



An audit of the polytrauma fracture detection rate of clinicians evaluating lodox statscan bodygrams in two South African public sector trauma units

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ABSTRACT

Background: Increasing global demand for specialized radiological investigations has resulted in delayed or non-reporting of plain trauma radiographs by radiologists. This is particularly true in resource-limited environments, where referring clinicians rely largely on their own radiographic interpretation. A wide accuracy range has been documented for non-radiologist reporting of conventional trauma radiographs. The Lodox Statscan whole-body digital X-ray machine is a relatively new technology that poses unique interpretive challenges. The fracture detection rate of trauma clinicians utilizing this modality has not been determined.

Objective: An audit of the polytrauma fracture detection rate of clinicians evaluating Lodox Statscan bodygrams in two South African public-sector Trauma Units.

Methods: A retrospective descriptive study of imaging data of Cape Town Level 1-equivalent public-sector Trauma Units during March–April 2015. Statscan bodygrams acquired for adult polytrauma triage were reviewed and correlated with follow-up imaging and patient records. Missed fractures were stratified by body part, mechanism of injury and ventilatory support. The fracture detection rate was determined with 95% confidence. The Generalised Fischer Exact Test assessed any association between the fracture site and failure of detection. Specialist orthopaedic review assessed the potential need for surgical management of missed fractures.

Results: 227 patients (male = 193, 85%; mean age: 33 years) were included; 195 fractures were demonstrated on the whole-body triage projections. Lower limb fractures predominated (n = 66, 34%). The fracture detection rate was 89% (95% CI = 86–93%), with the site of fracture associated with failure of detection (p = 0.01). Twelve of 21 undetected fractures (57%) involved the elbow or shoulder girdle. All elbow fractures (n = 3, 100%), more than half the shoulder girdle fractures (9/13, 69%) and 12% (15/123) of extremity fractures were undetected. One missed fracture (1/21, 4.7%) unequivocally required surgical management, while a further 7 (7/21, 33.3%) could potentially have benefitted from surgery, depending on follow-up imaging findings.

Conclusion: This is the first analysis of the accuracy of bodygram polytrauma fracture detection by clinicians. Particular review of the shoulder girdle, elbow and extremities for subtle fractures, in addition to standardized limb positioning, are recommended for improved diagnostic accuracy in this setting. These findings can inform clinician training courses in this domain.

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Introduction

There is growing global demand for specialized emergency radiological examinations, and an expectation that all such

examinations will be reported timeously [1,2]. The trend is exemplified by the burgeoning use of computerized tomography (CT) in trauma [3]. The increase in trauma-related CT has contributed to delayed or non-reporting of plain trauma radiographs internationally. This is particularly true in resource-limited environments, where patient management is largely determined by the radiographic interpretive skills of referring clinicians [1,2,4].

Failure to detect fractures is the most common error in Accident and Emergency Units (A&E) [5]. Missed fractures are one of the more common reasons for medical litigation [6,7], with up to 18%

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of malpractice claims involving emergency physicians [8]. The morbidity and mortality associated with missed fractures are well-documented [5,9–14].

A number of reports have documented the detection rate of abnormalities by non-radiologists reporting conventional trauma radiographs utilizing standard radiographic projections. Accuracies of 35%–68% have been recorded for A&E doctors blinded to clinical details [15,16], while those afforded clinical information achieved detection rates between 44% and 99% [10,17–19]. At least 95% accuracy is expected of formal radiologist reporting in this setting [20,21].

The Lodox Statscan whole-body digital X-ray unit is increasingly utilized for patient triage in busy units where resource-limitations preclude the universal use of CT “pan-scans” in polytrauma. The Lodox Statscan employs slit-beam technology to acquire a whole body antero-posterior (AP) projection (bodygram) in 13 s (Fig. 1). The radiation dose is sufficiently low to permit installation of the Lodox Statscan in the resuscitation area of trauma units, without surrounding lead shielding. Trauma staff do not require protective lead aprons [22].

