Spinal injuries in ejection from aircraft – Indian experience

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This study presents a detailed follow-up of spinal injuries cases encountered during ejections in the Indian Air Force from april 1987 to March 1993. During this period there were 65 cases of successful ejections. Analysis shows that out of the 17 cases of spinal injuries (injury rate 26.2%) involving 29 vertebral fractures. The fractures were further as per aircraft and anatomical location. Compression fractures were the most common. Of the successful ejectees, 7 underwent multiple ejections without sustaining any injuries. There was a preponderance of injuries at D11 and D12. Analysis of weight of 141 ejectees covering the period from 1974 to 1993 showed preponderance of weight range of 61–65 kg among the spinal injury cases (n = 41).

Keywords: Ejectees; Compression fracture; Vertebral injury.

The Indian Air Force (IAF) operates aircrafts fitted with different types of ejection seats. Ejections result in spinal injuries in quite a few cases. It is essential to analyse spinal injuries periodically. Two such analyses were carried out covering period of 1960 to May 1980 [1] (spinal injury rate 35.2%) and June 1980 to March 1987 [2] (spinal injury rate 27.5%). Both the studies reported vertebral compression fracture most frequently in the region of thoracolumbar spine. This paper is an update covering ejections during the period from April 1987 to March 1993. We have included some additional parameters for analysis of spinal injuries in this study.

Material and methods

Particulars of each pilot, his age and experience, details of the aircraft and the emergency leading to ejection were obtained from the approved proforma IAFF(MS) 1956. All proforma pertaining to the period from April 1987 to March 1993 were analysed. During collection of the daata, special attention was paid to spinal injuries. The details regarding the progress of the cases of spinal injuries were gathered from the case file records at the Department of Human Engineering in IAM..

Results

Incidence and injury analysis. A total of 384 ejections have taken place in IAF since 1960 [1, 2] and 352 of them were successful. The present study for the period from April 1987 to March 1993 includes a total of 73 ejections, of which 65 were successful. Out of these 65 successful ejections, 17 cases were of spinal injuries. In the present study the injury rate is only 26.2% (Table 1).

Table 2 shows that a higher incidence of ejections occurred from Mig series aircraft. A total of 29 vertebral fractures were sustained by17 pilots. Out of the 17 pilots ejected, 7 had sustained multiple vertebral fractures (Table 3). Yearwise distribution of the successful ejections and the area of spinal injuries is given in Table 4. It is seen that all the cases of vertebral fractures were in the thoracolumbar region and none were sustained in the cervical region. The vertebrae that were most commonly affected were D11 and D12. Of the spinal injuries, 85.5% were in the thoracic region, of which 42.6% were in the lower thoracic area. Only 5 out of the 29 sites involved were in the lumbar region.

Table 5 shows that 90.7% of the pilots ejected were below the age of 40 years. It is also interesting to note that 16 out of the 17 ejectees with spinal injuries were below this age.

Table 1. Salient details of ejections in different periods in IAF (1960–1993)

Period	Total	Fatal No. (%)	Successful No. (%)	Spinal injuries among successful ejectees (%)
1960–80	209	13 (6.2)	196 (93.8)	69 (35.2)
1980–87	102	11 (10.8)	91 (89.2)	25 (27.5)
1987–93	73	8 (10.9)	65 (89.1)	17 (26.2)
Total	384	32 (8.3)	352 (91.6)	111 (28.8)

Table 2. Distribution of successful ejections by aircraft type and year

Aircraft	Yearwise distribution							Total
	1987	1988	1989	1990	1991	1992	1993	
MIG series	9	4	10	3	10	6	3	45
Hunter	0	2	1	1	1	0	0	5
Ajeet	1	3	–	–	–	–	–	4
Jaguar	0	0	0	0	3	0	0	3
Iskara	0	0	0	0	0	1	0	1
Kiran	0	0	0	2	3	2	0	7
Total	10	9	11	6	17	9	3	65

Table 3. Spinal fractures vs aircraft types

Type of aircraft	No. of cases
MIG 21 T-75	6
MIT 21 T-77	2
MIG 21 T-96	2
MIG 23	2
Kiran	3
Hunter	1
Iskra	1

Table 4. Yearwise distribution of ejections and area of spinal injuries

Year	Total no. of ejections	No. of ejectees with injuries	Area of spinal injuries
1987	10	4	L3, 4 D7 D10, 11, 12 D9
1988	9	1	D12
1989	11	1	D10, 11
1990	6	2	L2 D12
1991	17	3	D10, 11 D3, 4, 12 D7
1992	9	5	D12 D5, 6, 7, 12 D11 D8 L1
1993	3	1	D11, 12, L1

During the period under review, 3 pilots were involved in multiple ejections. All of them had ejected once each prior to the period under review. None of these 3 pilots ejected in this period sustained any spinal injury.

