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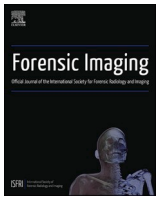
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An overview of digital X-ray (LODOX StatScan) usage in a South African medico-legal mortuary

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ABSTRACT

X-ray analysis of individuals who have died due to unnatural causes is important for the detection of potential skeletal pathologies, injuries, and foreign objects, which assists in the determination of the cause of death, recovery of evidence, and identification of the deceased. At the Johannesburg Forensic Pathology Services medico-legal mortuary (South Africa), the LODOX Statscan is used due to the system's capability to rapidly produce a full-human-body, high-quality digital image. This study aimed to provide an overview of which cases were selectively x-rayed using the LODOX Statscan at this facility. This was a retrospective mortuary case file review, which highlighted the frequency and reasons for x-ray usage over a four-year period (2016–2019) and described the demographics, circumstances of death and cause of death in x-rayed cases over a two-year period (2018 and 2019). A total of 2026 cases (15.28% of all cases received) were x-rayed over the 2016-2019 period. The purposes for selectively x-raying cases were to assist the autopsy (n=1735), identification (*n*=228), forensic anthropological analysis (*n*=34) and research (*n*=29). the most common circumstance and cause of death in the x-rayed cases was due to gunshot wounds (80% & 85% respectively). This study highlighted the benefits and limitations of low-dosage X-ray digital scans in a facility that is exemplary of many facilities in developing countries where the case numbers are significantly high, manpower is limited, and the lack of funding and infrastructure precludes the use of other modalities commonly used in developed countries, especially were gunshot wound cases are frequent.

Introduction

X-rays are a form of high-energy radiation with much shorter wavelengths when compared to ultraviolet radiation [1]. Since their discovery, they have been used at an increasing rate in various fields of science and medicine to treat and diagnose injuries by creating two-dimensional images of body tissues [1]. Radiographic imaging has been a crucial imaging technique used in forensic medicine for various diagnostic purposes such as diagnosing the cause of death, assessing skeletal fractures, internal injuries, and identifying the presence or absence of foreign objects [2–4]. Despite the global usage of forensic imaging to aid medico-legal investigations, very little has been published on current forensic imaging practices, including the limitations, and challenged experienced by forensic practitioners and how the usage varies between developed and developing countries [5].

Magnetic Resonance Imaging (MRI), Post-Mortem Computed Tomography (PMCT) scans, and conventional X-rays are commonly used in a forensic context and are applicable in forensic sciences fields such as forensic pathology, forensic anthropology, and forensic facial approximation [6–11]. For instance, PMCT scans are commonly used in developed nations for forensic medicine to supplement autopsy findings of unnatural death cases (e.g., cases of gunshot-related deaths, hanging, and drowning) [11] while conventional X-rays are widely incorporated in forensic anthropology laboratories to aid with documentation and interpretation of skeletal trauma in cases of gunshot wounds, suspected child abuse, and skeletonized remains [8,12]. However, PMCT and MRI scans are expensive, time-consuming, require access to specialized equipment and computer software, and adequate experience to operate [8,11]. This is particularly limiting in forensic facilities in developing countries, such as in South African medico-legal mortuaries, which are confronted with financial constraints, inadequate infrastructure, and a heavy caseload of unnatural death cases [8,13,14]. Another limitation to using CT and X-raying in medico-legal mortuaries is the high doses of radiation which may result in significant health consequences to those

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operating the devices or working near them, despite strict health and safety protocols, when the aging infrastructure of many forensic facilities in developing countries may pose a risk to workers [4].

As a result, many radiological devices have been deemed impractical for use in South African Forensic Pathology Services (FPS) medico-legal mortuaries. For these reasons, the low-dosage X-ray (LODOX) system has been favored as an alternative imaging tool for use in FPS facilities [10,14,15]. For example, in South Africa, LODOX and other x-ray facilities are not available in all forensic mortuaries. Many smaller mortuaries must transport bodies that require x-ray imaging to other larger facilities to be x-rayed before they can be autopsied. This causes a delay in the postmortem of such bodies. It also adds to the burden of the larger mortuaries. For example, the Gauteng Southern Cluster Forensic Pathology Services is comprised of eight medico-legal mortuaries. Only one of these facilities (Johannesburg FPS) has a LODOX system. The rapidity of the LODOX significantly shortens the time for imaging and provides for digital scans to be easily transferred between the mortuaries.

