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Air Crash Investigation: Pattern of Spinal Injuries, Management During the COVID-19 Pandemic, and Outcomes

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ABSTRACT

Background: Spinal injuries following an air crash can be fatal, and recognizing the patients who need immediate attention and early management could save those patients from ending up with lifelong disabilities and other consequences. However, taking appropriate actions in a pandemic situation presents additional challenges. We present our report of air crash victims with spinal injuries, along with their patterns, morphology, management, and outcomes during the COVID-19 pandemic.

Methods: An analysis was performed on the spinal injuries of victims of the Boeing 737 crash landing at the Karipur Airport (Calicut International Airport, Kerala, India) who were treated at a tertiary care referral hospital in August 2020. Details of the initial triage, patterns of injury, morphologies, mechanisms, management principles, and outcomes at 9 months postinjury were recorded and analyzed.

Results: Of the 47 patients received at our center, 44 survivors were triaged and 13 patients (29.5%) were identified to have spinal injuries of varying severities. The majority of the injuries were chance fractures at the lumbar level, followed by burst and compression fractures. A total of 6 patients underwent surgery, following all COVID-19 guidelines based on priority. All survivors had positive outcomes with our management. No complications such as secondary infections, worsening of neurological deficits, or implant failures were recorded.

Conclusion: A high incidence of spinal injuries is seen in air crash victims. Early prioritized surgical management in selected patients provides excellent outcomes. Disaster management during a pandemic situation is a difficult task, where proper planning and execution is necessary to provide optimal results.

Other and Special Categories

Keywords: air crash, spinal injury, COVID-19, pandemic, disaster management

INTRODUCTION

In a disaster situation, quick assessment of the injuries, along with appropriate prehospital triage and safe transport to tertiary care centers, influence the final outcome of the victims' condition. Fortunately, across the world, air crash disasters are rare compared with motor vehicle accidents. However, the rarity of air crash disasters means that the literature is sparse concerning spinal injuries in the context of air crashes. Spinal injuries, which are most frequently due to falling or motor vehicle accidents, may be fatal, and survivors may end up with lifelong disabilities and impairments of varying degrees.¹ The COVID-19 pandemic is nothing less than a disaster in itself, and managing orthopedic and spine trauma has been a challenge for all surgeons during this period. The question of whether to follow textbook indications, follow the latest organization guidelines, or go with our "gut" feelings in deciding whether to operate or conserve is a dilemma. The risks involved

in potential exposure to COVID-19 and the complications caused by anesthesia and surgery if the patient is positive for COVID-19 only makes the dilemma more difficult.

An amalgamation of disasters in the form of an air crash during a pandemic situation is what we witnessed in August 2020. The Air India Express 1344 Boeing 737 aircraft from Dubai (United Arab Emirates) to Calicut (Kerala, India) crashed at the Karipur International Airport on the evening of 7 August 2020. The aircraft was carrying 184 passengers, 4 cabin crew members, and 2 pilots.² While landing, it failed to stop before the end of the tabletop runway and plunged 9 to 10.5 m (30–35 ft) into a gorge, splitting the fuselage into 2 sections upon impact³ (Figure 1). This aircraft was run as a part of the Vande Bharat Mission, which helped repatriate Indian citizens from different parts of the world, as most routine international travel was suspended due to the COVID-19 pandemic. Such incidents during the



Figure 1. Scene at the site of the accident showing the crashed aircraft split into pieces.

pandemic could become challenging, not only to the rescue workers at the site of accident, but also to those doing triage at the emergency facilities.

In this study, we investigate the difficulties encountered in identification of, communication with, and management of these patients in full personal protective equipment (PPE) kits during the COVID-19 era. We also assess the patterns of spinal injuries, their morphology, and their management. In addition, we report the clinical and radiological outcomes at the 9-month follow-up point in these patients.

MATERIALS AND METHODS

A detailed analysis was performed on the spinal injuries of all victims of the Boeing 737 crash landing at the Karipur Airport who were treated at a single center tertiary care referral hospital in August 2020. Preliminary data about patient demographics and seat details during the flight were recorded. The method of the initial triaging system in the emergency setting, the level of spinal injury, the fracture classification (AO Spine classification of injuries), and the type of treatment were documented. Clinical and radiological outcomes at 9 months postinjury for all of the survivors treated at our center were recorded and analyzed. Victims and flight crew members who were treated at other hospitals are omitted from this report.

