

## Ejection in unusual Aircraft Attitude: A Case Report

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### Abstract

A Flight Cadet on a sector solo sortie ejected in an unusual aircraft attitude from Kiran Mk I (HJT-16) and sustained grievous spinal injuries. The decision to eject came after failed attempt to recover the aircraft in an inadvertent stall. Kiran Mk I is a trainer aircraft fitted with Martin Baker H4HA (Mk IV) seat. These seats impart much higher ejection forces to the occupant vis-à-vis the present generation ejection seats. Various phases of ejection sequence are associated with peculiar injuries, most concerning being the vertebral fractures. A through canopy ejection from an aircraft in an unusual attitude poses additional risks for spinal and other injuries. The effects of low level, unusual attitude, through canopy ejection, type of seat and aircrew mass, on injuries sustained by the pilot are discussed. The importance of training flight cadets in form of periodic and didactic presentations about ejection seat, harness, ejection posture and timely decision to eject are also discussed.

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### Introduction

In an aircraft, an ejection seat is a system designed to rescue the pilot or other crew of an aircraft in an emergency. In most designs, the seat is propelled out of the aircraft by an explosive charge or rocket motor, carrying the pilot with it. Once clear of the aircraft, the ejection seat deploys a parachute. The purpose of an ejection seat is pilot survival. The pilot typically experiences an acceleration of about 12–14G in the present generation seats. The earlier or older versions of seat relatively gave a much higher initial acceleration and 'jolt'. As a result of which compression fractures of vertebrae were a common and recurrent side effect of ejection, and were often a career-ending, if not fatal, injury for military aviators. Though most of the limitations are defined with ejection in wings-level or normal attitude of aircraft, unusual aircraft attitude ejection remains to be a cause of higher incidence of spinal and associated ejection injuries.

### Case Report

A 21 Yrs old Flight Cadet flying port seat ejected from Jet Trainer Aircraft during a sector

solo sortie. The ejection was initiated after initial attempts by the cadet to recover the aircraft from what apparently was an inadvertent stall. Having washed out speed the cadet decided to eject after failed attempts to recover. The aircraft was in a steep nose down attitude at low level. The cadet pulled the main firing handle (face-blind) and ejected through canopy. The parachute was fully deployed and pilot landed on ground feet first after and uneventful descent at normal rate. Having landed the cadet remained still as per his teaching and awaited SAR. At military hospital, the pilot was diagnosed to have Traumatic Paraplegia with other injuries.

### Discussion

#### *The Martin Baker Mk IV Ejection Seat*

The ejection seat in the aircraft was Martin Baker H4HA (Mark IV) designed in mid-1940's. Mk. 4 seat has a basic 80 feet per second ejection gun (proved to be sufficient for all requirements in those times). This ejection speed of 80 feet per

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second is considerably higher than the present generation ejection seat speeds which have been restricted to 60-65 feet per second. The higher ejection speeds impart higher G loads to the spine and in case of former it is about 25G for 100ms with a jolt of approximately 300G/s. This ejection speed in itself has been implicated as a cause for high incidence of spinal injuries and vertebral fractures in the ejected pilots over the years.

### ***Injuries Sustained***

The pilot sustained compression fracture DV12 with listhesis of LV1 and complete transection of spinal cord at the level of DV12-LV1. The other injuries included fracture lower 1/3<sup>rd</sup> of sternum, abrasions on chin and right shoulder and upper arm and contusion right elbow.

### ***Ejection Sequence***

The use of ejection seats to allow aircrew to escape from aircraft is generally lifesaving. However, their use exposes aircrew to forces that may be at the limits of human tolerance. The ejection sequence is extremely rapid. From initiation or firing of handle to full deployment of parachute after having cleared the aircraft structures, it is approximately 2.5 seconds. This sequence involves retraction of the harness and the feet followed by upward movement after canopy is jettisoned (or through canopy as in this case), deployment of drogue chute, seat stabilization and deployment of main parachute.

### ***Spinal Injuries and ejection speeds – Historical Perspective***

The problem of vertebral compression fractures was first observed on the early German ejection seats (1). Prototype versions of these seats produced peak accelerations of 12G and rates of rise (jolt) of 1100 G/s. The early ejection seats had ejection gun velocities of 53 ft/s and 60 ft/s, but in

later seats the gun velocity was increased to 80 ft/s. An 80 ft/s-1 velocity ejection gun enabled aircrew to eject safely at zero altitude, as sufficient height was gained to allow main parachute canopy deployment. Furthermore, the increase in gun velocity permitted the aircrew to eject at a high air speed so that clearance of the tail fin was achieved. Analysis of Royal Air Force (RAF) and Royal Netherlands Air Force (RANAF) ejections had showed there was an increase in vertebral fracture rates from 10% to 35% associated with the increase in the acceleration of the 80 ft/s-1 ejection gun (2). During the 1960s, considerable technical development of the ejection seat took place, which was driven by the dual need to automate the ejection sequence and to increase the safe ejection envelope. This led to the introduction of the rocket assisted ejection seat, which permitted the down rating of the ejection gun from 80 ft/s to 64 ft/s. Down rating the ejection gun to 64 ft/s reduced the acceleration acting on the spine and thereby reduced the spinal fracture rate.