The role of the polytrauma bodygram is to provide an initial, rapid assessment of major injury that requires prompt intervention. Bodygram findings also inform the need for further, standard radiographic projections of anatomical regions of concern. In acquiring the bodygram, standard radiographic positioning of the extremities is not invoked, since this is time-consuming, and time is of the essence in polytrauma. Prior research has highlighted the difficulty in interpreting AP bodygrams acquired without standard radiographic positioning [23]. It is therefore unlikely that non-radiologist bodygram reporting will match the accuracy achieved in the reporting of conventional trauma radiographs acquired with standard radiographic projections. It is nonetheless important to document bodygram reporting accuracy, thereby benchmarking norms.

While there are currently 44 Lodox Statscan units deployed in trauma units globally, to the best of our knowledge there has been no work on the overall fracture detection rate of clinicians utilizing the modality. Work to date has focused on image quality and the capacity of the bodygram to demonstrate bony injury as compared to other modalities [23–27].

South Africa (SA) has a high trauma burden. In 2015, the deaths and disability adjusted life years (DALYs) per million people that were attributable to road traffic accidents and interpersonal violence were almost double the global average [28]. In the same year, 14% of Cape Town deaths were due to unnatural causes [29].

Aim

An audit of the polytrauma fracture detection rate of clinicians evaluating Lodox Statscan bodygrams in two South African public-sector Trauma Units.

Methods

This was a retrospective descriptive study of the imaging data from the Trauma Units of Tygerberg Hospital (TBH) and Groote Schuur Hospital (GSH) in Cape Town, South Africa, for the period 1 March through 30 April 2015.

Tygerberg Hospital (1386 beds) and Groote Schuur Hospital (975 beds) are the main teaching hospitals of the Faculties of Medicine and Health Sciences of Stellenbosch University and the University of Cape Town, respectively. Each hospital has a Level-1 equivalent Trauma Unit, with a Lodox Statscan located in the resuscitation area [22]. Approximately 35,000 patients are managed between the two units, annually. The institutions utilize the same standard operating procedures for polytrauma triage. For



Fig. 1. A Lodox Statscan AP bodygram.

all patients, a Lodox Statscan AP bodygram and a localized lateral C-spine projection are acquired prior to any other imaging. Fractures detected or suspected on these initial projections are further evaluated utilizing standard, localized radiographic views, or CT. Trauma Unit doctors are responsible for initial evaluation of Statscan images. These are not routinely reported by radiology staff. The hospitals have fully digital radiology departments with the capacity for electronic imaging requests.

All Lodox Statscan bodygrams performed in the Tygerberg and Grootte Schuur Hospital Trauma Units during March and April 2015 for the triage of polytrauma victims aged 18 years or older were included in the study. Polytrauma was classified as any scenario with the potential to inflict multiple injuries, and included motor vehicle accidents, pedestrian vehicle accidents, falls from a height, mob assault, multiple gunshots and building collapse. Bodygrams performed for any reason other than polytrauma, such as for the assessment of the integrity of ventriculo-peritoneal shunts, for faecal loading or skeletal dysplasia, were excluded. Similarly, studies performed on patients younger than 18 years were excluded. Imbedded data-mining software was used to conduct customized searches of the respective hospital's picture archiving and communication systems (PACS), to retrieve all bodygrams meeting the inclusion criteria.

Two radiologists, blinded to clinical details and follow-up imaging, independently reviewed all bodygrams meeting inclusion criteria. Fractures were captured on a customized spreadsheet, recording location and description. Patients with an endotracheal tube were recorded. Multiple fractures involving a single bone were registered as a single data entry. Discrepancies in radiologist fracture reporting were resolved by consensus. Fracture data were then correlated with the initial imaging request form, follow-up radiological findings, and patient clinical records.