Initial Response

Mobile intensive care units and ambulances with medical teams in full PPE were immediately sent for rescue at the site of the accident, which was around 2 miles from the airport and 20 miles from the hospital. Patients in the emergency department were transferred to wards during the extrication time to provide space for receiving patients of the mass casualty. More than 75 doctors and nurses from various specialties arrived at the emergency department, donned PPE, divided into multiple teams, and immediately started to triage the 44 patients we received from the site. Difficulties were encountered in maintaining social distancing, identifying each other, checking patients' identification, and coordinating for further investigations; these were noted in the chaotic environment. However, all patients were triaged per the Advanced Trauma Life Support protocol (Table 1). A total of 3 patients were dead upon arrival, including the pilot and copilot of the aircraft. A total of 7 patients who were hemodynamically unstable

Table 1. Triage workup of all injured patients showing number of patients in each category and the list of injuries.

| Triage Color | Category | Patients (No.) | Injuries |
|--------------|---------------|----------------|---|
| Red | Immediate | 17 | 29 skeletal injuries (predominantly lower limb fractures), 13 spinal injuries, and 2 brain injuries |
| Yellow | Urgent | 19 | |
| Green | Minor | 7 | |
| Black | Dead or dying | 3 | |

were shifted to the intensive care unit immediately and stabilized. The rest of the patients under different triage categories proceeded to imaging investigations after a thorough primary survey and initial aid based on priority. COVID-19 testing was done for all of the patients using the TrueNat COVID-19 chip-based real-time duplex polymerase chain reaction test, as this system yielded quick results. A total of 2 patients were reported to be positive based on the results.

RESULTS

Aboard the Boeing 737 flight (Air India Express 1344) that crash landed at the airport on 7 August 2020, there were reportedly 190 passengers, including the crew. The crash ended up killing 19 passengers and both pilots. There were 4 cabin crew members and

165 passengers who survived. More than 100 of them were injured and taken to multiple hospitals and major tertiary care centers around the vicinity of the site of accident. Our center received 47 patients, including both of the pilots who were brought dead. Of the 44 survivors, 13 patients (29.5%), including 4 women and 9 men, were identified to have spinal injuries of varying severity (Table 2). In our case series, almost all of the patients were wearing a seat belt at the time of the accident, and their seat layout is shown in Figure 2.

A common pattern of injury was found to be chance fractures at the lumbar levels (L2:2, L3:1) followed by burst fractures (L5:1, L3:2) and compression fractures, predominantly in the thoracic spine. A total of 6 patients with compression fractures and 1 patient with a burst fracture, all with intact neurological status,

Table 2. Table showing management of all patients with spinal injuries, length of stay in the hospital, neurological improvement, and present functional status.

