Analysis of orthopedic injuries in an airplane landing disaster and a suggested mechanism of trauma

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ORIGINAL ARTICLE

Analysis of orthopedic injuries in an airplane landing disaster and a suggested mechanism of trauma

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Abstract Survival after an airplane disaster is rare. We describe the injuries of survivors of an airplane accident and present a common mechanism of trauma for victims. Descriptive data were gathered by interviews with patients, physical examination. Review of charts and patients X-ray films. Informations regarding the flight characteristics were obtained from Iran air safety board. All dead patients were clinically examined by legal medicine department. The suggested mechanism of trauma was established according to present knowledge of mechanism of fractures. From 105 passengers, 27 survived. There was no mortality during hospital course. Between dead passengers, lower extremity fractures were the most common followed by chest wall fractures. Among the survivors, neurosurgical help was needed only in one case for shunt application. Brain concussions and effusions and one hematoma managed conservatively. Two laparotomies were performed for one splenectomy and two hepatoraphy. One pelvic fracture and two femur fractures were occurred. Tibia fractures were the most common (17) followed by spine (14) fractures. Ten tibial fractures were open, and 15 were in distal third. All tibia fractures were fixed with IM locking nails or locking plates. Eight posterior instrumentations were applied for seven burst and two fracture-dislocations. In this landing accident, a combination of vertical loading along with deceleration force produced burst fractures of spine and distal leg fractures.

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Introduction

Today one of the paramount necessities for modern life is aviation. When measured on a passenger-distance calculation, air travel is the safest form of transportation available; however, many aviation accidents are mass disasters and result in loss of lives and community fear [1]. Airplanes are designed with features that can dissipate the kinetic energy of the passengers and minimize injury in the event of a crash landing. If a crash landing is necessary, passengers could be taught to keep the safety position in order to land more safely and to avoid obstacles injuries inside the aircraft as much as possible.

Several authors have already described the pattern of injuries in aircraft disasters [2, 3]. We describe the patterns of injuries in Boeing 727 landing crash with emphasize on the possible mechanism of trauma.

The objective of this study is to establish knowledge of the injury patterns and tolerance limit of the body in order to improve the care of patients in aircraft disasters.

Materials and methods

Accident analysis: The Iran Air-operated plane crashed near Lake Orumiyeh, 700 km (almost 435 miles) northwest of Tehran, after it took off from Mehrabad International Airport. The plane headed for the runway to land, but was forced to delay the touchdown due to bad weather. After unsuccessful second landing and at poor visibility condition, the aircraft tried for escalation but failed to and collapsed. The aircraft crashed into three parts and finally

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Fig. 1 Aircraft departed to three segments

stopped in a farmland about 15 km outside the airport (Fig. 1). There was no any explosion or firing. Despite the poor weather condition, all the victims apart from one case were evacuated to Orumiyeh hospitals in <3 h. The body of the exclusive case was found under the wing of airplane 36 h later. Immediate disaster headquarters was formed, and four teams of general surgery, orthopedic surgery, neurosurgery, and maxillofacial surgery were formed under supervision of deputy of treatment and managed the patients. Priority of evacuation of passengers was based on severity of trauma and the passengers who were likely to be alive.

Informative data were collected from the patients using history taking and physical examination and also with interview with the surgeons who were involved in emergency care of patients. Using the International Classification of Diseases, codes for air transport accidents (E840–E844) supplementary data were gathered through investigation in patient's charts and radiographies. Supplementary data regarding the main cause of death of patients were obtained from department of legal medicine. For burial permit issuance, all dead patients were clinically examined by legal medicine department. Autopsy was performed only on pilot and copilot for toxicological purposes. By arranging a special ward and staff for the victims of disaster, all patients were available for a short-term follow-up. All patients were examined for several times in following days after accident, and any further changes in medical condition of patients were recorded and used for the purposes of present study. The corresponding accident database and passenger's seat number maintained by the Iran air safety board was used to access aircraft information and environmental factors. Statistical analysis using Fisher's exact and chi-square tests was used to assess correlation between individual fractures and to determine any relation between patient's seat number and survivors.