Details regarding the type of injury sustained, the associated complications and the sequelae suffered by the 17 ejectees are given in Table 6. Compression fracture was seen to be the most common injury sustained.

The weightwise distribution of ejections and spinal injuries involving all types of aircrafts in IAF since 20 years is given in Table 7. Data were available only from the year 1974. Most of the pilots who ejected were in the weight range of 61–65 kg and the percentage of injury sustained by the pilots in this weight range was also more.

In this series 7 pilots had sustained multiple spinal fractures. Table 8 brings out the causes

Table 5. Agewise distribution of successful ejection

Year of ejection	Age			
	<40 years		>40 years	
	Successful ejections	Spinal injuries	Successful ejections	Spinal injuries
1987	8	4	2	–
1988	9	1	–	
1989	11	1	–	–
1990	6	?	–	
1991	15	3	–	–
1992	7	4	2	1
1993	3	1	2	–
Total	59	16	6	1

Table 6. Types of injuries and complications

Types of injury	No. of cases
Compression fracture	11
Compression fracture with disc prolapse/ sciatica	–
Chipping of vertebral body	3
Fracture with paraplegia	1
Fracture with spondylitis/lumbago	1
Fracture spinous process	1

of ejection which could have contributed to the malposture resulting in multiple fractures.

Hospitalization. All the cases with spinal injuries needed hospitalization and 12 out of the 17 cases were hospitalized for less than 60 days. Four ejectees had associated fractures of either humerus or femur and had to be kept longer for open reduction. One pilot developed paraplegia with spinal fracture and had to be hospitalized for longer than 60 days. All these cases were treated symptomatically with bed rest, anti-inflammatory analgesics and later with spinal exercises. The pilot who developed paraplegia with spinal injury was treated with lumbar traction and adjuvant therapy. Surgical intervention was not needed for any of these cases. After hospitalization, all of them were sent on sick leave for a period of 4–8 weeks.

Period of noneffectiveness from flying. Nine pilots out of the 17 cases returned to full fighter flying category within 12 months after ejection. Pilots who had associated fractures took as long as 18 months to get back their flying category. The longest time taken was about 20 months by a pilot who had anterior compression fractures of D8, 9 and 10. Another case of more than two vertebral fractures took 12 months more to get back to his flying duties.

Permanent grounding. Three pilots out of the 17 cases were made permanently unfit for ejection seat aircraft and helicopter due to persistent backache. One of these 3 pilots had advanced spondylytic changes. He was declared permanently unfit to fly. The pilot who developed paraplegia after ejection had a slow recovery. He could barely walk with assistance and was boarded out of service after two years. Out of the 7 pilots who sustained multiple vertebral fractures, only one was made permanently unfit to fly.

Discussion

The rate of spinal injuries among successful ejectees in the recent past has reduced considerably from the first incidence. The aircraftwise distribution of successful ejections compared in our study shows that out of the 65 ejections during the period under review, 45 (69.2%) had taken place from MIG series aircraft and this is attributed to the fact that IAF has more MIG series aircrafts than any other types. Out of the 45 ejectees from MIG series, only 12 had

Table 7. Weightwise distribution of spinal injuries (for the period 1974–1993)

Weight (kg)	No. of successful ejections	No. of ejections with spinal injuries
45–50	1	Nil (0%)
51–55	31	6 (19.4%)
56–60	20	4 (20.0%)
61–65	42	17 (40.0%)
66–70	26	7 (26.9%)
>70	31	7 (22.6%)
Total	141	41 (29.7%)

Table 8. Multiple fractures with regard to aircraft type and cause of ejection (n = 7)

Vertebrae involved	Type of aircraft	Probable cause of ejection
L3, 4	MIG21 T-75	Aircraft out of control
D10, 11, 12	MIG21 I-96	Bird strike
D10, 11	MIG21 T-75	Engine flame out
D10, 11	Kiran MK-II	Engine flame out
D3, 4, 12	MIG21 T-75	Aircraft out of control
D5, 6, 7, 12	Hunter	Engine seized while doing stall manœuvre
D11, 12	MIG21 T-77	Pilot error disorientation in cloud

sustained spinal injuries, giving an injury rate of only 26.6%. This proves that ejection forces encountered and the injury dynamics of MIG series aircraft are not generally very different from other aircrafts.

The incidence and frequency of vertebral fractures depends also upon various other factors, such as the altitude of the aircraft at the time of ejection, as well as some individual factors such as body height, body weight/ ejection jolt, positioning of head and torso during ejection, and so on [3].