| No. | Injury Pattern | AO Class | Spinal Injury Management | Time to Surgery | Length of Stay | Neurology at Admission | Neurology at Follow-up | Functional Status |
|-----|--|----------|---|-----------------|----------------|---|------------------------|--|
| 1 | Burst fracture L3 with complete paraplegia | A4 | L2-L4 stabilization with intermediate screws, laminectomy, and wide decompression | Day 1 | 45 | ASIA grade B | ASIA grade D | Walking with support, bowel/bladder intact |
| 2 | Zone 2 sacral fracture bilateral with spinopelvic dissociation, fracture spinous process of T1, T2, T3 (Figure 3) | C | Spinopelvic fixation (L4-S2AI screws) and decompression | Day 3 | 10 | ASIA grade B with bowel and bladder involvement | ASIA grade E | Walking without support, bowel/bladder intact |
| 3 | L2 chance fracture with paraparesis | B1 | L1-L3 short segment stabilization with intermediate screw fixation | Day 1 | 11 | ASIA grade B | ASIA grade E | Walks without support, able to bend, able to climb stairs |
| 4 | L2 chance fracture with complete paraplegia, transverse process fracture L1, L2, L3, L4, L5 | B1 | T12-L3 instrumentation, stabilization, laminectomy, and wide decompression | Day 2 | 45 | ASIA grade A | ASIA grade D | Walks with support, bowel/bladder intact, able to climb up, difficulty climbing down |
| 5 | L3 burst fracture with paraparesis, fractures of left lamina and body of C7, left transverse process of L2 and L3 and spinous process and bilateral transverse process of T11 (Figure 4) | A4 | L2-L4 stabilization and decompression | Day 2 | 31 | ASIA grade C | ASIA grade D | Walks with support, not able to climb stairs, not able to do job |
| 6 | L3 chance fracture with burn injury over the back, L1-L4 spinous process fracture | B1 | L2-L4 stabilization and decompression | Day 3 | 75 | ASIA grade E | ASIA grade E | Mobilization out of bed starting with walker, functionally dependent |
| 7 | T3 chance fracture | B1 | Advised to have surgery but refused, managed conservatively | - | 4 | ASIA grade E | ASIA grade E | Able to do all activities, mild back pain on prolonged activities |
| 8 | Fracture T3 vertebral body, fracture spinous process of T1, T2 | A3 | Conservative | - | 6 | ASIA grade E | ASIA grade E | Able to do all activities, back pain during prolonged standing |
| 9 | Compression fracture T3, T4, T5, T6, and T7, spinous process fracture C7, T1, T2, T5, and T6 (Figure 5) | B1 | Conservative | - | 6 | ASIA grade E | ASIA grade E | Mild back pain while lifting weight |
| 10 | T12 superior endplate impacted compression fracture | A1 | Conservative | - | 8 | ASIA grade E | ASIA grade E | Able to do all activities, returned to work |
| 11 | Fracture right transverse process of L5 | A1 | Conservative | - | 5 | ASIA grade E | ASIA grade E | Able to do all activities, returned to work |
| 12 | Contusion cervical spine, traumatic upper trunk brachial plexopathy (C5, C6) | - | Conservative physiotherapy | - | 18 | Left shoulder abduction grade 0/5, grip strength weak | Good motor recovery | On physiotherapy, difficulty in lifting object with left upper limb |
| 13 | L5 vertebrae body burst fracture | A3 | Conservative | - | 21 | ASIA grade E | ASIA grade E | Started walking with support, not able to do job |

Abbreviation: ASIA, American Spinal Injury Association.

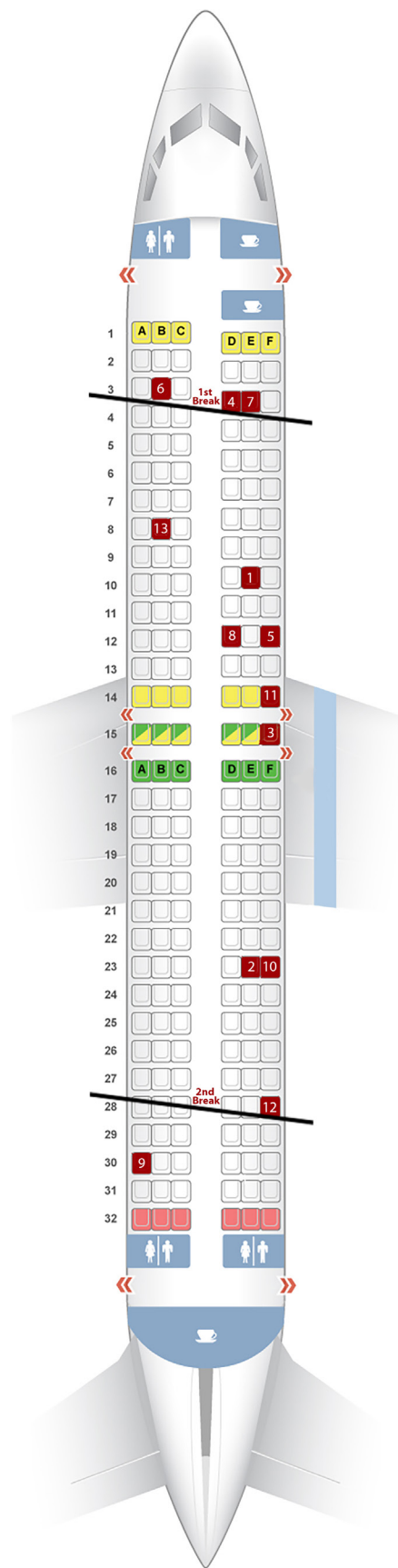


Figure 2. Seat layout of the flight showing the sections of the aircraft (marked in black lines as first and second break) and seat numbers of passengers who sustained spinal injuries (marked in red, patient ID as given in Table 1).