The LODOX Statscan is a digital full-body scanner with low x-ray dosage exposure compared to other radiographic devices [15]. This system was initially designed and developed for security purposes in the South African mining sector to frequently and quickly detect illegal smuggling of diamonds by mining employees [15]. It was later recognized as an effective tool for use in South African medico-legal mortuaries with high caseload (e.g., the Johannesburg FPS receives approximately 3500–4000 cases per annum). The LODOX system is of particular use for the purpose of identifying skeletal traumas (Fig. 1) and foreign objects (e.g., bullets) during postmortem examinations (Fig. 2), as it can produce full-human-body, high-quality digital images in approximately 13 seconds, within quick successions. This rapid turn-around time improves workflow and quality assurance in such facilities [15–17]. Moreover, it can produce anteroposterior and lateral human body images (Fig. 1) with reduced manual manipulation of a decedent's body by the FPS staff. The digital images produced by LODOX result in a single, full-body image that can be easily manipulated by zooming to magnify and localize a particular area of interest for diagnostic purposes [10,15]. It is easy and safer to use (i.e., requires minimum experience to operate and has low radiation levels), and bodies can be scanned fully clothed or whilst still inside a body bag in a medico-legal setting [10,15,18]. Due to its minimal radiation scattering, it can be installed directly in the mortuary without increasing the health risk of the staff [15,18]. The LODOX Statscan unit is also cost-effective, with installation and maintenance costs lower than those of traditional radiographic modalities (e.g., conventional X-rays, PMCT scans, and MRI systems) hence it can be advantageous in forensic facilities of developing countries [10,14].

The use of the LODOX system in South African medico-legal mortuaries has been well documented in the available literature [10,19–24]. A study done by Douglas et al. [20] demonstrated that the LODOX Statscan unit at the Salt River Forensic Pathology Laboratory, in Cape Town, South Africa, was efficient at assisting in determining the cause of death in paediatric cases that had undergone radiographic imaging. The study concluded that the time efficiency of the LODOX Statscan unit was more likely to improve workflow, thus reducing the backlog of cases [20]. A study by Bernitz and Verster [21] also demonstrated how the LODOX unit at the Pretoria FPS was used to successfully identify victims of mass disaster situations through dental identification of severely mutilated bodies, including decomposed and severely burned bodies. Furthermore, a case report by Loots and du Toit-Prinsloo [22] on fatal pica (substances with no nutritional value) reported how the LODOX system at the Pretoria FPS was specific and sensitive in identifying and confirming the presence of multiple sharp foreign objects in the gastrointestinal tract of the deceased. The LODOX Statscan was also efficient at determining the presence of firearm projectiles in cases of gunshot-related death at the Salt River FPS as the produced radiographs aided forensic pathologists with the localization and retrieval of bullets, reducing the amount of time taken to examine the deceased individual [23]. Similar findings were observed on a case study from the Tygerberg FPS, whereby a firearm projectile from a headshot was found in the victim's abdomen as revealed by the LODOX radiographs, whereas external examination only revealed a penetrating gunshot wound to the skull [24]. Knowing the precise location of the bullet allowed for easier retrieval and a careful examination of the tissue and organs along the bullet's track. A study by Esterhuysen *et al.* [25] highlighted the incorporation of the LODOX Statscan unit in forensic anthropology cases and its use to examine skeletal and mummified remains to provide accurate estimations of their age, sex, and stature, which are vital parameters in cases of unidentified skeletal remains admitted to FPS facilities. As such, more findings like this are likely to encourage the South African government to install the LODOX system in several other medico-legal mortuaries. As such, this will allow rapid scanning of unnatural death cases prior to a postmortem examination, supplement autopsy findings, and thus reduce the associated backlog of unnatural death cases in associated FPS facilities.

South African FPS facilities have heavy caseloads of unnatural death cases resulting in some cases not being radiographically assessed and analyzed for the presence of skeletal injuries (e.g., bone fractures) and/or foreign objects (e.g., bullets) before a postmortem examination [26]. Moreover, the Johannesburg FPS facility, in addition to possessing a single LODOX Statscan device, receives approximately 3500 cases per

