An Analysis of Spinal Injuries after Ejections and Crash Landings in the I A F

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This study includes detailed follow up of spinal injury cases involved in successful ejections and crash landings in the Indian Air Force. In the period 1960-'80, there were 69 spinal injury cases from 209 sucecssful ejections. During 1974-'80, out of 46 pilots involved in crash landings, 5 sustained spinal injuries. The maximum incidence of ejection spinal injuries has been seen in Marut Aircraft. Compression vertebral fracture has been the most common injury. Most cases were hospitalised for less than 30 days. Majority of spinal injury cases resumed flying within 16 months; 22 pilots could not resume fighter flying. Only 2 spinal injury cases were invalided out of service.

During any inflight emergency where the safety of the crew, is jeopardised, a pilot is left with only two choices, either to abandon the aircraft inflight or to skilfully crash land the aircraft. The designers of aircraft ejection seat always take into consideration the human spinal tolerance since the spine of a seated pilot is the most vulnerable part for ejection injuries. The same is the case with a properly restrained pilot who crash lands his aircraft. The incidence of spinal injuries has been worked out by various workers for many Air Forces all over the world. For Indian Air Force the spinal injury among survived ejections has been in the range of 30%. The long term effects of these injuries have not been studied in much detail. It is needless to emphasise that a severely bruised back can be a cause of considerable human sufferings and loss of valuable trained man-hours, not forgetting the long term arthritis sequelae. In this study, all the IAF aircrew who sustained spinal injuries have been followed up in respect of their types of injury, hospitalisation and long term effects.

Review of Literature

Ejection Seat

Germans were the first to use explosive charged ejection seat in 2nd World War (1939). Later, improved versions were made in 1945 by Dornier, Focks, Wolfe and Heinkel. In Britain, Martin-Bakers defined human tolerance limits as early as 1945. Even today they are manufacturing ejection seats with the same parameters, i.e , peak acceleration below 21 'G' for less than 100 m Sec at a rate of 250-300 G/Sec. Watt's[19] work evolved human tolerance criteria in 1945-47 suggesting peak acceleration below 18-21 'G'.

Incidence

Verma et al[10] reported the incidence of spinal injuries during survivable ejections in IAF over 15 years period (1957-1972) as 30% in 105 pilots.

Another study in IAF by Rai et al[7] mentions similar figures in 66 survivable ejections. Delahaye et al[1], in their study of 105 successful ejections over a 15 years period, found 22 cases (11.2%) in French Air Force. Rotondo[8] studied 100 cases of ejections carried out by Civil and Military Italian pilots over a period of 20 years. Out of 89 cases, 15 sustained vertebral fractures (16.9%).

Mechanism of Spinal Injury

Levy[6], reviewing the spinal injury problems of successful ejections in his study of ejection seat design and vertebral fractures, found the problems to be related mainly to two areas, i.e., poor body positioning and excessive ejection forces.

The most common type of spinal injury is vertebral compression fracture and the most frequently affected area is thoraco-lumbar zone. Kazarian[5] derived the order of frequency as T 12, L 1, L 5, C 5, C 7, L 2, T 11, L 3, L 4, T 10, C 4 and C 6. Rai et al[7] studied data of 52 IAF pilots who sustained 87 fractures and found the incidence as T 12 (25%), L1 (20.8%), T1 (12.7%) and C 5 (5.8%). Sharda[11], in his study, reported the involvement of T 12 (25.45%) and L1 (23.63%).

Hospitalisation and Follow Up

This is one aspect of spinal injuries where literature available is quite scanty. Hirsch and Nachemson[3] followed up 55 pilots who ejected during 1957-60 in the Royal Swedish Air Force. All the 13 vertebral fracture cases returned to jet flying except one case whose injury was quite recent. Period of follow up for all cases was as follows :— 3-4 years in 8 pilots, 2-3 years in 11, 1-2 years in 20 and less than 1 year in 15 pilots. Among vertebral injury cases, one case developed gibbus after compression fracture of T 6 and was off flying for one year. Other 11 cases returned to active service again between 0-4 months (2 months on an average). Jones et al[4] studied ejections with Martin Baker (MB) seats in U S Navy and compared the incidence with British data on M B seats and Swedish data on SAAB seats as well as MB seats. Out of 165 survived ejections, 34 (21%) had vertebral injuries. Most of these pilots were treated conservatively with only rest, followed by hyper extension exercises. Some were fitted with braces and a few were fitted with Plaster of Paris casts. Out of the initial 7 cases, 5 cases were invalided out for radiculoneuritis, degeneration of inter-vertebral discs with localised arthrosis, arthritis and muscle spasm. But later on all cases returned to flight status after short periods of non—flying and limited flying (dual place, non-ejection seat aircraft) status. The Swedish pilots returned to flight status after 2 months on an average, as compared to 3-6 months in the case of U S Navy and British pilots. Hospitalisation period in U S Navy was less than 1 month in 9 cases, 1-3 months in 17 cases, 3-6 months in 4 cases and ½-1 year in 2 cases. Time of return to full flying status was as shown in Table-I.

