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Cross-sectional Study

An analysis of air-crash injury patterns presenting at a level 1 trauma unit in Johannesburg, a retrospective cohort study

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A B S T R A C T

Background: In the twenty-first century, transportation disasters and subsequent injuries are on the rise, in particular air travel, and, thus, contributing significantly to the morbidity and mortality. Aviation injuries are not common in South Africa, injuries and outcomes of patients involved in aircraft crashes are unknown. We aimed to describe the injury patterns, and mortality rate resulting from air crashes presenting at a level 1 trauma centre in Johannesburg, South Africa.
Methods: Data was collected between January 2011 and December 2019. The hospital trauma database was used to obtain data related to patients who were involved in aircraft crashes. Their demographics, type of related aircraft, injuries sustained, injury severity score (ISS), new injury severity score (NISS), revised trauma score (RTS) surgical intervention carried out, length of stay in ICU, length of hospital stay, morbidities, 28-day mortality and outcomes (discharge/death).
Results: Fifty-two (52) patients (mean age was 44,8 years) were identified. The mean ISS was 9, and NISS was 11. Patients were occupants of civilian, non-commercial, powered aircraft. Fixed wing constituted 63,46%, followed by helicopters 21,15% and 7,69%. Spinal injuries were the most common injury in our patients, followed by soft tissue injuries and rib fractures. The median hospital stay was 10 ± 22 days. The overall in-hospital mortality rate was 7.7 %
Conclusion: Majority of patients sustained musculoskeletal injuries. We suggest that these injured patients should be managed at a Level 1 facility in view of combined multiple injuries sustained during the crash.

1. Introduction

In the twenty-first century, transportation disasters and subsequent injuries are on the rise, in particular air travel, and, thus, contributing significantly to the morbidity and mortality of this millennium [1–3]. However, information regarding injuries sustained by air crash survivors is lacking [1,3]. As the number of commercial and non-commercial flights are increasing, health care facilities are faced with a rise in the number of patients with air crash injuries [1,2]. Consequently, management guidelines must be formulated for the treatment of patients with these air crash injuries.

According to the South African Civil Aviation Authority, 565 aviation accidents and incidents were reported from 2011 to 2019 [4]. The injuries and outcomes of patients involved in these accidents are unknown [4]. There is little data to describe injury patterns and outcomes of patients in aviation accidents within our setting. Consequently, to find data on the frequency distribution of aviation injury patterns in hospitalised patients, one must use other data sources [1,3,4].

Injury patterns from several aircraft disasters have been previously described [5–7]. Some authors have described injury patterns and fatalities from aviation accidents based on their patients and aircraft data [1–7]. Friedman et al. described that when the plane impacts with the ground, the landing gear of an aircraft may be retracted, resulting in energy being directly transmitted from the aircraft to the passengers, through the body of the aircraft from the bottom going upwards along the axial skeleton causing vertebral column injuries [1]. Therefore, it is of utmost importance that survivors of such crashes be transferred to an adequately equipped trauma centre [1–6].

In 2009, Baker et al. aimed to explore the configurations of aviation-related injuries in hospitals in the United States of America (USA) whilst comparing them to the aviation deaths over the same time frame (2000–2005) [3]. This study revealed just over 4500 aviation-related (87% non-commercial aircraft, and 7% commercial aircraft) deaths that occurred in the USA – an average of 753 per year, with one death for every 1.3 hospitalisations [3]. This represents the largest number of patients reported to date. Lower limb fractures/injuries were most common sustained injuries, followed by head injuries, various open soft tissue wounds, upper extremity fractures/injuries, and lastly internal organ injuries [3,8,9]. Head injuries were the cause of most fatalities. This study's case-fatality showed that 39% were due to vascular injuries, 13% due to burns, followed by 8% from head injuries [3].