Trauma Unit staff were deemed to have detected a fracture if further, localized imaging of the area in question was performed, and the fracture was stipulated in the request for follow-up imaging. In cases where fractures demonstrated on the bodygram had no subsequent imaging, the patient's clinical notes were reviewed, to establish if the fracture had been detected and to determine any factors precluding follow-up imaging. Subjects who demised during resuscitation or were referred to a step-down facility after initial triage were excluded from analysis. Fractures that were not visible on the bodygram but demonstrated on subsequent CT studies were excluded from analysis. The overall accuracy of fracture detection by the Trauma Unit staff, and the pattern of missed fractures were determined. Each missed fracture was stratified as "overt/obvious" or "subtle" by consensus of the study radiologists. The fracture detection rate was determined with 95% confidence and the Generalised Fischer Exact Test assessed any association between the fracture site and failure of detection. Specialist orthopaedic review assessed the potential need for surgical management of missed fractures.

The study was approved by the Health Research Ethics Committees of the respective universities as well as by hospital management.

Results

Two hundred and twenty-seven ($n = 227$) patients (males = 193, 85%; mean age 33 years) met inclusion criteria.

One-hundred-and-ninety-five fractures ($n = 195$) were demonstrated in 125 (55%) patients. Traffic-related ($n = 96$, 42%) and firearm ($n = 72$, 32%) injuries accounted for three-quarters of cases. Extremity fractures (lower = 66/195, 34%; upper = 57/195, 29%) were most common ($n = 123$, 63%).

Forty-two of 48 fractures (42/48, 88%) were identified in the study's 49 intubated patients. Ninety ($n = 90$) fractures were

demonstrated amongst 96 road traffic victims, of which 13 were missed (14%). Six percent of gunshot-related fractures were missed (4/62) in 72 patients. The overwhelming majority of missed fractures (20/21, 95%) were stratified as subtle.

One hundred and seventy-four fractures ($n = 174/195$) were identified by trauma doctors, representing an 89% (95% CI = 86–93%) detection rate. (Table 1). Motor vehicle injuries were implicated in more than half (13/21; 57%) the undetected fractures. The large majority of missed fractures (15/21, 71%) involved the extremities, particularly the shoulder girdle (scapula and clavicle; 9/21, 43%). (Table 2) Missed scapula fractures ($n = 5$) breached the glenoid fossa in one instance, but mostly involved the spine or supraspinatus portion, and were associated with fractures at other sites, including the contralateral scapula ($n = 2$), clavicle ($n = 2$), humerus ($n = 1$), ribs ($n = 1$), forearm ($n = 3$), lower limb ($n = 3$), spine ($n = 1$) and pelvis ($n = 1$). Of note, all elbow fractures ($n = 3$) were undetected (3/21, 14%); two were intra-articular, while the third showed avulsion of the lateral epicondyle. (Table 2) Fracture site was associated with failure of detection ($p = 0.01$).

Orthopaedic opinion was that one missed fracture (1/21, 4.7%) unequivocally required surgery, while a further seven (7/21, 33.3%) could potentially have benefitted from such management, depending on follow-up imaging findings. (Table 2)

Discussion

This is the first study of the collective fracture detection rate of trauma departments utilizing the Lodox Statscan bodygram for polytrauma triage. As such, it contributes to our understanding of the clinical role of a relatively new imaging modality.

The 89% (174/195) fracture-detection rate by trauma doctors in this study is at the higher end of international norms for non-radiologist reporting of conventional trauma radiographs in the clinical environment [10,19,17,18], albeit below the best results achieved in such a setting. However, it is substantially higher than the 68% fracture-detection rate documented in a previous study of trauma-radiograph interpretation by doctors blinded to clinical details [16]. This underscores the pivotal role of both the initial clinical examination, and a subsequent head-to-toe "secondary

Table 1
Summary of all fractures.

