

Spinal injury in multiple ejections

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ABSTRACT

Compression fracture of spine, especially in the thoraco-lumbar region, is the commonest significant injury sustained following an ejection. The disposal of the post ejection cases in Indian Air Force (IAF) is done taking into consideration the symptoms of the pilot, neurological deficits if any, range of axial movements, stability of the fracture and the MRI findings. Cases of fully healed stable compression fractures are given full flying category. However, there is always a doubt whether damaged area is unduly susceptible to repeat fracture during subsequent ejection. The present study was undertaken to analyze the cases of pilots who have ejected more than once to determine whether there is an increased probability of sustaining spinal fractures after an ejection in which there may or may not have been spinal fracture. Digital data base available at Air Headquarters, RK Puram was scrutinized to determine the cases of pilots who had ejected more than once. There have been 22 cases of multiple ejections in IAF from 1973 till date. Out of these, 20 pilots had ejected twice whereas two pilots had ejected three times. Only three pilots out of 22 sustained spinal fracture in both the ejections. Both the pilots who undertook third ejection sustained spinal fracture during the third ejection; one of them did not have any injury during the first two ejections. Although the sample size is small, this study reveals that an ejection does not expose an individual to an increased incidence of spinal injuries during successive ejections.

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Ejection seat is the most commonly used escape equipment for emergency in-flight abandonment in military fighter aircraft. Ejection once initiated produces forces between 12 to 20 G, for up to 500 ms with an onset rate up to 300 G/s, which act primarily in the long axis of the spine causing the seat to move upwards.

A load of 18-20 G applied vertically to the spine is tolerated when the trunk is supported in hyperextension, but as the body flexes, this tolerance is reduced to 3-10 G. Forces in excess of this tolerance limit can lead to anterior lip wedge fractures and in some cases, burst fractures [1]. Many factors, like the total weight of the occupant-seat assembly, the attitude of the pilot's body in relation to the seat, relative airspeed at the time of ejection and the altitude of ejection, determine the actual value of the force that an ejection seat will produce and in turn the nature and severity of injury to the spine.

The region of the vertebral column most susceptible to injury following ejection is the thoracolumbar junction between T10 and L2 vertebrae. Kraus [2] has reported that 64.2% of those with bony injuries sustained fractures of

the thoracolumbar junction. The thoraco-lumbar junction is predisposed to rotational and compression injury as it is situated between the rigid thoracic spine and mobile lumbar spine. During axial loading, the thoracic spine is protected by the rib cage and the lumbar spine by inwardly directed facet joints, which take up to 33% of the axial load and 45% of shear and torsional forces thereby minimizing injury [3]. Injuries at other levels are usually related to forward flexion as a result of improper posture during egress and are less common.

Studies carried out by the United States

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Air Force (USAF) report compression fractures as the leading type of injury sustained in 468 ejections [4]. Compression fractures are due to axial loading of the spine and generally involve the anterior part of the vertebral body. Since they involve mainly the anterior column, they are usually stable.

The disposal of the post ejection cases in Indian Air Force (IAF) is done taking into consideration the symptoms of the pilot, neurological deficits if any, range of axial movements, stability of the fracture and the MRI findings. The standards followed by the USAF [5] in evaluation of post ejection spinal injuries are also based on the above guidelines with maximum stress being laid on stability of the fracture. Return to flying varies from 3 months to 2 years, depending on the stability of the fractures. Cases of fully healed stable compression fractures, are given full flying category as there is no evidence to suggest that the damaged area is unduly susceptible to repeat fracture.

Asymptomatic pilots without any evidence of spinal fracture on MRI are re-flighted on fighter aircraft after six weeks. Cases of multiple vertebral fractures of thoraco lumbar region, even when fully recovered, should be decided with caution for fighter flying, since such extensive damage is likely to be accompanied with some undiagnosable injury to the para-vertebral structures. Likelihood of development of some abnormalities of the spinal curvature is also greater in these cases. Excessive dynamic overloads during the subsequent ejection may worsen the damage.

The present study was undertaken to analyze the cases of pilots who have ejected more than once to determine whether there is increased probability of sustaining spinal fractures after an ejection in which there may or may not have been **spinal** fracture.

Material and Methods

Digital data base available at Air HQ, RK Puram, New Delhi were scrutinized to determine the cases of pilots who had ejected more than once. Medical documents of these pilots as well as available Courts of Inquiry were perused to determine the occurrence of fracture and associated injuries during the ejection, medical disposal of these pilots and type of aircraft from which ejected.

Results

There have been 22 cases of multiple ejections in IAF from 1973 to 2004. Out of these, 20 pilots had ejected twice whereas two pilots had ejected three times. Average interval between two ejections was 64.3 months (range 7 to 136 months). Thirteen pilots out of 22 ejected from the same aircraft type both times.

Spinal injury occurred in 13 out of the 24 ejectionees including third ejection in two cases. Six pilots sustained compression fracture spine in their first ejection. One pilot each sustained fracture of spinous process C6, transverse process L3 and L4 and extremities fracture. During the second ejection, five aircrew sustained compression fracture of the spine and one sustained fracture coccyx. Both the pilots who had three ejections sustained spinal fracture during the third ejection; one of these had not got any injury during the first two ejections.

A total of 18 vertebrae were involved in the fractures due to involvement of more than one vertebra in 5 cases. T7, 8 and 12 were involved in four cases each; T5 in three and T6, T9 and L1 in one case each. 18 pilots were given full flying medical category including fitness for ejection seat aircraft whereas four cases were awarded restricted flying category after the second ejection. Two pilots were made permanently unfit for ejection seat aircraft

following third ejection.