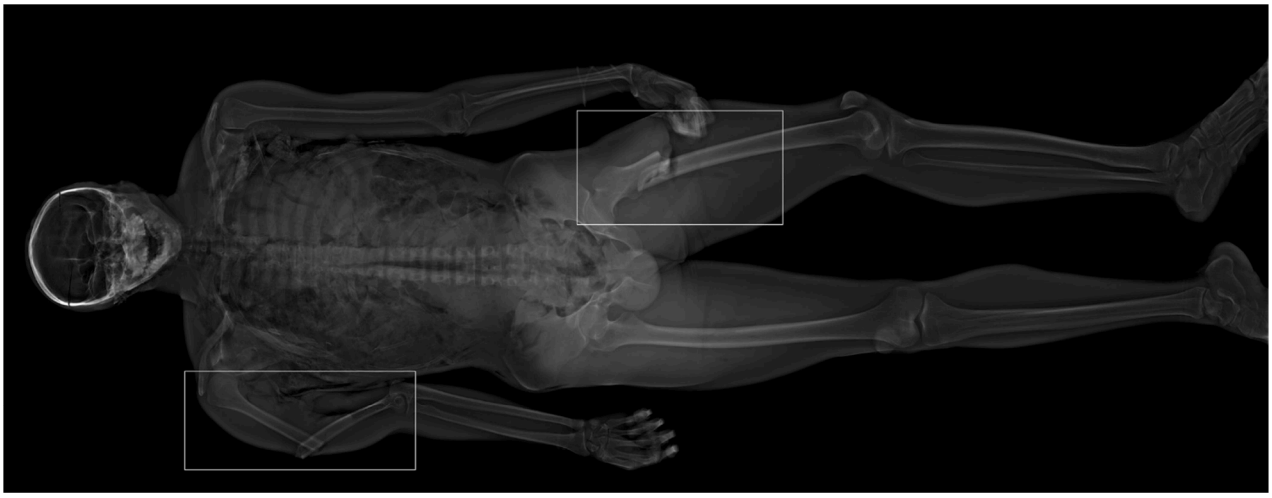


Fig. 1. Lodox Statscan image showing skeletal fractures (in rectangles) of a humerus at midshaft and proximally on a femur.