FRACTURES			
Location	Total	Detected	Missed
Head & neck (22)	22	22 (100%)	0
Skull & mandible	20	20	0
Cervical spine	2	2	0
Thorax (25)	25	21 (84%)	4 (16%)
Ribs	22	19	3
Thoracic spine	3	2	1
Abdomen & pelvis (25)	25	23 (92%)	2 (8%)
Lumbar spine	5	4	1
Pelvis	20	19	1
Upper Limb (57)	57	43 (75%)	14 (25%)
Scapula	13	8	5
Clavicle	9	5	4
Humerus	9	9	0
Elbow	3	0	3
Forearm	15	14	1
Wrist	1	1	0
Hand	7	6	1
Lower Limb (66)	66	65 (98%)	1 (2%)
Hip	4	4	0
Femur	25	25	0
Knee	3	3	0
Tibia/Fibula	25	25	0
Ankle	5	5	0
Foot	4	3	1
Total:	195	174	21

Table 2
Details of undetected fractures by location (ETT=endotracheal tube; MVA= motor vehicle accident; GSW=gunshot wound; PVA=pedestrian vehicle accident; CA=community assault, Assault NOS=assault not otherwise specified).

No	Location	Mechanism of injury	ETT (y/n)	Description	Subtle (Y/N)	Surgery Required?
1	Scapula	MVA	No	Superior angle	Yes	No
				Lateral margin	Yes	No
2	Scapula	Assault NOS	Yes	Acromion - comminuted, minimally displaced	Yes	No
3	Scapula	GSW	No	Spine, laterally	Yes	No
4	Scapula	PVA	No	Supraspinatus fossa	Yes	No
5	Scapula	GSW	No	Neck, glenoid involved	Yes	Possibly
6	Clavicle	MVA	No	Left, midshaft	Yes	No
7	Clavicle	MVA	No	Left, lateral	Yes	No
8	Clavicle	PVA	Yes	Right, midshaft	Yes	No
9	Clavicle	Fall	No	Left, distal 3 rd , undisplaced	Yes	No
10	Elbow	PVA	No	Right ulna medial epiphysis, intra-articular	Yes	Possibly
11	Elbow	PVA	Yes	Olecranon avulsion	Yes	Possibly
12	Elbow	PVA	No	Avulsion right lateral epicondyle of humerus	Yes	Possibly
13	Forearm	GSW	Yes	Comminuted, minimally displaced left ulnar diaphysis, no dislocations	No	No
14	Hand	CA	No	Right 2nd proximal phalanx	Yes	Yes
15	Rib	MVA	No	Right and left, laterally	Yes	No
16	Rib	MVA	No	Right 10th posterior	Yes	No
17	Rib	PVA	No	Left 9th laterally	Yes	No
18	T-spine	Assault NOS	Yes	Vertebral body compression T5,T6, T7	Yes	Possibly
19	L-spine	PVA	No	Left transverse processes L3,L4)	Yes	Possibly
20	Pelvis	GSW	No	Left iliac bone	Yes	No
21	Foot	MVA	Yes	Right, metatarsal	Yes	Possibly

survey” of all trauma victims, to ensure that no fracture is overlooked. Our findings provide a useful benchmark for further work in this domain, as well as affording insights into potential interventions for improved bodygram reporting.

Missed fractures were characterized their subtlety (20/21, 95%), highlighting the need for extreme vigilance when reviewing whole body radiographs. Factors contributing to subtlety include superimposition of bones, bowel gas, artifacts (ECG electrodes and IV lines) or soft tissues (T-spine), the small size of some fracture fragments and their location at the periphery of the film (metatarsal and metacarpal fractures) (Fig. 2, data in brief). The single missed fracture not deemed subtle involved the ulna diaphysis. The finding that more than a third (8/21, 38%) of missed fractures could potentially have been considered for surgical management, if appropriate follow-up views had been obtained, underscores the importance of this study.