were managed conservatively. Surgical management was planned in 7 patients, and priority was given to patients based on their neurological status. As the patients had international travel, as per guidelines, all surgeries were planned in COVID-19–designated ORs, irrespective of their COVID-19 status. Performing these surgeries in a negative pressure operating room and wearing multiple layers of clothing (full PPE, lead aprons, and surgical gowns) and face shields was draining, and it was highly stressful to all of the staff involved. Multiple orthopedic and spine surgeries were planned in the operating room over the next 3 days, and a total of 6 patients underwent spine surgery during that time. One patient with a D3 chance fracture with a American Spinal Injury Association (ASIA) grade E impairment refused surgery and was discharged home. One patient tested positive for COVID-19, but he was asymptomatic.

Only 2 patients sustained multilevel noncontiguous injuries in our cohort, including one patient with a sacral injury and upper thoracic injury and a second patient with a lumbar fracture associated with a lower cervical injury. Patients were classified on the basis of the AO spine classification system⁴ into 5 type A injuries, 6 type B injuries, and 1 type C injury.

All patients were managed conservatively, and 5 of the 6 were functionally independent at the latest follow-up and showed significant neurological improvement (Table 3). No complications such as secondary infections, worsening of neurological deficits, or implant failures were recorded in any of the 13 patients. A 50-year-old man with an L2 chance fracture with complete paraplegia (ASIA grade A) showed significant recovery to ASIA grade D status and is functioning independently. A 31-year-old man with a D3 chance fracture who refused surgery was also doing well on follow-up and was functioning independently but had upper back pain while walking.

The patient who had the longest hospital stay (75 days) was a 36-year-old man with multiple injuries (facial injuries, open fractures of the lower limbs and humerus, talar bone loss) and burn injuries over the back at the site of the lumbar burst fracture (L3 level). This patient had to undergo multiple operations and revision spinal debridement surgeries before plastic surgeons could intervene and provide a flap cover. At the 9-month follow-up, the patient had normal neurological status with implants in situ and started non-weight-bearing mobilization.



Figure 3. A 26-year-old woman sustained an uncommon injury (patient ID No. 2) and presented with American Spinal Injury Association (ASIA) grade B injury including bowel and bladder deficits. Computed tomography image/magnetic resonance imaging showed “H”-shaped fracture of the sacrum with sacropelvic dissociation. She underwent spinopelvic fixation with decompression of S2 foramina. She started weight-bearing mobilization at as early as 4 weeks and recovered completely to ASIA grade E, including full recovery of bowel and bladder control.

DISCUSSION

Fortunately, aircraft accidents are rare worldwide when compared with high-velocity road traffic accidents and trauma caused by falling. Baker et al⁵ showed that aviation-related injuries result in approximately 1000 hospitalizations each year in the United States, with an in-hospital mortality rate of 2%. Spinal injury incidence, mechanisms, and management are well described in the literature regarding the common modes of injury,⁶ but the evidence is limited with respect to spinal injuries secondary to aircraft accidents. The literature suggests predominant lower limb injuries in these patients.^{5,7} Older literature^{8–10} regarding aircraft accident management may suggest a higher rate of incidence

of missed fractures due to the lack of availability of modern imaging, like CT images and MRI. There also is a discrepancy in the incidence of spinal injuries, as diagnosing spinal injuries in fatal accidents^{11–14} is often excluded. There have been many scenarios where air crashes have led to high mortality rates, and the incidence of spinal injuries therefore cannot be analyzed.

Although MRI was available at the center, a CT image was considered the investigation of choice to save time, establish a diagnosis, and prioritize the patients who needed surgery first. Also, following COVID-19 guidelines for sanitation was more difficult to manage with MRI than with the CT image. When there was sufficient time available during the waiting period for surgery, an