TABLE—I

	No. of pilots returning to flying status			
	1-3 months	3-6 months	6-12 months	>12 months
U S Navy	6(30%)	9(45%)	5(25%)	—
British	7(32%)	10(45%)	4(18%)	1(5%)
Swedish	11(91%)*	—	1(9%)	—

*0-4 months average 2 months

Rotondo[8], in his study of 15 spinal injury cases post-ejection in Italian Air Force, found that no surgical or reduction manoeuvres were needed as there were no complicated or myelic fractures. In majority of cases, Plaster of Paris jacket was given for 4 months on an average, and then a reinforced corrective corset worn for a longer time. 14 subjects out of 15 recovered complete fitness for flight after varying periods.

Roychoudhary et al[9] evaluated 38 cases of spinal disabilities in IAF. Out of 26 cases of spinal fractures, 16 were due to ejections, 6 due to crash landings and 4 due to road accidents and ejection test rig trials. 17 cases returned to fighter flying and the other 9 cases were allowed flying only in non-ejection seat aircraft. No case was made permanently unfit for flying duties.

Gupta et al[8] studied the relationship of spinal disabilities and flying. They evaluated 31 cases of spinal fractures. Out of these, 18 cases went back to full flying duties after varying lengths of time. Eight cases were found unfit for ejection seat aircraft and were made fit to fly transport/helicopters.

Verma et al[10] reviewed the hazards of vertebral column abnormality in relation to acceleration forces due to ejections. According to them, in simple wedge compression fracture of thoracolumbar region the anterior depth (height of vertebral body) after healing may get permanently reduced by one quarter to one third of the undisturbed posterior depth. In such cases the intervertebral discs and the annulus are generally undamaged. Such cases are treated on conservative lines and recover completely in about 3 months and if asymptomatic with full, painless movements, full fighter flying may be restored after 6 months of observation. Cases with multiple vertebral fractures need caution during assessment for fighter flying as there is likelihood of associated undiagnosable injury to paravertebral structures or changes in spinal curvature. Such cases will be more suited for transport flying. Comminuted fractures involve disorganisation of vertebral body to the extent that its anterior height could get reduced more than one third. Inter-spinous ligaments and intervertebral discs often get damaged. These are unsafe or unstable fractures and fighter flying should not be permitted in such cases.

Material and Methods

Details regarding the total number of ejections and crash landings, pilots' particulars and details of aircraft and other relevant information were collected from the records available in the statistical section of the Directorate of Flight Safety. Relevant Courts of Inquiry files were studied to extract information pertaining to the circumstances of ejection/crash landing and immediate sequelae. Medical documents (AFMS F-1) of the concerned pilots were studied to extract details regarding period of non-effectivity, medical category and final disposal. Wherever possible, the concerned pilots were contacted in person and necessary discussions were held to get first hand information.

After obtaining the available details, a systematic analysis was done. Efforts were made to look into specific problems contributing directly or indirectly to the injury and its sequelae.

Results and Discussion

a) Incidence

In 209 successful ejections involving 196 pilots, 69 ejections (33%) caused injury to 66 pilots.

One pilot sustained injury only during the first ejection while subsequent 2 ejections in the same type of aircraft were uneventful. Although the total number is small it clearly highlights that multiple ejections do not expose an individual to an increased incidence of spinal injuries during successive ejections.

Available data in respect of crash landings pertain to a period from 1974 to 1980. A total number of 46 pilots were involved in aircraft accidents and only 5 pilots sustained spinal injuries. Three of these pilots were from fighters, one from helicopters, and one was injured in a ground accident while adjusting his seat in a Canberra aircraft.

b) Distribution of Vertebral Fractures

In 69 ejections causing injury to 66 pilots, a total number of 110 vertebrae were damaged.