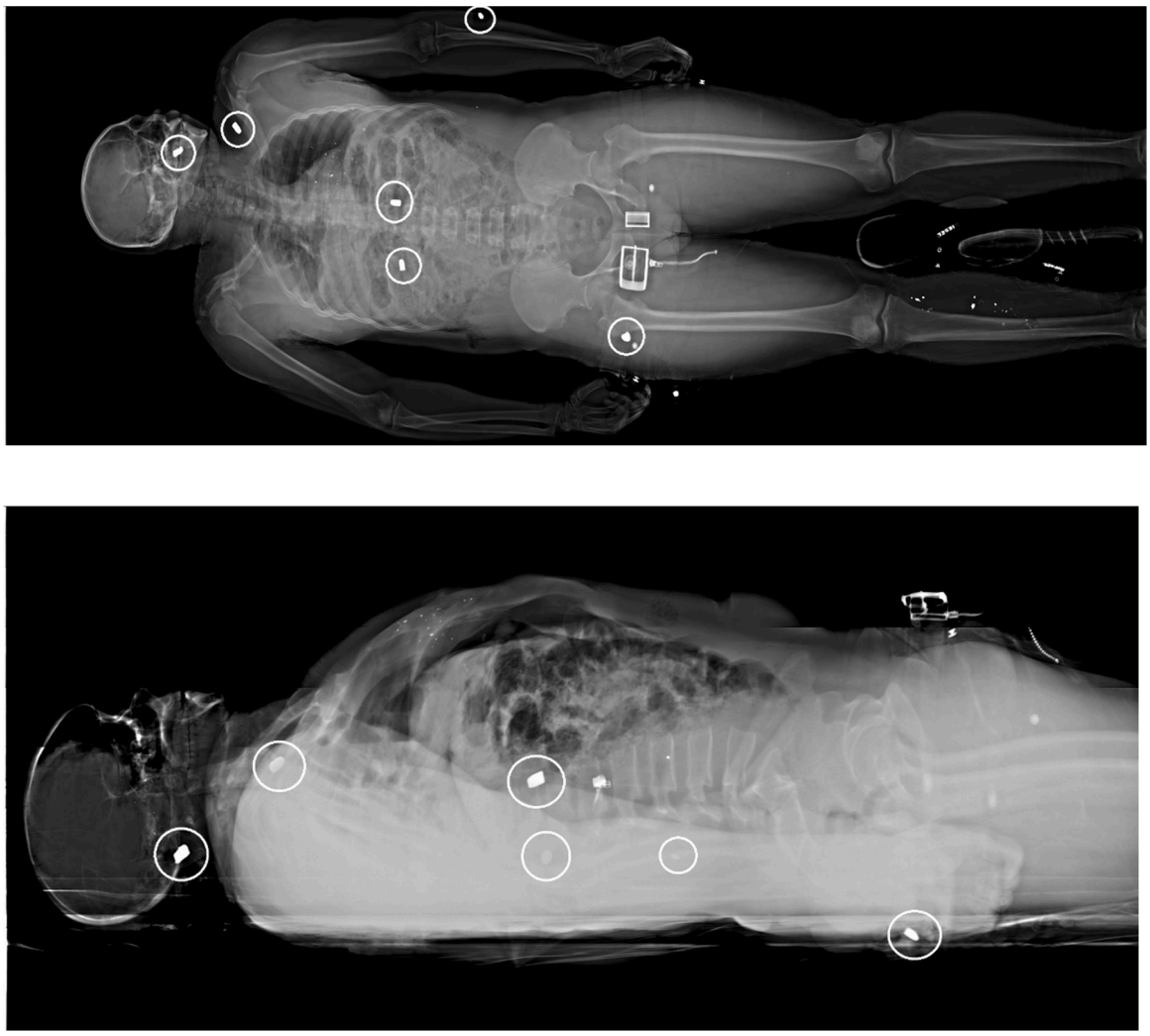


Fig. 2. Lodox Statscan images in an anteroposterior (top image) and lateral (bottom image) planes of a multiple gunshot case. In circles are multiple bullet projectiles within the deceased, prior to their retrieval.

annum, resulting in a certain category/categories of unnatural death cases (e.g., gunshot wound-related deaths) selected for an x-ray scan for the purpose of supplementing overall autopsy cases. Moreover, there is currently insufficient literature about the categories of unnatural death cases that may undergo radiographical scanning before postmortem examination in South African FPS facilities. Thus, this was a retrospective casefile overview study of unnatural death cases that were selected for radiographic scanning at the Johannesburg FPS and served as a pioneer study documenting categories of unnatural death cases scanned with the LODOX Statscan unit at an FPS facility. This study highlights the x-ray imaging experience of one of the busiest forensic mortuaries in South Africa, and provides an overview of the benefits and limitations of low-dosage X-ray digital scans in a facility that is exemplary of many facilities in developing countries where the case numbers are significantly high, manpower is limited, and the lack of funding and infrastructure precludes the use of other modalities commonly used in developed countries, such as PMCT.

Methods

This study aimed to provide an overview of which unnatural death cases were selectively x-rayed using the LODOX Statscan at the Johannesburg Forensic Pathology Service (JFPS) medico-legal mortuary. The objectives of the study were to highlight the frequency and reasons for x-ray usage (categorized into four purposes: assist in autopsy, identification of the deceased, forensic anthropological analysis, and research purposes) over a four-year period (2016–2019) and described the demographics, circumstances of death and cause of death in x-rayed cases over a two-year period (2018 and 2019). Ethical clearance for the study was approved by the Human Research Ethics Committee – Medical (Clearance certificate M210411).

This study was a retrospective mortuary case file review. The JFPS was selected as the research site because it is one of eight medico-legal facilities in the Southern Cluster of Gauteng Forensic Pathology Services and is involved in the conduction of medico-legal investigations of unnatural death cases as stipulated in the Inquests Act (Act 58 of 1959) [27]. This site was selected because it retains an operational LODOX Statscan unit that is extensively used to radiographically scan certain unnatural death cases admitted to the facility. The cases that are selected to be x-rayed are at the discretion of the forensic pathologist or medical officer performing the post-mortem investigation. All cases are not x-rayed due to the large case load at the facility (approximately 3500 cases are received per annum). Other cases that are x-rayed include unidentified bodies that are referred to the Human Decedent Identification Unit (ID Unit) at the JFPS, skeletal cases that require forensic anthropological analysis and cadavers from the University of Witwatersrand's School of Anatomical Sciences, which are x-rayed for research purposes.