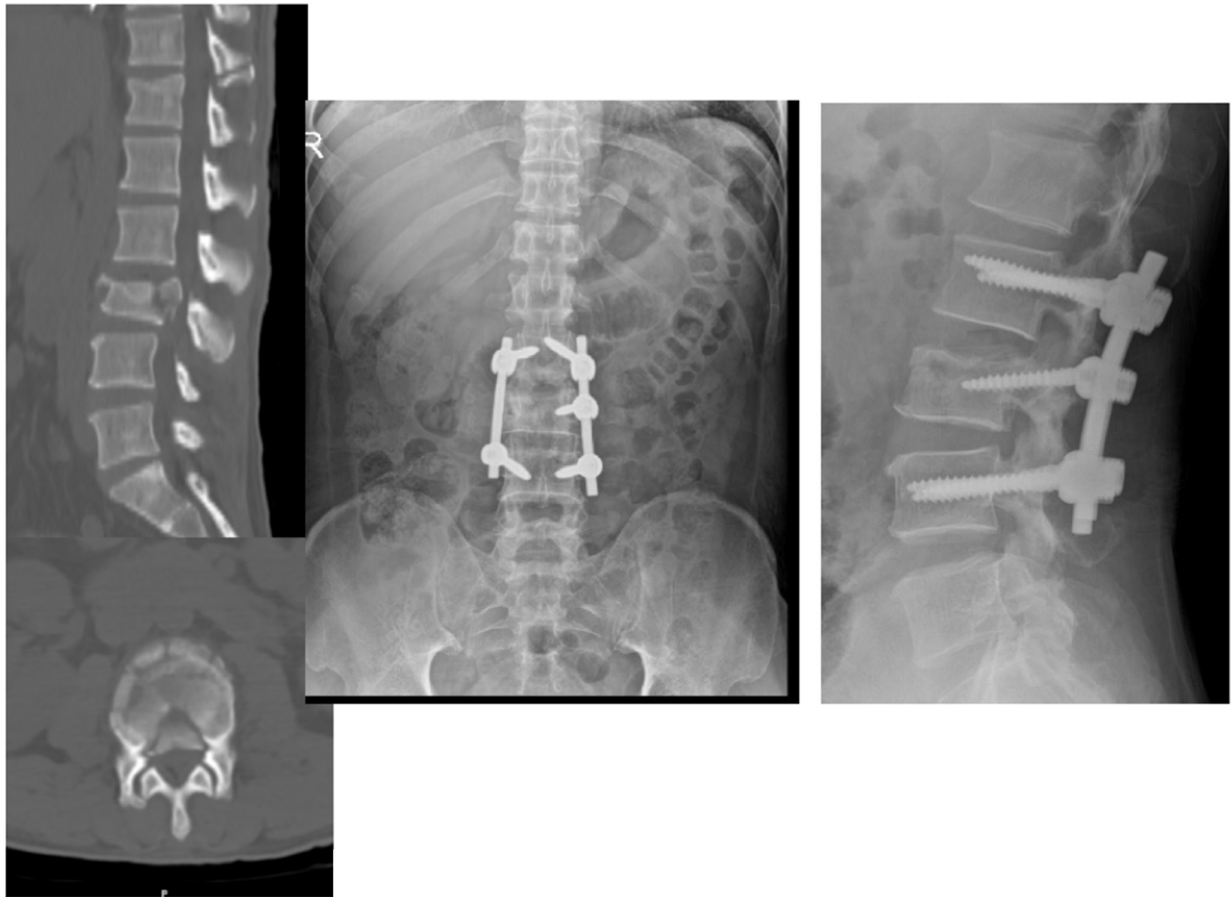


Figure 4. Case illustration of surgically managed patient (patient ID No. 5): 52-year-old man with L3 burst fracture, American Spinal Injury Association grade C injury. Short segment fixation with intermediate screw was performed with decompression.

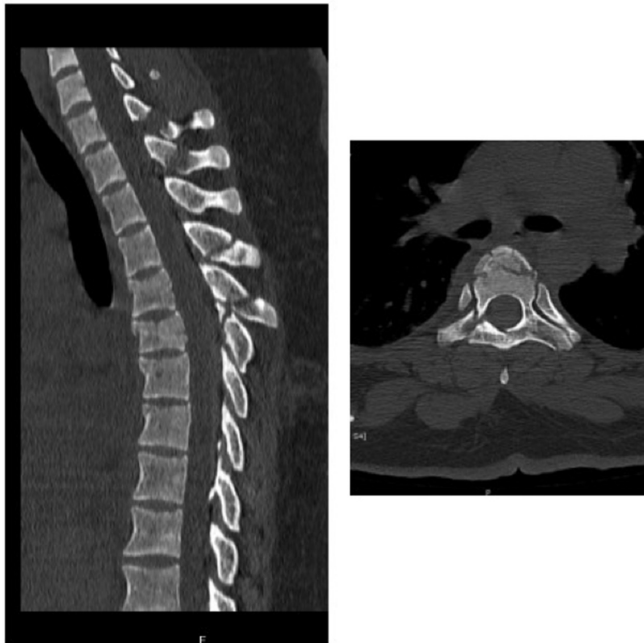


Figure 5. Case illustration of conservatively managed patient (patient ID No. 9 in Table 1): 24-year-old woman with multilevel dorsal level compression fractures with injuries of spinous processes, American Spinal Injury Association grade E.