Rautji et al. discussed the injury pattern examined in the post-

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mortem findings in eight occupants of a light executive jet aircraft crash [9]. One body was severely burnt, but the other seven were not. On serum blood toxicology, it was established that there was no carboxyhaemoglobin present [9]. Therefore, all burns were sustained post-mortem; concluding that the cause of death in all these cases was polytrauma [9–11]. This evaluation found that the most commonly occurring fractures were ribs (72.3%), skull (55.1%), facial bones (49.4%), tibia (37.9%), and pelvis (36%) [9]. The common organ injuries were liver (48.1%), lung (37.6%), heart (35.6%), spleen (30.1%), and haemorrhagic cerebral and pulmonary injuries being 33.3% and 32.9%, respectively [9]. Once again, injuries of sudden deceleration transmitted in a vertical fashion were also described, resulting in vertebral column injuries and extensive visceral damage [9–12].

A report discussed by Afshar et al. illustrated that up to 85% of injuries of survivors of a Boeing 727 flight were extremity injuries (particularly lower limb injuries), followed by vertebral column injuries at various levels, and a minority sustained internal organ injuries [13]. Similarly, Rowles et al. (1990) concluded that most M1 Kegworth air crash injuries were orthopaedic in nature, approximately 85%, and 3.8% required general surgical procedures [8,14,15] (laparotomies, thoracotomies, vascular repair, and a tracheostomy).

Aviation related deaths are often fatal, with most patients dying at the scene; however, with increased safety and improvement in medical management, patients are surviving aviation accidents [1–6]. Among the aviation-related deaths reported between 1980 and 1990, polytrauma was listed as the immediate cause of death in 42% of fatalities, followed by head injuries (22%), internal organ injuries of the thorax, abdomen, pelvis (12%), burns (4%), and drowning (3%) [1,9–11].

Analysis and interpretation of aviation-pattern injuries may provide healthcare facilities with planning information on the spectrum of possible injuries that may be expected, and, furthermore, tools for a protocol and guidelines on the comprehensive and complete management of such patients.

Aim of the study was to describe the injury patterns, and mortality rate resulting from air crashes presenting at a level 1 trauma centre in Johannesburg, South Africa.

2. Method

This retrospective study was conducted at a single institution. All cases of injuries sustained after an aviation crash that presented to our institute were identified between January 1, 2011 and December 31, 2019. The patients were identified in the hospital trauma database in this nine-year study.

Their demographics, type of related aircraft, injuries sustained, injury severity score (ISS), new injury severity score (NISS), revised trauma score (RTS) surgical intervention carried out, length of stay in ICU, length of hospital stay, morbidities, 28-day mortality and outcomes (discharge/death) were recorded.

3. Statistical analysis

Means (±SD) are presented for continuous variables and frequencies (%) are presented for categorical variables. All analyses were done using STATA version 15. Continuous variables were first tested for normality using Shapiro-Wilk test. The Fisher's exact test was used to test for significance of relationship between categorical variables. Univariate and multivariate analysis were conducted on the data. *P*-value of <0,5 was considered statistically significant.

Ethics approval was obtained from the University of the Witwatersrand Human Ethics committee and the hospital CEO. Ethics number M180463 was allocated to the study. The work was reported in line with the STROCSS criteria [.

4. Results

Fifty-two (52) patients presented to our centre with injuries sustained after an aviation crash. There were 44 men in the study, and the mean age was 44,8 years (Table 1). The 19–45 years old group was the largest, contributing 40% of all patients.

Sixty-nine percent of the patients injured were Caucasians. The mean ISS was 9, and NISS was 11. Nineteen patients had an ISS of 16 and above. The mean systolic blood pressure on presentation to the resuscitation bay was 124 mmHg, and the pulse rate was 97 beat per minute. None of our patients required prehospital adrenalin administration. The median Revised Trauma Score was 7,8, but 4,1 on the mortality cases.

All our patients were occupants of civilian, non-commercial, powered aircraft. Fixed wing constituted 63,46%, followed by helicopters 21,15% and 7,69% were microlight crashes. All patients needed hospital admission, with 21 patients admitted to the ICU. The average number of diagnoses were 3,5 per patient. Spinal injuries were the most common injury in our patients, followed by soft tissue injuries and rib fractures (see graph1). Sixty-one percent of patients admitted needed surgical intervention, most of which were orthopaedic in nature.