The inclusion criteria for this study comprised all unnatural death cases x-rayed using the LODOX Statscan unit prior to postmortem

examination between 01 January 2016 and 31 December 2019, as recorded on the LODOX Statscan database, including cases processed by the ID Unit, skeletal cases x-rayed for forensic anthropological analysis and cadavers x-rayed for research purposes. Data were sourced from the death register books (completed at the admission of each body, which includes preliminary information provided by forensic pathology officers and police officers). autopsy reports, pathologist notes, radiological images, and the South African Police Service (SAPS) 180 forms (death scene form completed by a police representative). The following variables were recorded: autopsy findings, cause of death, circumstances of death, demographic profile (sex and age), day of the week, month and year scanned, and the purpose for the x-ray. Radiographic scans for cases from other mortuaries but scanned at the JFPS, those for maintenance/service purposes, and those for training purposes were excluded from the sample.

The data was separated into two periods. A four-year period (2016–2019) was used to highlight general trends in terms of the frequency and reasons for x-ray usage. A two-year period (2018 and 2019) was used to describe more specific trends in the demographics, circumstances of death, and cause of death in x-rayed cases. This study was completed in partial fulfilment of an Honors degree, which limited the scope of this study; however, general trends were still able to be highlighted.

Data was analyzed using PAST 4.0 [28] computer software programs. A Shapiro-Wilks test of normality was used to assess the distribution of the age-at-death sample distribution for the JFPS facility autopsy cases scanned between 2018 and 2019 (i.e., parametric, or non-parametric distribution). Moreover, descriptive summary statistics for the age-at-death dataset was conducted for the time-period, and parameters such as the mean, median, range, skewedness, and standard deviation were recorded. Summary statistics were also conducted for male's and female's age-at-deaths. A two-sample Mann-Whitney U test was conducted to compare between male's and female's average(mean) age-at-death for JFPS scanned autopsy cases. For all statistical analyzes, a significant level (α) of 0.05 was used to determine a statistical difference.

Results

General trends observed in the 2016–2019 period: reasons for x-raying unnatural death cases and frequencies

Over the four-year study period (2016-2019), 2026 (15.3%) cases were scanned using the LODOX Statscan unit at the Johannesburg Forensic Pathology Service (JFPS) from a total of 13307 admitted cases. These included 1735 autopsy cases (86%), 228 ID unit cases (11%), 34 skeletal cases (1.6%), and 29 cadavers for research (1.4%) from the JFPS and other FPS facilities. An extensive breakdown of the types of cases x-rayed per year is demonstrated on Table 1 and the increase in x-ray scans for identification purposes from 2017 to 2019 is due to the ID Unit becoming fully operational in 2017. Of the overall 13,307 cases admitted to the facility, only 446 cases were not autopsied mainly due to due to infectious diseases (such as tuberculosis) or being cases of natural deaths.

The annual number and proportion of cases being x-rayed increased each year from 2016 (n=307; 9.9%) to 2019 (n=753; 21.2%) (Table 1). Although most cases were from the JFPS, the number of cases being refereed from other FPS facilities in the province for radiographic scans increased from three facilities in 2016 to seven FPS facilities in 2019, including the Victim Identification Center of the South African Police Services.

There were no notable temporal trends or patterns observed in the number of cases x-rayed per month or season.

Table 1
Overall amount of the types of cases x-rayed using the LODOX Statscan unit at the Johannesburg FPS facility from January 2016 to December 2019. A total of 13307 unnatural death cases were admitted over the four-year period.

Types of cases	Number of x-rayed cases per year (%)				
	2016	2017	2018	2019	Total
Autopsy	305 (99%)	333 (99%)	500 (79%)	597 (79%)	1735 (86%)
ID Unit	0	3 (1%)	111 (18%)	114 (15%)	228 (11%)
Skeletal	2 (1%)	0	19 (3%)	13 (2%)	34 (1.6%)
Cadavers for research	0	0	0	29 (4%)	29 (1.4%)
Total	307 (100%)	336 (100%)	630 (100%)	753 (100%)	2026

Detailed trends observed in the 2018 and 2019 period: Demographic profiles, circumstances, and cause of death

Over the two-year period of 2018 and 2019, the average age-at-death was 36.6 years, with an age range of 6 months to 91 years (SD=11.9, median=35 years, mode=30 years, n=496 cases with known age) (Table 2). The dataset for the age-at-death was skewed to the right side of the mean (skewness=0.961) and the tail of the distribution curve (outliers) was longer on the right side. The differences between the average age-at-death of male's and female's unnatural death cases were statistically significant (U=5787, z=2.0566, p=0.0397). Males (93%) constituted the largest proportion of the sex groups compared to females (6%) (Table 2).