The aircraft altitude in the ejection phase is also very important. It is frequently unfavourable for many different reasons (loss of control, weather conditions, etc.), so the pilot may be subjected to complex accelerations during ejection. This modifies the pilot–seat relationship. The body position is of considerable pathogenetic importance in the biodynamic mechanism of the production of spinal fractures after ejection [4]. For example, if the aircraft is tilted to one side during ejection, there is lateral flexion of the trunk whose severity depends on the appropriateness of the harness design. Forward flexion is limited by the straps. When a low-positioned control system is used, it is found that flexion is more marked for subjects with long thorax and short arms [5]. In a tight turn, the acceleration generated by the manœuvre is added to the acceleration of the seat. In spins the –Gx acceleration developed by the rotation thrusts the pilot to the harness. If the anchorage points of the harness are low down, the spine is placed in forward flexion. This change of spinal geometry favours vertebral fractures [6]. Under these conditions, it is possible that the pilot will be unable to place his spine against the seat back completely and correctly during the extremely short period of time between the triggering of the ejection gun and the ejection itself.

Similarly, the low seat pan has a tendency to obliterate the lumbar lordosis and accentuate the dorsal kyphosis. If the legs are brought back, the lordosis is corrected but the dorsal kyphosis remains unchanged. A high seat position obliterates the lumbar curvature but has a small influence on dorsal statics. The height of the seat pan should thus be adjusted to the physical type of the subject. It should be adjusted so that the thighs remain in contact with the seat pan and the angle between the thigh and the trunk is 135°.

According to the pilot's constitution, the weak point of the spine can be the thoracolumbar spine or the middle thoracic spine. In order to prevent incorrect position, it is necessary to train pilots to extend actively the spine after grasping the handle and before pulling it to operate the ejection device, even though the harness system imposes the correct altitude. The influence of measurements of the pilots on vertebral bending was studied by the US Army. It was found that a sitting height of 5th percentile increases the risk of fracture at the L1 level, and a sitting height of 95th percentile increases the risk at D8 [7]. This is slightly different from our findings of vertebral fractures at D11 and D12. However, the statistics of the US Army and the US Navy represent a different distribution for the same seat.

The percentage of load applied on a single vertebra increases progressively from the cervical to the lumbar region and, according to many authors, ranges from 7% of the total body weight at C4 to 20% at D1, 25% at D6, 50% at L1 and 60% at L5 level [6]. It is known that the break load, indicated in G, ranges from 18 to 25 G for lumbar vertebrae at different ages. It was found that it ranged from approximately 700 to 900 kg for the last thoracic and first lumbar vertebrae in people aged from 19 to 40 years [4, 7]. This corroborates the age-related incidence of spinal injuries in the present study. Further, an analysis of injury and pilot age will help us have an insight into their flying experience. Malposture due to inexperience could be one of the causes for these injuries in the younger pilots.

Most ejections take place at air speeds of 150 to 500 knots. Speed is an aggravating factor and all the published statistics emphasize the increased incidence of lesions, particularly fractures. At high speeds the breaking action of the seat-stabilizing parachute cannot always be effective. High speeds diminish the chance of safe ejection.

The other factor causing spinal injuries is weight/ejection thrust ratio. A lot of emphasis is now given to body weight requirements, as women are being selected for flying in the IAF. Female pilots in the low-weight category with a different distribution of mass, will have a change in the centre of gravity. This makes the seat more prone to tumbling. Also, females, with their high fat content, have reduced muscle mass and lean body mass. Even though there is an increase in the chance of injury by 4% on DRI calculations with low body weight, the weightwise distribution of injury shown in Table 8, however, indicates that the maximum incidence of injury in successful ejectees is in the weight group of 61–65 kg and the injury incidence is relatively lower in the lower and higher weight groups. It is difficult to compare injury rates to weight groups. It is difficult to compare injury rates to weight when the aircrafts, missions and life support equipments are so different. It is possible that if all these potentially confounding variables had been controlled, the results would have been different. However, the present observation that the pilots in the 61–65 kg weight group are most susceptible to spinal injuries needs further detailed evaluation.

Finally, the clinical and radiological evaluation of ejectees is very important. As per the existing policy of IAF, X-ray examination of the whole spine should be carried out immediately after ejection and, if negative, the same should be repeated after four weeks, irrespective of the symptoms. The pilot is taken off flying for one week and then regular preflight check is carried

out daily with weekly clinical examinations. If there are no clinical and radiological findings, the spinal surveillance is stopped. However, in order to avoid missing cases of disc pathology and other soft-tissue abnormalities, it is advisable to carry out investigations like MRI/CT scan whenever the symptoms do not correlate to the injury. Following clinical and radiological recovery, ejection spinal injury cases are evaluated at the Institute of Aerospace Medicine by subjecting them to aviation stresses such as acceleration and vibration in aeromedical simulators. All clinically normal cases are cleared for flying.

The incidence and the type of injuries analysed in this study have indicated a better picture in terms of spinal injuries sustained by IAF pilots during this period of survey as compared to the earlier period between 1960 and 1987. Treatment for these spinal injuries has been successful in most cases with minimal or no residual effects.

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