Results

From 105 patients, 27 were alive on hospital arrival and the remainders were dead. Extreme body disintegration was not found in any of dead cases. Pilot and copilot both had been died immediately after accident. The patients who were admitted in other hospitals (because of the proximity to the scene) were ultimately referred to Imam Khomeini tertiary trauma center hospital. None of the patients who were alive on arrival expired. Finally, 27 patients were available for study.

Between dead passengers, there were 20 fractures of skull, 29 maxillofacial fractures, 9 neck fractures, 3 thoracolumbar fractures, 52 chest wall fractures, 13 abdominal traumas with 4 cases of definite internal organ ruptures, 32 upper extremity fractures, and 55 lower extremity fractures. It was very difficult to declare the direct cause of death in dead passengers. The cause of death was an estimated one, suggested by the expert legal medicine staff. Multiorgan crushing injury has been registered as the most common cause of death in patient's charts.

Table 1 shows distribution of injuries between patients. The most common injuries were orthopedic. Among the orthopedic injuries, fracture of lower extremities and spine were more common (Fig. 2). Totally, there were 50 fractures (considering tibiofibular fractures as one and excluding rib fractures). From this pool of fractures, 31 (62 %) were happened in lower extremities, of them 28 (90.3 %) were occurred distal to knees. *P* value using Fisher's exact test was not statistically significant for concomitancy of different fractures. Seventy percent of survivors remembered their seat number and for these patients the most common seats were in anterior crashed segment. Most of the middle segment victims were dead.

Fifteen spinal fractures were present (Table 2). Seven of them were unstable burst fractures, and three were fracture-dislocations. All these fractures underwent posterior instrumentations. In two patients, intra-canal fragments were needed to be removed through posterolateral approach. Five other fractures were compression type and managed conservatively. Among the spinal fractures, one was in cervical spine and four were in thoracic region. Cervical fracture was C1 lateral mass fracture. From remaining 10 lumbar fractures, seven were occurred in L1, two in L3 and one in L2. One case with burst L1 fracture was complicated by paraplegia and was paraplegic on discharge. One traumatic syringomyelia from C2 to C6 and one dura rupture were identified in two patients. There was no seat-belt-type spinal fracture.

There were 17 tibiofibular fractures in 12 patients. One of these fractures was isolated tibia fracture, and ten were open (type 1 and 2). Of 17 tibia fractures, 15 occurred in distal third of leg. Five of tibial fractures were bilateral, and

Table 1 Injury pattern in survivors

	Tibia-fibula	Maleoli	Spine	Femur	Pelvis	Metatarse	Calcaneus	Radius	Ulna	Other injuries
1										Brain contusion
2		+	+							Hepatoraphy-pulmonary emboli
3	+ +		+							
4			+				+			LC
5			+	+					+	LC
6	+		+							
7		+								LC
8		+	+		+					
9			+							Hydrocephalus-hemiparesis
10	+		+					+		
11		+								
12								+		
13			+							
14		+	+							SAH-deltoid ligament injury
15	+									
16										
17	+		+							LC-syringomyelia
18	+		+			+				
19		+	+			+				LC
20		+								Brain contusion
21	++	+	+							LC
22	+	+	+							
23	+									Splenectomy-hepatoraphy
24	++			+						LC
25	++									Hemothorax
26										
27	++									LC-fat emboli

+ = fracture in limb, ++ = bilateral fracture. *LC* lung contusion

one of them was segmental. All tibia fractures were managed by surgery. For 13 cases, interlocking IM rod or plating was applied and four fractures managed with external fixator. No neurovascular injury was found in these patients, and none of them complicated by early infection. One of these patients developed clinical manifestations of fat emboli syndrome and recovered later. This patient had bilateral tibial fractures.