A total of 11 circumstances of death categories of unnatural death cases were x-rayed at the time of admission to the facility, prior to the conduction of an autopsy (Table 3). Individuals killed with a firearm discharge constituted the highest proportion of cases (80%). These were followed by unknown (6.6%) and anaesthetic-related (6.1%) cases (Table 3). The remaining circumstances of death categories constituted about seven percent of cases. Cases categorized as 'unknown' involved unknown circumstances of death from decomposed deceased individuals and/or skeletonized human remains.

The x-rayed cases all fell into one of 11 cause-of-death categories after the completion of a postmortem examination (Table 4). Gunshot wound-related deaths constituted the highest proportion of the cause of death categories (85.5%). Although observed in lower proportion, deaths due to blunt force injuries (3.7%) were the second most recorded cause of death category. These were followed by cases whereby the cause of death was still under investigation (2.8%), and unascertained (2.1%) (Table 4). Cases still under investigation involved cases whereby the forensic pathologist was awaiting either toxicological and/or histological analysis results to supplement autopsy and x-ray findings.

Table 2
The demographic profiles of cases scanned at Johannesburg FPS facility using the LODOX Statscan unit for postmortem examinations from 2018 to 2019 (n=574 unnatural death cases).

Categories		Number of cases	Percentage (%)
Sex	Male	535	93.2
	Female	35	6.1
	Undetermined	4	0.7
Age (years)	0–10	3	0.5
	11–20	16	2.8
	21–30	162	28.2
	31–40	169	29.4
	41–50	95	16.6
	51–60	30	5.2
	61–70	15	2.6
	71–80	4	0.7
	81–90	1	0.2
	91–100	1	0.2
	Undetermined	78	13.6

Table 3
The circumstances of death categories for x-rayed unnatural death cases at the Johannesburg FPS from 2018 to 2019 as reported at admittance.

Circumstances of death	No. of cases	Percentage (%)
Firearm discharge	460	80.1
Unknown	38	6.6
Anaesthetic-related death	35	6.1
Motor vehicle accident	10	1.7
Sharp force injuries	10	1.7
Burns	9	1.6
Blunt force injury	3	0.5
Hanging	3	0.5
Poisoning/Drugs	3	0.5
Sudden unexpected death	2	0.3
Fall from height	1	0.2
Total	574	100

Table 4
The causes of death categories recorded after autopsy for cases x-rayed at the Johannesburg FPS between 2018 and 2019.

Cause of death	No. of cases	Percentage (%)
Gunshot Wound	491	85.5
Blunt Force Injuries	21	3.7
Under investigation	16	2.8
Unascertained	12	2.1
Sharp Force Injuries	9	1.6
Organ failure	8	1.4
Burns	5	0.9
Multiple injuries	4	0.7
Mechanical asphyxia	3	0.5
Poisoning	3	0.5
Natural	2	0.3
Total	574	100

Unascertained cases involved those whereby the forensic pathologist was not certain of the cause of death as no decisive information could be obtained during postmortem examination.

Discussion

Previous studies have investigated the pattern of autopsy findings in association with radiographic images; presenting findings in demographic profiles, circumstances of death, associated trauma, cause of death, the manner of death [29–33]. However, very little has been published on forensic imaging practices of unnatural death cases at medical and/or FPS facilities and trends in the cases that have been imaged [5].

Gunshot wound related deaths

In the present study, cases whose circumstances and/or cause of death were gunshot wound-related were the most common cases selected for radiological scanning. This included cases with penetrating gunshot wounds (a bullet projectile that passes into a body region but not through it, resulting in the bullet being lodged in a particular region [34]) (Fig. 2) and perforating gunshot wounds (a bullet that passes through a body region, piecing the underlying body organs, and exiting the body [34]). In cases of penetrating gunshot wounds, the use of the LODOX Statscan is crucial for detecting and locating potential bullets or bullet fragments, particularly in cases with multiple gunshot wounds (Fig. 2). Ballistic evidence is crucial in gunshot-related death cases [35] and the use of the LODOX system can provide more accurate information about the location of bullet projectiles from a high-quality 2D-digital radiographic image. Due to the rapid digital imaging, the time taken to search for projectiles minimizes the time taken to locate the projective and as a result shortens the time taken to conduct the postmortem investigation in cases with ballistic trauma. A limitation of the LODOX system is that it produces 2D-digital radiographic images, not 3D images, such as in PMCT, so the locating of projectiles is still limited; however, the rapid scanning and manoeuvrability of the system to scan in anteroposterior and lateral planes (Fig. 2) allows for faster locating and recovery of projectiles than traditional x-ray systems which are still used in many forensic mortuaries in South Africa. Recovered ballistic evidence can be used by the police to identify the type of weapon used in committing the crime, reveal any potential links related to the crimes as well as be used in building a strong parallel criminal case [35]. In cases of perforating gunshot wounds, the LODOX Statscan system is less efficient at determining the trajectory of a bullet projectile in perforating gunshot wounds, and such cases are scanned to confirm the absence of bullet projectiles and if they indeed exited the body. As a result, more cases of individuals killed with a firearm discharge were scanned at the JFPS facility and mainly selected for an x-ray scan compared to other circumstances of death categories.