Our finding that undetected fractures were predominantly in the appendicular skeleton (12/21, 57%) is not unique to bodygram reporting. The review of diagnostic errors in polytrauma by Stanescu et al. (2005) highlighted the risk of overlooking periarticular fractures, particularly in the shoulder girdle and feet [30], while studies involving conventional trauma radiographs have shown a similar preponderance (Ng et al. 136/286, 48% [7]; Enderson et al. 21/41, 51% [31]; Freed et al. 107/162, 66% [32]).

The scapula is a complex flat bone, with numerous overlapping osseous structures on AP projection, accounting for the ease with which fractures can be overlooked [33,34]. Nonetheless, the rate of missed scapular fractures in our cohort (6/12, 50%) was somewhat higher than the 31% (31/100) documented by Harris et al. (1988) [35]. Tadros and coworkers (2008) showed that patients with missed scapula fractures had higher median injury severity scores compared to those with detected fractures, and that missed scapula fractures were often masked by other severe thoracic injuries [33]. Scapular fractures are clinically significant, since they indicate high impact trauma [35] and may herald additional severe injuries such as rib and thoracic spine fractures, haemopneumothorax and pulmonary contusion [35,36].

The importance of scapula fracture detection and characterization are underscored by three recent manuscripts [37–39]. Algan Kaya and coworkers, reported on a cohort of 684 patients who had

sustained blunt chest trauma, documenting a higher incidence of scapula fractures (11.3%) than previously documented in this setting, and confirming that those *with* scapula fractures had significantly higher injury severity scores than subjects without such fractures [37]. Surace and coworkers assessed parameters that impact function after scapula fracture. They showed that more than 95 percent of scapula fractures had associated injuries, that approximately 10 percent are optimally managed with open reduction and fixation, and that those undergoing surgical intervention had superior long-term functionality. Specific advantage accrued when surgery was performed for fractures involving the glenoid [38]. Additionally, Porcellini and co-workers reported on a new surgical approach for optimal long-term outlook for fractures of the body and neck of the scapula [39].

Although elbow fractures represent a small proportion of injuries in our cohort (3/195, 1.5%), all were missed, and could potentially have benefitted from surgical management. Elbow fractures were the second most commonly missed fracture (19/162, 12%) in the study by Freed *et al.* [32]. Detection of such fractures is important, since intra-articular fractures are potentially debilitating, with long term complications such as deformity, disability and post-traumatic osteoarthritis.

The potential for improving image interpretation accuracy after appropriate training has been well documented [10,40,41]. The identification of standard “review” areas in the different modalities of diagnostic imaging is therefore of value, for both educational and quality assurance purposes. To date, there has been no formal recommendation that review areas be incorporated into the standard reporting methodology of Statscans. The results of this study suggest the extremities and particularly the shoulder girdle and elbow as specific review areas when evaluating bodygrams in a trauma setting. A standard reporting template would further aid memory and ensure all necessary areas are assessed. The Statscan is a relatively new imaging tool, in use for approximately two decades [23] and as such formal training/orientation programs for trauma doctors in hospitals where the Statscan is installed are likely to be of value in optimizing interpretation accuracy. Furthermore, clinical findings remain crucial in guiding the need for investigation of high-risk areas such as the appendicular skeleton and cervical spine.

Strengths of this study include the congruence of polytrauma imaging protocols across the two units evaluated, and the alignment of the study methodology and cohort size with that of previously published manuscripts investigating the clinical utility of the Lodox Statscan bodygram [24,42,43,22,27,44]. The narrow confidence interval underscores the adequacy of the sample size. Despite the retrospective nature of the study, the modern PACS provides robust and comprehensive clinical data, ensuring the integrity of findings.

Conclusion

This is the first study to benchmark the accuracy of bodygram polytrauma fracture detection by trauma clinicians. We recommend a systematic approach to bodygram reporting, particular review of the shoulder girdle, elbow and extremities for subtle fractures, as well as standardized limb positioning, as measures to improve the diagnostic accuracy. These findings can inform clinician training and refresher courses in this domain.

Declaration of Competing Interest

Neither of the authors have any conflicts of interest to declare.

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