Nine patients had malleolar fractures. Two of them were bilateral, and one was open. All fractures except for one were bimalleolar or trimalleolar. The case with isolated lateral malleolar fracture had also complete deltoid ligament tear, which was repaired during fixation of lateral malleolus. One patient had grade three ankle sprain with instability without fracture. She managed with casting and leaved the hospital to be followed in Tehran for ligament repair. All malleolar fractures were supination-external rotation or supination abduction type.

One patient had calcaneal fracture with concomitant L1 fracture. This patient had also spinal cord injury. Fracture of calcaneus was intra-articular, and his Bohler angle was decreased. Due to his poor general condition, he was managed with closed reduction and casting. His spinal fracture was fixed later with posterior instrumentation. Two other patients had comminuted fracture of navicular and metatarsal. They were managed with closed reduction and casting.

There was only one case with open book pelvic fracture and SI joint dislocation. This patient was referred to another center for definite treatment according to his family request.

In upper extremities, two patients had fracture of distal radius. These fractures were simple and managed with closed reduction and casting.

Some degrees of brain concussion were present in all patients except one. Neurosurgical intervention was performed in one case for shunt application. Three patients with brain effusion and one subarachnoid hematoma did not need surgery. One traumatic syringomyelia from C2 to C6 was also managed conservatively. Eight patients had multiple rib fractures. Nine patients developed respiratory problems for

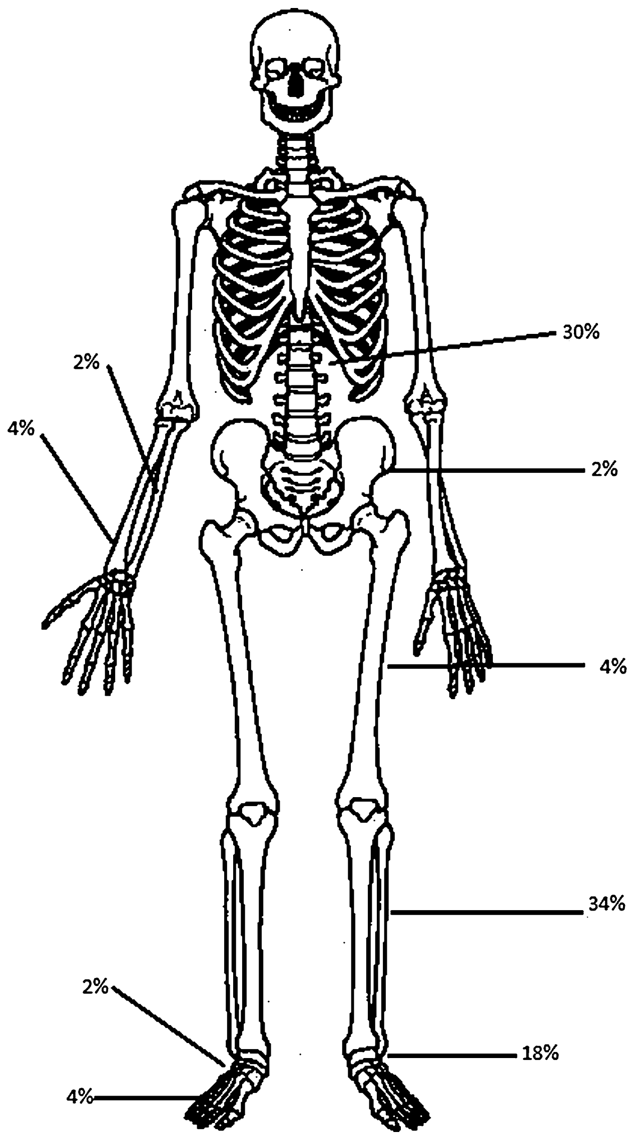

Fig. 2 Skeletal distribution of various fractures

which seven chest tubes were applied. Three chest tubes were applied immediately in hospital, and four were applied later in ICU because of progressive respiratory distress syndrome. One splenectomy and two hepatoraphy were done for spleen and liver ruptures.