The third most common circumstance of death selected for radiological scans was anaesthetic-related deaths; however, this result can be misleading without context. These cases are often listed in the death registers at admission to the mortuary as anaesthetic-related deaths due to their being admitted to the mortuary from a hospital or clinic; however, a review of their case file documentation reveals that they often have a history of gunshot wounds requiring surgical intervention. As such, the use of postmortem imaging devices can be a crucial tool in the scanning of bodies whereby the circumstance surrounding the cause of death is reported to be anaesthetic related.

Other unnatural death cases

The second most common circumstances of death cases selected for radiological scans were cases of unknown circumstances of death. These were associated with the unascertained cause of death and/or a cause of death that was under investigation as no decisive information could be obtained from postmortem examination or the forensic pathologist was likely awaiting results from either toxicological/histological analysis to supplement autopsy findings. Other unnatural death cases selected for radiological scans included circumstances of death associated with motor vehicle accidents, blunt force/sharp force injuries (Fig. 1), poisoning/drugs, hanging, and sudden unexpected death cases. However, these made-up a small proportion of scanned cases over the two-year study period, thus LODOX Statscan findings were likely used to guide forensic pathologists to an optimum diagnostic approach of the case, preparation of autopsy, and exclusion of other factors as potential causes and mechanisms of death.

Unidentified bodies

The LODOX Statscan unit at the JFPS facility is not only used for autopsy purposes, but it is also used by the in-house Human Decedent Identification Unit to scan unnatural death cases of individuals of unknown identity. Up to 10% of all cases received at the JFPS are unidentified bodies (approximately 350 unidentified bodies per year). As such, the LODOX unit is used to aid with the potential identification of such individuals, through detecting and recording unique features associated with these individuals, such as skeletal pathology, healed skeletal trauma, foreign objects (e.g., prostheses, implants) (Fig. 3), as well measuring the approximate standing height of the body - using the LODOX Statscan's measuring function - which can potentially be compared the living stature of the deceased. These secondary identifiers assist in developing the profile of the unidentified individuals, which are provided to the South African Police Services to assist them in the identification of decedents. This information is also recorded on a database compiled by the identification unit in the hopes of assisting future identifications if family members come forward at a later stage [36].

The LODOX Statscan is also used to produce radiographical images

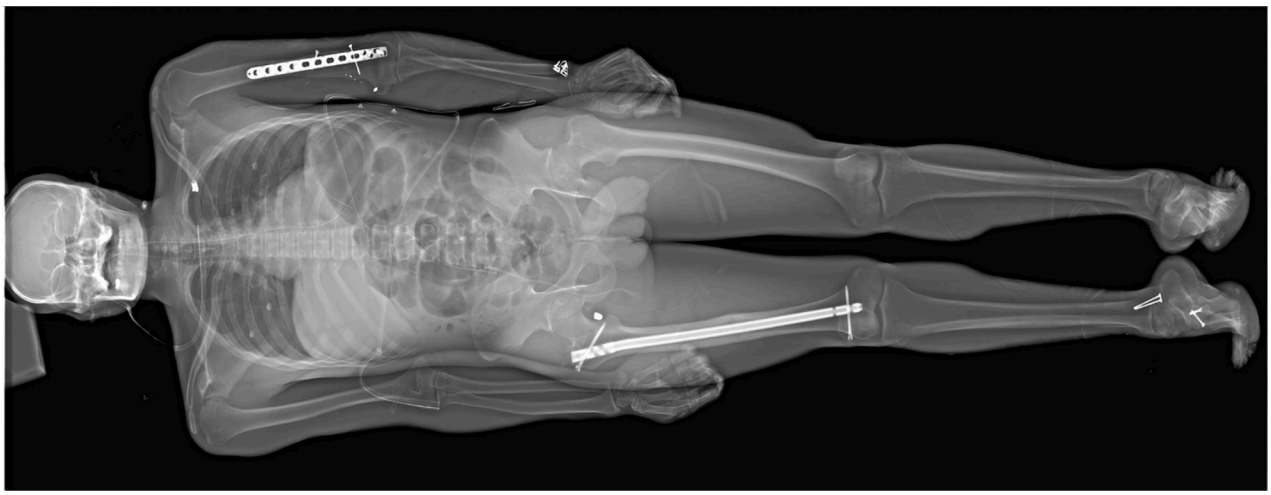


Fig. 3. Lodox Statscan image in a posteroanterior plane showing surgical implants on the right humerus, left femur, and left foot.