### ***Injuries in various stages of ejection***

Injuries during ejection may occur at any stage and are generally peculiar to the stages. The typical injuries are listed in table 1.

Injuries during ejection through canopy and unusual aircraft attitude

In this case the ejection occurred through the canopy. Ejection through canopy gives rise to various hazards like (4):

- (a) Modification of the acceleration profile for the seat and of the seat occupant causes greater accelerations at the level of the seat and of the body segments represented by the pelvis thorax and head. This produces greater compression of the vertebrae.
- (b) Impact between the canopy and the head, shoulders and knees.

**Table- 1 Injuries in various stages of ejection (Lewis 2002))**

	<b>Stage of Ejection</b>	<b>Type of Injury</b>
1	Ejection Path	Burns from MDC, rocket motor flash, drogue gun.
2	Through Canopy	Perspex injuries, Canopy (Mid-rib), Injuries to cervical spine, shoulder injuries, flailing limb injuries
3	Ejection Gun Firing	Spinal compression fractures, femoral fractures
4	Windblast	Wind blast flail injuries
5	Drogue parachute deployment	Spinal injury from drogue parachute opening shock
6	Main parachute canopy deployment	Spinal injuries from main parachute opening shock loads. Head and cervical spine injuries from helmet and parachute riser interaction
7	Landing injuries	Lower limb fractures, spinal injuries

(c) Tearing of the protective clothing, damage to survival equipment and laceration to underlying tissue may be produced by fragments of transparency which have pierced various layers of clothing

At the beginning, the seat accelerates with moderately high speed which is arrested by the contact of canopy breakers with the canopy thus, causing momentary retardation of the man-seat combination. Whilst the seat retards, the occupants continues to move in upward direction, literally independent of the seat. The seat gains the speed the moment canopy gives way. Finally the seat catches up with the occupant producing a secondary acceleration of the occupant and a deceleration of the seat. Thereafter, the acceleration profile of the seat and the occupant follow almost parallel paths (3). This secondary contact of occupant's pelvis with seat pan increases the forces acting on the spine and result in more severe injuries. Lewis in his paper has stated that sternum fractures may occur from forcible contact of the chest, either by the chin as the forward flexed head comes in to contact with the transparency, or when the chest is struck by a piece of detached canopy. Whereas, a possibility of sternal fracture due to force vectors

causing the sternum to be the fulcrum in case of ejection cannot be negated. Langdon (1974) studied the fragmentation characteristics of the transparency materials and found that the physical characteristics of stretched acrylic alter with temperature. In response to an increase in temperature, stretched acrylic becomes more malleable and resists penetration as it stretches and balloons over the emerging seat (5). At higher temperature of the canopy, there is higher resistance to penetration hence resulting in higher acceleration injuries.

The position of the pilot during ejection is a critical factor in causing spinal fractures (3). An inappropriate posture assumed by the pilot or inevitable due to aircraft attitude may lead to relative weakness in the vertebral column and can give rise to injury when the acceleration would otherwise be tolerable. The factors that modify the position of the pilot are numerous. The attitude of the aircraft at the time of the ejection is important as it alters the relationship between the seat and the pilot. In a nose-down ejection, the pelvis may separate from the seat even if the harness is adequately tightened. Similarly, in ejections from a steeply banked aircraft there is lateral flexion. A

very slack harness gives greater freedom of movement of the trunk, which bends considerably during ejection. It is presumed that in the earlier ejection seats fitted with a face blind, forward flexion of the trunk was limited by retention of the head behind the face blind. Since the major component of the ejection acceleration is in the long axis of the spine, in nose-down or a steep bank, significant flexion forces may be present and further aggravate the flexion as the line of seat thrust does not coincide with the long axis of the spine. The included angle is the angle between the axis of the spine and the line of thrust and large values favour the development of fractures of the vertebral column by hyperflexion. Even when sitting in the correct ejection posture the geometry of the seat structure prevents the spine from aligning with the axis of thrust and when the included angle is large, as is expected in a steep nose down attitude, it will have the same effect as exaggerated flexion of the trunk.

### **Conclusion**

Ejection mechanism in an aircraft is lifesaving, at the same time dangerous and can cause grievous injuries, spine being feared the most. Ejection seats have saved thousands of lives. Despite remarkable

developments over the past six decades many countries continue to use older versions of ejection systems. The present generation seats have reduced chances of spinal injuries by reducing the incident acceleration to the occupant. The single most important factor in determining the extent of injuries to the spinal column remains the posture of the occupant in relation to the seat

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