MRI was also performed. Lack of utilization of MRI due to timing, resources, and sanitization protocol may be responsible for the underestimation of posterior osteoligamentous tension band injuries and the discrepancy in classification for some patients.

Analysis of the 2011 Iran Air Boeing 727 crash by Mirzatolooei et al¹⁵ showed 78 people were killed and 27 people survived out of 105 passengers. A total of 15 out of the 27 patients had fractures to their spine, predominantly at the thoracolumbar junction (7 burst fractures, 5 compression fractures, and 3 fracture dislocations). A relatively lower number of deaths in our case series is probably for 2 reasons. First, the brunt of the injuries were suffered by the pilots, as the nose of the flight hit the ground from the tabletop runway, which helped reduce the speed during deceleration. Also, there was no fire accident following the crash in this case, which saved lives of most of the passengers. This was unlike many other air crash incidents, including a strikingly similar air crash on a tabletop runway in Mangalore (India) in 2010, which had only 8 survivors and 158 deaths;

Table 3. Master chart of patients showing patient morphology, mode of injury, associated injuries, and COVID-19 status on admission to the hospital.

| No. | Age/Sex | Mode of Injury | Seat No. | COVID-19 Status on Admission | Seat Belt Status | Spinal Injury | Associated Injuries |
|-----|---------|--|----------|------------------------------|------------------|---|--|
| 1 | 23/F | Jammed under the seat | 9E | Negative | Yes | Burst fracture L3 with paraplegia | Type 3 Schatzker fracture right proximal tibia, comminuted pilon fracture with bone loss right, comminuted fracture lateral malleolus with bone loss, comminuted fracture calcaneum right side, comminuted intra-articular fracture left distal femur, comminuted intra-articular fracture distal humerus left and fracture |
| 2 | 24/F | Jammed under the seat | 23E | Negative | Yes | Zone 2 sacral fracture bilateral "H" type with spinopelvic dissociation, fracture spinous process of T1, T2, T3 | Right scapula fracture; fracture right second, third, and fourth ribs; fracture right clavicle; bilateral mild hemothorax (right > left) with underlying lung contusions |
| 3 | 34/M | Topped around the seat, hanging on seat belt | 15F | Negative | Yes | L2 chance fracture with paraparesis | |
| 4 | 51/M | Did not remember | 3D | Negative | Yes | L2 chance fracture with complete paraplegia, transverse process fracture L1, L2, L3, L4, L5 | Type 3B open comminuted distal tibia and fibula fracture right leg, lateral malleoli fracture left ankle, fracture neck of talus left ankle; comminuted fracture cuboid left foot; bilateral multiple rib fractures with hemopneumothorax; type 1 respiratory failure, right lower zone pneumonia, mild hemoperitoneum with splenic laceration |
| 5 | 52/M | Did not remember | 12F | Negative | Yes | L3 burst fracture with paraparesis, fractures of left lamina and body of C7, left transverse process of L2 and L3 and spinous process and bilateral transverse process of T11 | Comminuted fracture proximal humerus right, comminuted fracture midshaft clavicle right, comminuted fracture scapula right, trimalleolar fracture right ankle, head injury; left subarachnoid hemorrhage with intraventricular hemorrhage, minimal hemothorax |
| 6 | 36/M | Did not remember | 3B | Positive | Yes | L3 Chance fracture with burn injury over the back, L1-L4 spinous process fracture | Fracture right orbitozygomatic complex + right maxilla + facial lacerations, open fracture dislocation left ankle with talus bone loss left, right proximal tibia fracture, type 2 open fracture right elbow, type 2 open comminuted fracture right humerus shaft, soft tissue defect over the right lumbosacral region, left ankle and right lower aspect of leg, multiple bilateral rib fractures with bilateral hemopneumothorax on intercostal drainage in situ, fracture right distal humerus |
| 7 | 31/M | Sudden forward bending | 3E | Negative | Yes | T3 chance fracture, unstable spine injury | |
| 8 | 64/M | Thrown out with the seat | 12D | Negative | Yes | Fracture T3 vertebral body, fracture spinous process of T1, T2 | Minimal right pneumothorax, morel-lavallee lesion right thigh, anterior cruciate ligament and medial meniscus partial tear, supraspinatus tendinitis |
| 9 | 24/F | Thrown out from the seat upward | 30A | Negative | No | Compression fracture T3, T4, T5, T6, and T7; spinous process fracture C7, T1, T2, T5, and T6 | |
| 10 | 29/M | Sudden forward bending | 23F | Negative | Yes | T12 superior endplate impacted compression fracture | |
| 11 | 29M | Sudden forward bending | 14F | Negative | Yes | Fracture right transverse process of L5 | |
| 12 | 29/F | Did not remember | 28E | Negative | Yes | Contusion cervical spine, traumatic upper trunk brachial plexopathy (C5, C6) | Contusion maxilla with subcutaneous hemorrhage right, partial tear anteriomedial bundle of anterior cruciate ligament on femoral attachment left, grade 3 chondral injury patella right, grade 3 chondral injury patella left |
| 13 | 28/M | Did not remember | 8B | Negative | Yes | L5 vertebral burst fracture, no deficits | Closed both bone forearm, comminuted fracture right, closed humerus distal shaft fracture left, closed olecranon undisplaced fracture left, closed shaft of femur fracture right, closed fracture dislocation talus left-Hawkins type 4, fracture medial malleolus left, P compartment release right forearm, fracture scapula left, multiple injuries right foot, bilateral lung contusions |