Maximum incidence of spinal injury was in the dorso-lumbar region (28%) followed by mid-thoracic (5%) and lower cervical (4%) regions. In crash landings also, the maximum incidence of spinal injury was in lower dorsal and lumbar regions of the spine.

c) Ejection Injury vs Aircraft Type

The details of ejections and spinal injury rates in different aircrafts are given in Table-II

TABLE-II

Aircraft	No. of successful ejections	No. of ejections causing injury	Injury rate percentage (%)
Marut	10	6	60.0
Hunter	38	16	42.1
Type-77/66	43	12	27.9
S-22	30	17	56.7
Gnat	36	9	25.0
Mystere	19	2	10.5
Type-96/69	8	3	37.5
Canberra	1	0	—
Toofani	7	0	—
Vampire	8	2	25.0
Iskara	1	0	—
Kiran	7	2	28.6
Type-75	1	0	—
	209	69	33.0

Maximum number of ejections have been in Type 77 aircraft. Maximum injury rate has been in Marut (60%) followed by S-22 (56.7%), Hunter (42.1%) and T-96 (37.5%). Other aircraft show an injury incidence between 25 and 28%.

Aircraft-wise distribution of injuries to different segments of spine among successful ejectees is given in Table-III.

TABLE III

Aircraft	SPINAL SEGMENT				
	Cervical	Upper thoracic (T1-T9)	Thoraco lumbar	Lower lumbar	Sacro-coccy-geal
Gnat	3	2	4	0	0
Type-77/66	2	3	7	1	1
Type-96/69	0	2	1	0	0
S-22	0	0	13	0	1
Hunter	0	2	13	0	1
Marut	1	0	4	0	1
Kiran	0	1	2	0	0
Vampire	0	0	2	0	0
Mystere	0	0	2	0	0

Maximum incidence of injury is localised to thoraco-lumbar region of the spine. The cervical fractures have been seen only in Gnat (3), T-77 (2) and Marut (1) aircraft. The most likely cause of cervical and high thoracic fractures in Gnat aircraft can be postural inadequacy on account of neck flexion.

d) Types of Injury

Types of injuries encountered in this study of all ejections and crash landings are shown in Table-IV

TABLE-IV

Type of injury	No. of cases
Back contusion and strains	2
Spondylitis, lumbago and backache	2
Compression fracture	62
Subluxation, complete fracture and chipping of vertebral body	4
Fracture spinous process	2
Fracture transverse process	2
Disc prolapse, disc injury and sciatica	4
Fracture Coccyx	3
Total	81

In majority of cases where more than one vertebral injury occurred, the most common involvement was of adjacent vertebrae. Only in 8 cases of multiple vertebral fractures, the trend was different (Table V).

TABLE-V

Sl. No.	Vertebrae fractured	Type of aircraft
1	DV9 and LV1	S-22
2	DV9 and DV12	T-77
3	DV8, 12 and LV1	T-96
4	DV5, 9 and 10	S-22
5	DV7, 8 and LV1	Kiran
6	DV9, 11, 12 and LV1	Hunter
7	DV8 and 12	Gnat
8	DV11 and fracture coccyx	S-22

The mechanism of 2 vertebral fractures at distant sites is difficult to explain due to ejection forces per-se. It is quite likely that some of these injuries may have resulted from bad posture during egress phase, parachute opening or landing on ground.

e) *Period of Hospitalisation & Management of Spinal Injuries*

Out of a total 209 ejections, 66 pilots were hospitalised for varying lengths of time. The period of hospitalisation is shown in Table-VI

TABLE-VI

Period of Hospitalisation (days)	No. of pilots
0—10	7
11—20	13
21—30	20
31—40	7
41—50	4
51—60	5
> 60	7
Total	63*

*3 cases were hospitalised twice.

Most pilots were discharged from hospital by about 30 days and the others took longer periods depending upon the severity and symptomatology of injury. Three pilots were hospitalised more than once for the same disability due to aggravation of their symptoms/disability.

After hospitalisation, 49 pilots were sent on sick leave for a varying period of 4-8 weeks, averaging 6 weeks. One case was sent on sick leave after his second hospitalisation also Thirtyfour pilots were treated with Plaster of Paris cast and remaining were treated with rest and analgesics One pilot sustained complete fracture CV4-5 and had to be given skull traction along with Plaster of Paris, followed by cervical collar for 3 months. Surgical intervention was needed in only 2 cases. Both underwent laminectomy and removal of a portion of intervertebral disc to relieve cord-compression. Five pilots, who ejected and sustained injury during war, were treated initially in Pakistan and their hospitalisation documents could not be perused.

f) *Non Effectiveness for Flying Duties*

Details of non-effectiveness for flying duties are shown in Table-VII.