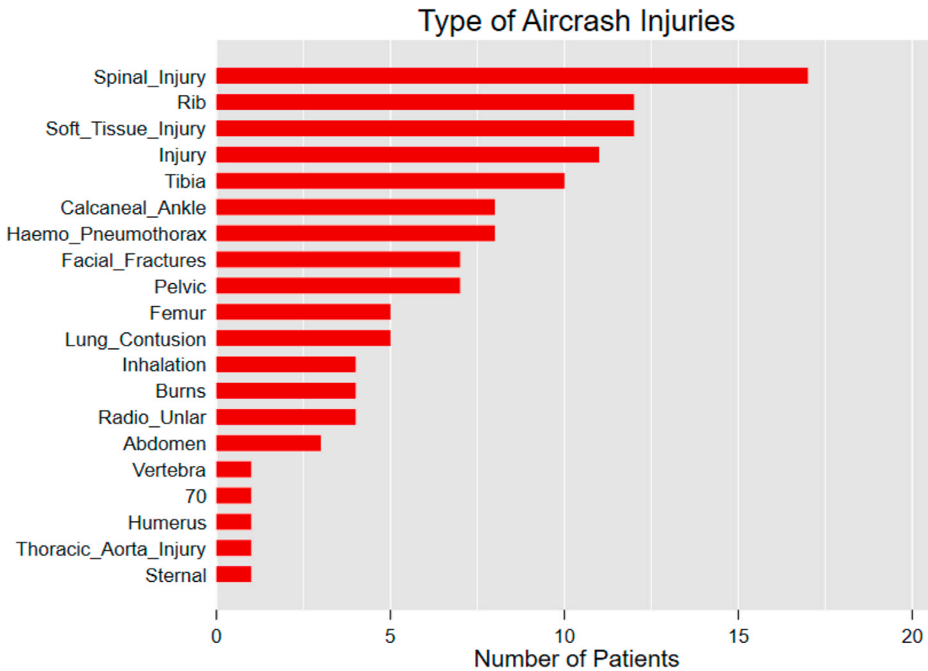
The median hospital stay was 10 ± 22 days. Recorded morbidities were negligible, with three cases complicated by mild pneumonia and two with wound sepsis. Majority of patients were discharged home (87%). Three patients were discharged to a rehabilitation facility for further care (see Table 2). The overall in-hospital mortality rate was 7.7%; four patients died (see Table 3) while in hospital. The ISS, NISS, RTS were 9(4–18), 9(4–22) and 7,8(7,0–7,8) respectively in the survival group versus 31,5(17–54),33,5(20–56) and 4,1in the mortality group. All mortalities were related to those who were travelling in fixed wings (see Table 4).

5. Discussion

The total number of patients in our study over a period of nine years shows that this is not a common occurrence within our setting. Sixty-nine percent of our patients were Caucasians; this is in keeping with

Table 1
Baseline characteristics by mortality.

Variable	Overall n (%) N = 52	Dead n (%) N = 4	Alive n (%) N = 48
Sex			
Male	44 (84.62)	4 (100.0)	40 (83.33)
Female	8 (15.38)	0 (0.0)	8 (16.67)
Ethnicity			
Indian	1 (1.92)	0 (0.0)	1 (2.08)
Caucasian	36 (69.23)	4 (100.0)	32 (66.67)
Black	15 (28.85)	0 (0.0)	15 (31.25)
Age in years mean ± sd	44.87 ± 12.78	42.75 ± 20.76	45.04 ± 12.21
Systolic Blood Pressure mean ± sd	124.79 ± 22.22	149.50 ± 32.84	122.73 ± 20.26
Pulse mean ± sd	97.46 ± 17.73	108.75 ± 9.54	96.52 ± 17.99
Revised Trauma Score median (IQR)	7.8 (4.10, 7.80)	4.1 (4.10, 4.10)	7.8 (7.00, 7.80)
Injury Severity Score median (IQR)	9 (4.0, 22.0)	31.5 (17.0, 54.5)	9 (4.00, 18.00)
New Injury Severity Score median (IQR)	11 (4.0, 25.50)	33.5 (20.5, 56.5)	9 (4.00, 22.00)
Surgical Procedure			
None	20 (38.46)	2 (50.0)	18 (37.50)
Sloughectomy	2 (3.85)	0 (0.0)	2 (4.17)
ORIF	28 (53.85)	1 (25.0)	27 (56.25)
Spinal OP	2 (3.85)	1 (25.0)	1 (2.08)
Type of Aircraft			
Fixed wing	33 (67.35)	4 (100.0)	29 (64.44)
Helicopter	12 (24.49)	0 (0.0)	12 (26.67)
Microlite	4 (8.16)	0 (0.0)	4 (8.89)



