044	20.6	1.0	11	7	9	1.2	11	7	9

Conclusion:

Image quality is maintained in all images with the insertion of the 0.1 mm Cu filter above 110 kVp, while the effective dose is reduced between 20.6 % and 30.1 %. The filter is now standard on all LODOX Statscan units.

Appendix 3: **Data Sheet**

Participant Number:

Participant Details:

Age

Gender M F

Mode of injury MVA MBA PVA

FFH STAB GSW OTHER

Investigations:

X-Ray: Types Total Dose

Lodox: Y N
Dose

CT: Types Total Dose

Accumulative Dose

MVA = Motor vehicle accident, MBA = Motorbike accident,
PVA = Pedestrian-vehicle accident, FFH = Fall from height, GSW = Gunshot wound

Appendix 4: Ethics clearance letter.

R14/49 Dr Zuko Booi

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

CLEARANCE CERTIFICATE NO. M151006

NAME: (Principal Investigator)	Dr Zuko Booi
DEPARTMENT:	Surgery Charlotte Maxeke Johannesburg Academic Hospital
PROJECT TITLE:	Effective Radiation Dose Received by Severely Injured Trauma Patients During Emergency Investigations
DATE CONSIDERED:	30/10/2015
DECISION:	Approved unconditioally
CONDITIONS:	
SUPERVISOR:	Maeyane Moeng
APPROVED BY:	Professor P Cleaton-Jones, Chairperson, HREC (Medical)
DATE OF APPROVAL:	30/10/2015

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 Secretary in Room 10004, 10th floor, Senate House, University.
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 resubmit the application to the Committee. **I agree to submit a yearly progress report**.

Principal Investigator Signature Date

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

Appendix 5: Turn-it-in Report

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by Deirdre Kruger

Submission date: 19-Jan-2018 08:40AM (UTC+0200)
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