Only three pilots sustained spinal fracture in both the ejections. One pilot sustained fracture T7 in first ejection and fracture T8 in the second ejection. Second pilot sustained fracture T8 and T9 in first ejection and T5 in the second ejection. Third pilot sustained fracture in all three ejections; fracture T5 and T8 in first ejection, T12 in the second ejection and third ejection revealed multiple spinal fractures (T4, T8, T9 and T12 (old) with degenerative disc disease (C3-4 and C5-6). This pilot was made unfit for ejection seat aircraft since the spine had degenerative changes because of the multiple compression fractures and it was opined that any more ejection might exceed the tolerance of the spine.

Discussion

Spinal fractures continue to be the commonest major injury sustained following an ejection despite the significant technological improvements in the ejection seat design. Disabilities of the spine that permanently distort the spinal curvatures may increase the predisposition to spinal fractures following an ejection [6]. The normal spinal curvature helps in attenuating ejection forces. Any distortion of these curves will transmit the ejection forces unattenuated, thus accentuating the forces and exposing the vertebrae to increasing chances of damage.

The disposal of the post ejection cases in IAF is done taking into consideration the symptoms of the pilot, neurological deficits if any, range of axial movements, stability of the fracture and the MRI findings. Asymptomatic pilots without any evidence of spinal fracture on MRI are returned to flying on fighter aircraft after six weeks [7]. Stability of spinal fractures is being determined based on Denis' 3-column concept. One or two column involvement

(except involving middle column-posterior one third of vertebral body with annulus fibroses and Posterior Longitudinal Ligament) are stable fractures and are the most common following an ejection, in a simple wedge compression fracture, the anterior depth, as observed after healing, may get permanently reduced by one quarter or one third of the undisturbed posterior vertical depth. In such cases, the intervertebral discs and annulus are generally undamaged.

Such cases of single vertebral fracture are normally treated on conservative lines and recover completely in about 3-6 months. If there is clinical and radiological recovery, the pilot is able to withstand simulated aviation stresses and there is no functional deficit on human engineering evaluation, these cases are put back to fighter flying at the end of six months of observation.

Unstable fracture i.e., spinal fracture involving middle column, burst fracture and fracture dislocation are serious, as they may involve disorganization of vertebral body to the extent that its anterior height could get reduced by more than one third. Interspinous ligaments are often ruptured or avulsed and the intervertebral discs between the two vertebrae are invariably ruptured or destroyed. Such cases are awarded non-flying category for longer periods and usually made unfit for ejection seat aircraft as the site remains unstable with developing evidence of kyphosis or even scoliosis. Similarly, cases of tears of anterior and posterior longitudinal ligament and traumatic Schmorl's nodes are unfit to fly ejection seat aircraft. Tear of Anterior Longitudinal ligament lead to anterior disc hernia ion stimulating peripheral osteophytes leading to spinal instability. PLL tear leads to posterior - posterolateral disc hernia ion causing neurological symptoms. Traumatic

Schmorl's nodes may lead to persistent backache
3rd spinal instability.

Smelsey reviewed and analyzed 116: Individuals who made two or more emergency non-combat ejections from USAF aircraft [8]. It was seen that overall success rate was better on the second ejection. It was also seen that injury on the first ejection led to a higher success rate on subsequent ejections. Thirty-five individuals in this category had a success rate on the second ejection of 97.1%. 81 individuals who did not receive an injury had a subsequent success rate of 83.3%. It has concluded that vertebral fracture on the first ejection did not predispose an ejectee to additive injury on a subsequent ejection.

Studies conducted in IAF during various periods have analyzed the cases of two or more ejections. Between 1960 and 1980, 14 aircrew out of 209 ejections had multiple ejections and only three had spinal fracture during the first as well as second ejection. A pilot ejected three times, sustained spinal injuries only during first ejection while subsequent two ejections on the same aircraft type were uneventful. Another pilot developed lumbago after second ejection. He also had cervical spondylosis but there were no vertebral fractures [9]. 5 pilots ejected more than once between 1980 and 1987 and two pilots each sustained fracture during the first as well as second ejections [10]. However, between 1987 and 1993, 3 pilots who had ejected once earlier did not have any spinal injuries in either of the ejections [11]. Out of 71 ejections between 1993-98, 8 aircrew ejected twice [12], 5 of them sustained spinal injuries on both occasions and 3 aircrew escaped spinal injuries on both occasions.

The USAF has records of six pilots with stable compression fractures who ejected a second time without suffering injury, one aviator ejected four times without subsequent injury [13]. In the present study, 3 pilots out of 22 had compression fracture spine in first ejection but no injury during second ejection. The previous experience of ejection may have influenced the actions of some and probably resulted in saving their lives. Delaying the decision to eject has always been one of the important causes of preventable fatalities. Previous ejection probably sensitizes

the pilot to initiate timely ejection as well as the importance of assuming correct posture prior to ejection in the event of a subsequent ejection. There is no evidence to suggest that the cases of fully healed stable compression fractures are unduly susceptible to repeat fracture.

Conclusion

Spinal column with normally developed curves, when put in proper posture prior to ejection, can withstand the ejection forces reasonably well. Despite all the care taken in the design of the seat and ballistics for its function, vertebral fractures in varying percentages with different ejection systems do occur. Proper spinal posture, whereby the thrust is borne uniformly and in a balanced manner, is by far the single major variable, which if controlled can reduce the injury to the spinal columns to a negligible figure. Although the total number is small in this study it clearly highlights that multiple ejections do not expose an individual to an increased incidence of spinal injuries during successive ejections.

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