Graph 1. Aircraft injuries.

Table 2
Admission summary.

Days in intensive care unit (days) 5,6 ± 15
Hospital length of stay (days) 10 ± 22
Discharge destination
Home 45
Rehab 3
Death 4
Breakdown of Deaths

Patient	Days in hospital	Underlying cause of death
27-year-old male	1	Major burns
67-year-old male	1	Complications of polytrauma
24-year-old-male	11	Major burns
53-year-old male	4	Major burns

Table 3
Factors associated with ISS>15.

Variable	ISS ≥ 16 n (%) N = 19	ISS < 16 n (%) N = 33	p-value
Sex			
Male	18 (94.74)	26 (78.79)	0.23
Female	1 (5.26)	7 (21.21)	
Ethnicity			
Indian	0 (0.00)	1 (3.03)	0.59
Caucasian	15 (78.95)	21 (63.64)	
Black	4 (21.05)	11 (33.33)	
Age in years mean ± sd	46.74 ± 12.90	43.79 ± 12.77	0.43
Systolic Blood Pressure median (IQR)	126 (120, 139)	124 (92, 133)	0.071
Pulse mean ± sd	103.79 ± 20.31	93.82 ± 15.22	0.050
Revised Trauma Score median (IQR)	4.1 (4.1, 7.8)	7.8 (7.8, 7.8)	<0.001
Surgical Procedure			
None	2 (10.53)	18 (54.55)	0.002
Sloughectomy	1 (5.26)	1 (3.03)	
ORIF	16 (76,19)	14 (42.42)	
Spinal OP	2 (10.53)	0 (0.00)	
Type of Aircraft			
Fixed wing	10 (58.82)	23 (71.88)	0.559
Helicopter	5 (29.41)	7 (21.88)	
Microlite	2 (11.76)	2 (6.25)	
Mortality			
Alive	16 (84.21)	32 (96.97)	0.132
Dead	3 (15.79)	1 (3.03)	

the economic distribution patterns in South Africa. These subgroups of patients are most likely to afford private fixed-wing or helicopters which would explain the injury distributions.

Majority of patients involved in aviation accidents in our data are males; this is in keeping with international literature [1–5,13,16]. The most vulnerable age group to aviation injuries was 19-45-year-olds in our study. This is also the observation noted by Baker et al. [3]; the reason might be these are economically and physically active population group. There were two children injuries in separate accidents that presented to our facility. Children are most vulnerable to injuries in aeroplane crashes [1,3,6]. Fortunately, in our study, they had minor injuries.

Most patients presented to our trauma centre with normal vital signs as shown by mean systolic BP and pulse on presentation. Sixty-three percent of patients had an ISS less than 15. The average RTS was also 7,8. Aviation injuries are often fatal; the presentations to our facility are because most patients with severe injuries die at the scene. Those that do make it to the hospital would have self-selected themselves.

Our results of injury patterns provide hospitals with useful planning of likely injuries that can be expected after aviation crashes [17]. Spinal fractures were the most common injuries sustained, with rib and soft tissue injuries also frequent. In a study at the United States of America by Baker et al., lower limb injuries were the most common injuries sustained [3]. However, they included parachute injuries in their data. Spine injuries were the second most common injuries, and these were mostly in helicopter crashes patients [3]. Majority of our patients did not require life-saving surgical intervention but required orthopaedic surgical management.