most of the bodies were charred beyond recognition).¹⁶ Lee et al¹⁷ reported only 3 cases of spine fracture caused by a commercial airplane accident in 2013, with 307 passengers aboard. Each of the 3 patients suffered a compression fracture at the midthoracic and thoracolumbar junction.

As observed in our patients, the majority of the severe spinal injuries presented with varying degrees of neurological deficits. Whether the injuries were primary in nature at the time of incident or secondary as the patients were pulled out of the jammed seats and shifted to hospital in available vehicles other than ambulances without spine board is something to ponder upon. Analyzing the severity of injury with the seating position, it was found that majority of patients with severe injuries were seated in the front third of

the plane. Though conclusions cannot be made with this evidence, suggestions to improve the energy absorbing capacity of the seats in the front half of the plane could help in preventing severe injuries in future air crash events. Attempts by flight engineers to design better seat belts, similar to the crew seat supports with 4-point contact rather than the present 2-point contact seat belts would be helpful in prevention of flexion distraction injuries. Trials to lower the gravitational force in vertical deceleration phase of accident could be game changing in the future.

As described earlier, this study distinguishes itself due to the timing of the air crash, which was during the peak of the COVID-19 pandemic in India. COVID-19, just by itself, warrants consideration as a "mass casualty" incident.¹⁸ Disaster management

during a pandemic is not a simple task, and following the principles of the “disaster cycle” is important. Mitigation of an air crash is not possible, but adequate preparedness in terms of preventing a shortage of manpower and equipment (eg, PPE) and infrastructure organization take precedence. Disaster planning takes exercise, practice, and revision.¹⁹ Like in most institutions across the world, the pandemic was not anticipated to this extent, and proper planning to escalate the demand of manpower and PPE was necessary at the time of the air crash, which was excellently done.

As far as an air crash disaster management plan is concerned, a mock disaster drill was performed at the same site (Calicut International Airport) in 2012. Medical personnel from our institution, with the specified role of disaster management team, were involved in performing the mock exercise. The mock drill definitely helped those who were present in the emergency department on the day of the air crash to triage and manage effectively. None of the staff members involved in managing air crash patients from the emergency ward, and none of the surgeons and staff members involved in their surgeries, became positive for COVID-19. These outcomes speak for themselves about how following standard guidelines is in everyone's best interest.

CONCLUSION

Early prioritized surgical management in selected patients provides excellent outcomes in spinal injuries caused by air crashes. Disaster management during a pandemic situation is a difficult task, and proper planning and execution are necessary to provide optimal results. This study emphasizes the need for mock disaster management drills for better planning and preparation for such untoward events. Analysis of the results may help to enhance air travel safety if measures are taken to prevent such injuries in future incidents.

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