Discussion

In this study, fractures of lower extremities were more common than upper extremities. The most common fracture was fracture of tibia and fibula, and most of them were open and comminuted fractures. The second common fracture between survivors was spinal fracture. Most of the spinal fractures were burst type.

A 2007 study by Popular Mechanics found that passengers sitting at the back of a plane are 40 % more likely to survive a crash than those sitting in the front [4], although that article also quotes Boeing, the FAA and a website on aircraft safety, all claiming that there is no safest seat. The article studied 20 crashes, not taking in account the developments in safety after those accidents. Our study also approve that there is no safe seat in landing crush injuries. The aircraft was departed to three segments, and there were patients from all parts of crashed airplane.

The most similar airplane crashing injury was happened in 2009 at Amsterdam airport after an unsuccessful landing of a Boeing-737 [5]. In that accident, 17 % of the patients had a spinal fracture and 34 % had fractures of lower extremities. There was no in-hospital mortality. Comparing to that study, there were more mortality and relatively higher percent of spinal fractures in this accident which may represent a higher energy of trauma. Interestingly, the pattern of injuries was very similar to our accident. In both the lower extremities, fractures were the most common followed by spinal fractures. There was no in-hospital mortality in both accidents. Postma and coworkers have also scrutinized the delay between accident and hospital arrival of casualties in Amsterdam airport accident. They concluded that although the accident was in an urban area, there was a significant delay between the time of the accident and the arrival of the casualties at hospital emergency departments [6]. In our study, the accident was happened in a farmland about 15 km outside the airport and in a very snowy weather. Near to 3 h after accident, all victims were in hospitals.

In this accident, 27 patients (25.7 %) survived. The chances of survival in a crash due to a standard failure or explosion at a high altitude are negligible [7]. However, this crash occurred during landing (i.e., when the aircraft's speed is relatively low). In addition, during landing the fuel of aircraft was so low and the crash was not complicated by explosion or fire. These factors can explain the significant number of survivors. In addition, factors like the angle of ground touch and weight of the aircraft and ground characteristics may play important role [8]. In the report of the national institute of health of US, the highest case-fatality rate, (39 %), was in patients with injury to blood vessels, followed by burn patients (13 %), and patients with head injury (8 %). Li [9] noted a decrease in the annual number of fatalities with burn injuries, from 188 in 1980 to 90 in 1990. This suggests a decrease in burn injuries. We partially attribute the good prognosis of our hospitalized patients to the absence of the burn among the patients.

Of the most important injuries in this accident and its similar landing accidents were spinal fractures. The spinal fractures were a mostly burst type fracture which indicates a vertical force to the spine. This type of fracture coincides

Table 2 Spinal fractures in survivors

	Level	Type	Neurologic deficit	Posterior instrumentation
1	C1 and L4	Lateral mass fx	Hemiparalysis due to brain injury	–
2	T12	Burst	–	+
3	L3	Burst		+
4	L2	Fx-dislocation	–	+
5	L1	Burst	–	+
6	L1	Burst	Incontinency-spinal epidural hematoma	+
7	L3	Burst	–	+
8	L1	Burst	–	+
9	T12	Compression-flexion	–	–
10	L1	Burst	Paraplegia	+
11	L1	Fx-dislocation	–	+
12	L1	Compression-fx	–	–
13	T5–T7	Compression-fx	–	–
14	L2	Fx-dislocation	–	+
15	T8	Compression-fx	–	–

with scarcity of head and face major traumas. It seems that the major factor in producing the fractures was not the decelerating force but vertical force from crashing down. In fact, as there was no major obstacle to hit the aircraft, it was pulled for a long distance and the energy of movement was taken gradually. Rostykus in his study on airplane landing accidents have shown that pilots who failed to use both lap belt and shoulder harness were more likely to die (adjusted RR, 6.8; 95 % CI, 1.8–25.5), as were those who used only the lap belt (adjusted RR, 1.7; 95 % CI, 1.3–2.2), compared with pilots who used both restraints [10]. In this study, there was very significant rate of head and face and upper extremities fractures in dead patients compared with survivors. Although pattern of injuries in survivors does not support the recommendation for shoulder strap, very high rate of skull and maxillofacial fractures between expired patients indicates its use (Fig. 3). It means that in airplane landing accidents the possibility of recovery from a head and neck injury is very low. Further studies are needed for strict recommendation of shoulder straps in airplanes.