TABLE-VII

Period in Months	Unfit for all types of flying. No. of pilots	Unfit for Fighter flying. No. of pilots
0—4	14	8
5—8	26	11
9—12	20	12
13—16	6	8
17—20	0	2
21—24	1	2
25—28	1	2
29—32	0	1
33 and above	3	3
Permanently unfit	0	22
Invalided out	2*	2*
Still under review	3	3
Total	76	76

Note :

Ejections-69, Crash landing-5
2 cases were upgraded to A1G1 (medical category for fully fit) but had complications and were downgraded though the flying category was restored later.
* Same cases.

Out of a total 74 pilots (ejections 69 and crash landing 5) involved, majority of them were non-effective for all flying duties for a period ranging from 0-12 months. Sixty cases resumed restricted flying duties (non ejection seat) by end of 12 months and 11 cases took longer periods to resume even restricted flying. Three cases were quite recent and a finality regarding recovery had not been reached.

Out of the 14 pilots who started restricted flying within 4 months of their injuries, 8 pilots had compressed vertebral fracture and 5 had resumed flying duties as early as 2½ to 3 months.

Out of the 3 pilots who took longer time (more than 32 months) to resume restricted flying, 2 cases were invalided out finally and one took 42 months to resume flying.

Thirtythree pilots returned to full fighter flying by the end of 16 months. Eight of these cases had resumed full flying duties within 4 months after ejection. The shortest time taken by one pilot was only 3 months after his spinal injury, a compression vertebral fracture. Twenty two cases were declared permanently unfit for ejection seat flying.

g) Missed Cases of Spinal Injury During Initial Radiological Examination

A total number of 7 cases of vertebral fractures who were either symptomatic or asymptomatic could not be diagnosed during their initial clinical as well as radiological examination of the spine after their accidents. Majority of these cases became symptomatic at a later date when exposed to flying stresses and their subsequent investigations revealed radiologically proved fracture. As per IAF policy it is mandatory to repeat spinal X-Ray in ejection and crash landing cases whether an individual is symptomatic or not. This has a definite practical advantage in diagnosing the initially missed cases.

h) Symptomatic Cases without Radiologically Proved Spinal Injury

In a few cases, the ejectees complained of constant or intermittent backache or stiffness of back. However, their X-rays of spine were repeatedly negative and did not confirm any injury. Dynamic radiography, as suggested by Delahaye et al[1] may be tried in evaluating such cases.

References

1. Delahaye RR, Pannier R, Seris, H. Auffaet, R, Carre, B Mangin, H and Teyssandier, MJ. Pathophysiology an pathology of affections of spine inAero-space Medicine AGARDAG—140-70, Aug. 70.
2. Gupta, JK, Kapur RR, Jeswani, AP: Assessment of spina disabilities in relation of flying Journal of Aero medic society of India 13 : 55-61, 1970.
3. Hirsch, C and Nachemson, A. Clinical observations o the spine in ejected pilots. Aero-space Medicine 34 629-632, 1963.
4. Jones, WL, Madeen, WF & Iuedeman, G. Ejection sea acceleration and injuries. Aero space Medicine 35 ; 55 1964.
5. Kazarian, IE. Identification and classification of vertebr fractures following emergency capsule egress fro military aircraft. ASEM. 49 : 150-157, 1978.
6. Levy, PM. Election seat design and vertebral fracture Aero Space Medicine 35 : 545—549, 1964.
7. Rai, K and Gurusiddappa, G. Spinal pattern due t ejections. Aviation Medicine 23 : 41-47, 1979.
8. Rotondo, G. Spinal injury in jet pilots : Mechanis Follow-up and Prevention. ASEM. 46 : 482-484, 1975.
9. Roy Choudhury, A and Kapur, RR. Incidence o spinal disability among IAF pilots—Follow-up of 38 case Aviation Medicine 22 : 21-24, 1978.
10. Verma, SP and Roy Choudhury, A. Aircraft ejectio injuries patterns and trends in IAF - 1957 to 197 Journal of Aeromedical Society of India 16:57, 1973
11. Verma, SP and Sharda, PC. Catapult - ejectio forces and the abnormal vertebral column - A review o hazards. Aviation Medicine 20 : 23-31, 1976.
12. Watts, DT and Mendelson, ES. Tolerance to vertica acceleration required for seat ejection. J Avia Med. 18 : 554, 1947.