for forensic anthropological analysis of skeletal cases admitted to the JFPS facility. Since autopsy results are unlikely to be conclusive in determining the cause of the death and demographic profile in skeletal cases, such remains are sent to a forensic anthropologist for forensic anthropological analyzes for the estimation of the remains' biological profile (sex, population affinity, age-at-death & living stature). For such cases, the LODOX unit is used to document any potential objects commingled with the remains that might be harmful to the individual handling and processing the remains, and to document any potential skeletal traumas (Fig. 1) and pathologies. Moreover, it also assists the forensic anthropologist by recording evidence prior to the bones being macerated and cleaned. These radiographs also have the potential for future research into the effectiveness of using such radiographs primarily for the estimation of the biological profiles of the unidentified skeletal remains using virtual methodologies [37].

Research opportunities presented by the LODOX Statscan system: anatomical sciences cases

In addition to providing medical and forensic uses, the LODOX system also provides opportunities for research purposes. The LODOX unit at the JFPS is also used to obtain radiographical images of cadavers housed at the University of the Witwatersrand's School of Anatomical Sciences. These donated human cadavers are used to teach anatomy to students. These cadavers are now also being scanned at the JFPS to aid in the conduction of research about "virtual anthropology" - a growing worldwide clinical research field based on osteometric analyzes of skeletal remains from digital images derived from various radiographical modalities [37,38]. The use of the LODOX unit at the JFPS presently provides researchers with opportunities to develop and test virtual forensic anthropological methods by assessing landmark recognition and measurement accuracy when applied to two-dimensional images [10]. This is a growing field of research that is investigating whether virtual and dry bone osteometry can be used interchangeably [38]. Furthermore, the full-body LODOX images of anatomy cadavers are more likely to allow for the teaching of anatomical sciences at the university holistically, through the combination of human gross anatomy with that of LODOX images, a method of teaching that aims to be implemented in the future at the School of Anatomical Sciences.

Conclusion

This study has presented the current forensic imaging practices, and the benefits and limitations of digital x-ray imaging, as experienced at one of the busiest forensic mortuaries in South Africa, especially in facilities in a developing country where the case numbers are significantly high, manpower is limited, and the lack of funding precludes the use of other modalities commonly used in developed countries, such as PMCT. Considering the advantageous characteristics associated with LODOX and the high proportion of scanned firearm discharge and gunshot-wound unnatural death cases at the Johannesburg FPS, it is evident that the LODOX Statscan unit plays a valuable role in the detection and recovery of bullet projectiles/fragments in firearm-related deaths (that are retained and submitted to the police as ballistic evidence) at this facility. The device also plays a role in the documentation of skeletal pathologies and injuries that are used to supplement autopsy findings and the potential identification of unidentified deceased individuals. Although the facility's SOP suggests that ideally all bodies be scanned, the large number of cases received by the facility limits the wholescale scanning of all bodies. As such, it is up to the judgment of the pathologists to determine which bodies are scanned. The annual increase in the frequency of use of the LODOX system indicates the growing perceived value of the system by pathologists in postmortem investigations.

Ethics approval

This study was approved by the University of the Witwatersrand's Human Research Ethics Committee – Medical (Clearance certificate M210411) and the study was performed in accordance with the ethical standards as laid down in the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

Source of funding

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Availability of data and material

Data sharing not applicable to this article as no datasets were generated or analyzed during the current study.

Code availability

Not applicable

Consent to participate

Not applicable

Consent for publication

Not applicable

CRediT authorship contribution statement

Boikano M. Morele: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Validation, Visualization, Writing – original draft, Writing – review & editing. **Lawrence Hill:** Conceptualization, Data curation, Methodology, Resources, Supervision, Validation, Visualization, Writing – review & editing. **Craig A. Keyes:** Conceptualization, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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None.

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