Scarcity of upper extremity fractures and very high incidence of lower extremities injuries between survivors correlates with study of others. Baker [11] reported that the lower limb fractures were the most common injury and constituted 27 % of all hospitalized injuries among the aviation-related hospitalization in US. In New Zealand, Chalmers et al. [12] also found that the most common injury in crashes of fixed-wing aircraft was to the lower extremities, while spinal injuries were more common in helicopter crashes. In our patients, the most common fracture between lower extremity injuries was the fracture of tibia. Most of

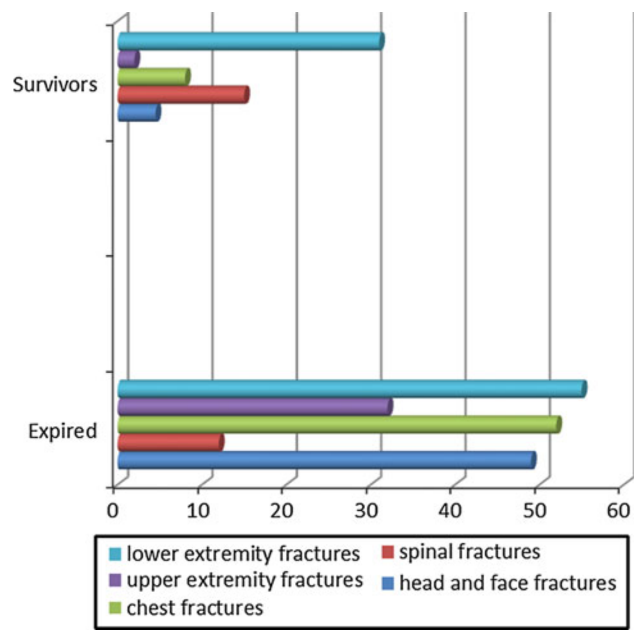

Fig. 3 This *graph* shows different pattern of fractures between survivors and expired cases

the tibia fractures were open and were in distal third of the bone. These patterns of fractures suggest a direct mechanism of trauma to the distal legs. If we add the numbers of malleoli fractures to this count, one can be more assure that a common hitting object may be involved in producing lower extremity fractures. In our suggested scenario, passengers who were in their seats and had fastened their seat belts confronted with a combined vertical and deceleration force. The vertical force caused spinal fractures. It had also crushed the floor of a rapidly decelerating aircraft. The usual position for seating of passengers during landing is 90–90 flexion of hips and knees. We could not find any posterior dislocation of hips or patellar fractures, so the hitting objects resulted from vertical and deceleration force should be located distal to knees. The main object in distal parts of the front seat in Boeing 727 is the foot bar which is a metallic bar that has been originally designed to elevate passenger's feet and make comfort for passengers. This device may be the main causative agent that produced lower extremity fractures in this crashing injury.

The prominence of lower limb fractures in hospitalized patients in this study and in the fatality study reported by Wiegmann and Taneja [13] underscores the potential value of modifications to the various structures likely to be contacted by feet and legs when a crash occurs. It is an axiom in the mechanical arts that modification of cause will change results. Knowledge of mechanism of injuries is a centrally important element in any proposed increase in safety factors through engineering effort. Alteration in position of foot bar and the possibility of its packing during landing may be considered in design of future seats of aircrafts.

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Conflict of interest The authors declare that they have no conflict of interest.

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