Our study only looked at aircraft injuries, and it excludes parachute injuries. Sixty-seven percent of our aircraft injuries were from private planes, followed by helicopters. We have few microlight accidents (8%), and we might see more patients injured in the future, as more people getting into aviation sports [4]. None of those involved in microlight crash in our study died.

The median hospital stay was 10-days, with most patients being

Table 4
The relationship between type of aircraft and outcomes.

Variable	Fixed Wing n (%) N = 33	Helicopter n (%) N = 12	Microlite n (%) N = 4	p-value
Systolic Blood Pressure mean ± sd	128.52 ± 21.83	123.33 ± 20.85	109 ± 27.99	0.24
Pulse mean ± sd	98.55 ± 17.52	96.25 ± 14.47	92.25 23.26	0.76
Revised Trauma Score median (IQR)	7.8 (4.1, 7.8)	7.8 (7.8, 7.8)	7 (5.15, 7.8)	0.44
Injury Severity Score median (IQR)	9 (4, 17)	9.5 (4, 23)	13 (4, 24.5)	0.92
New Injury Severity Score median (IQR)	9 (4, 22)	11 (4, 23)	15.5 (4, 27)	0.99
Surgical Procedure				
None	13 (39.39)	5 (41.67)	1 (25.00)	0.97
Sloughectomy	2 (6.06)	0 (0.00)	0 (0.00)	
ORIF	17 (51.52)	7 (58.33)	3 (75.00)	
Spinal OP	2 (6.06)	0 (0.00)	0 (0.00)	
Mortality				
Alive	29 (87.88)	12 (100.00)	4 (100.00)	0.69
Dead	4 (12.12)	0 (0.00)	0 (0.00)	

admitted into a high dependency ward because of the multiple injuries they sustained. In-hospital morbidities were negligible in our study. Fewer operations were required in patients that survived compared to the ones who died. This might be related to the severity of injuries sustained by patients who died, and the nature of severe burn-related surgical management.

Our overall in-hospital mortality rate was 7.6%, all withing 28-days of hospitalisation. Three of the four patients that died had median ISS and NISS scores of 31,5 and 33,5, respectively. This was in patients who sustained major burns (>70%) with associated inhalation injuries. Burns sustained in air crash injuries have a high case-fatality rate [9]. The mortality rate in our study is in keeping with the overall mortality reported in the literature [1,3]. Most patients with ISS >16 had no major physiological abnormalities, as shown by the median blood pressure and pulse rate; this explains the low mortality rate reported [18–22]. This is in keeping with previous studies in south Africa and understanding of outcomes related to physiological data [16,17]. The administration of prehospital adrenalin in our local setting carries a mortality rate as high as 37,5% [23]; none of our patients presented with prehospital administration of adrenalin in this air crash study.

To our knowledge, this is the first published description of aviation-related hospitalised injuries and death at a Level 1 Trauma Centre in Johannesburg, South Africa.

6. Limitation of the study

This is a retrospective study with smaller numbers in the nine-year period. Long term follow-up was not included in this study. The study was conducted at a single Trauma centre with potential selection bias.

7. Conclusion

Aviation related injuries are not common in South Africa, with patients presenting to the hospital haemodynamically stable. Majority of patients sustain musculoskeletal injuries. The overall mortality rate was 7.6%. We suggest that these injuries should managed at a Level 1 facility in view of combined multiple injuries sustained during the crash.

Conflicts of interest

Authors has no conflict of interest to declare.

Sources of funding

No funding for the study was required.

Ethical approval

Ethics approval was obtained from the University of the Witwatersrand Human Ethics Committee. Ethics approval number M180463.

Research registration Unique Identifying number (UIN)

1. Name of the registry: Clinical trial.gov.
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3. Hyperlink to your specific registration (must be publicly accessible and will be checked): https://register.clinicaltrials.gov/prs/app/action/LoginUser?ts=1&cx=-jg9qo4.

Author contribution

Study design.
Data collection.
Writing.
Manuscrit préparation.

Guarantor

Dr. S Makhadi.
Trauma Fellow.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.amsu.2021.102194.

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