Original Article

Survey of the ejection injuries vis a vis flight profile of the aircraft at the time of ejection

Sqn Ldr S Bhargava* . Air Cmde Randhir Singh@

Aviator safety forms a part of preservation of resources through accident prevention, which can be defined as organised and constant effort to prevent errors or the results from errors. The successful ejection of the seat and the occupant depends upon a number of factors including the speed, altitude and flight path (attitude) of the aircraft. These factors are therefore directly related to the injuies sustained by the pilots. This paper surveys the ejection injuries occurred in Western air command in the year 1995 and 96 to establish a co-relation if any, with the aircraft flight profile. 17 effective ejections had taken place in the said period, of these 52.9% had major injuries including injury to the spine, upper and lower limb. 11.7% had minor injuries. 23.5% suffered from multiple fatal injuries. 11.7% of the ejectees had complete safe ejection with no injuries. The mean altitude of ejection was 1500 meters with a range of 66 to 4000 M. Similarly the mean air speed at ejection was 559 ± 151 kmph SD. The G load was not significantly increased at the time of ejection. The average time of the rescue was 58 ± 5.6 min SD. It is revealing that there is a noticeable incidence of ejection related major injuries even though ejection has occurred in the safe envelope. Even with the advancement in fighter aircraft technology vis a vis combat capabilities with equally advanced escape system, the ejectees are not injury free. Hence it is pertinent to study and co-relate the injuries sustained during ejection with the various flight parameters.

Keywords: Ejection injuries

Aviator safety forms a part of preservation of resources through accident prevention, which can be defined as organised and constant effort to prevent errors or the results from errors. The preservation of life is the main objective whenever hazards of accident conditions preclude the successful completion of the mission.

The amount of acceleration required for successful ejection of the seat and the occupant depends upon a number of factors including the speed, altitude and flight path (attitude) of the aircraft. These factors are therefore directly related to the injuries sustained by the pilots. In the earlier studies Roy Chowdhary et al (1978) [1], Rai (1979) [2] and MM Dogra et al (1982) [3] have brought out the various spinal injuries

* *Classified Specialist (Av Med), FIS, Air Force Station Tambaram.*
@ *PMO, HQ EAC, IAF, Shillong*

sustained by the pilots during ejection. However no co-relation has been established between the injuries and the ejection forces or the flight parameter at the time of ejection. With the advent of advanced fighter aircraft with their highly combat nature of the flight it is now pertinent to study and co-relate the injuries sustained during ejection with the various flight parameters. Search and rescue activities have also been reviewed. Utilisation of the facilities and the time taken to reach the site of the accident have been highlighted. This paper surveys the ejection injuries occurred in Western air command in the year 1995 and 96 to establish a co-relation if any, with the aircraft flight profile.

Material and methods

The accident investigation reports of all aircraft accidents involving fighter aircrafts in the year 1995 and 96 were reviewed. These reports were provided by the CFSIO HQ WAC. Pertinent section of accident reports were reviewed including the summary of the mishap, the investigation results, analysis and recommendations. Pertinent data were recorded of each accident, including the cause of the accident, flight parameters at the time of ejection (air speed, altitude and G load) And also the attitude of the aircraft prior to the ejection was noted. The various injuries sustained by the aircrew were noted out of the aeromedical assessment report.

Results

Review of the COI investigation reports revealed that a total of 17 effective ejections had taken place in the period 1995-96 to 1996-97 (table I). This includes a mid air collision in which three air crew and two aircraft were involved. Of these 43.7% where due to Human Error and a similar percentage due to technical defects. Bird strike the third cause contributed to 12.5% of the accidents (table II). The percentage distribution of injuries amongst these ejectees are tabulated (table III). 52.9% had major injuries including

Table 1: Aircraft accident rate

Sl No	Type of Aircraft	Ejection Seat	Year	
			1995-96	1996-97
1	MiG 21	KM1 M	04	04
2	MiG 23	KM1 M	03	02
3	MiG 27	KM1 M	01	01
4	Jaguar	MB 9	01	01

Table 2 : Reasons for aircraft accident (with percentage)

Sl No.	Type of Errors	Percentage	Year	
			1995-96	1996-97
1	HE	43.7%	04	03
2	TD	43.7%	03	04
3	BS	12.5%	02	–
4	Others	–	–	–

injury to the spine, upper and lower limb. 11.7% had minor injuries, 23.5% suffered from multiple fatal injuries. 11.7% of the ejectees had complete safe ejection with no injuries. Table IV show causes of various injuries at ejection. The mean altitude of ejection was 1500 M with the range of 60 to 4000 M. Similarly the mean air speed at ejection as per COI was 559 ± 151 kmph. Table V, VI, VII shows the relationship of various injuries to the flight parameters at the time of ejection. The G load was not significantly increased at the time of ejection except for two cases where radial acceleration of 10 g and 0 g were recorded on SARRP film before crash. I both cases no ejection was initiated and resulte in fatality. SAR activity shows nil utilisation o survival packs. The average time of the rescu was 58 ± 5.6 min. SAR helicopter or ambulanc was utilised on most occasions except on tw occasions in which a two wheeler was utilise for evacuation by the aircrew himself.

Table 3 : Percentage injuries during ejection

Sl No	Type of injuries	Number	Percentage
1	Major	09	52.9
2	Minor	02	11.7
3	Fatal	04	23.5
4	None	02	11.7

Table 4 : Cause of injuries at ejection

Sl No	Type of injuries	Total	EJT Force	Fouling	Wind Blast	Land ing	Percentage
1	Spinal	07	07	–	–	–	41.1%
2	Upper limb	03	–	02	01	–	17.6%
3	Lower limb	01	–	–	–	01	05.6%
4	Fatal	04	–	–	–	–	23.4%
5	Miscellaneous	03	–	01	–	02	17.6%

Table 5 : Attitude of aircraft relative to injuries

Sl No	Attitude of aircraft	Total	Major injury	Minor injury	Fatal	No injury
1	Level	06	04	02	–	–
2	Climb	01	01	–	–	–
3	Spin/Bank	05	02	–	01	02
4	Dive/nose down	05	02	–	03	–

Table 6 : Altitude of aircraft relative to injuries

Sl No	Altitude of aircraft (meters)	Total	Major injury	Minor injury	Fatal	No injury
1	0 - 500	06	02	03	–	01
2	500 - 1000	01	01	–	–	–
3	1000 - 1500	01	01	–	–	–
4	1500 - 2000	06	04	–	–	02
5	2000 - 2500	01	01	–	–	–
6	2500 - 3500	01	01	–	–	–
7	3500 - 4000	01	01	–	–	–

Table 7 : Air speed of aircraft relative to injuries

Sl No	Altitude of aircraft (kmph)	Total	Major injury	Minor injury	Fatal	No injury
1	250 - 350	04	02	03	–	02
2	350 - 450	02	01	–	01	–
3	450 - 550	03	03	–	–	–
4	550 - 650	03	02	–	01	–
5	650 - 750	03	02	–	01	–
6	750 - 850	01	–	–	01	–

Discussion

The amount of acceleration required for successful ejection of the seat and the occupant depends upon a number of factors including the speed, altitude and the flight path of the aircraft. If the flight path of the aircraft is resulting in positive G forces a greater catapult force may be required because of the increased effective weight to be over come and the effective trajectory of the seat is encroached upon by the curvelinear path of the aircraft. Also if there is a high sink rate the effective forces are reduced in proportion to the sink.

The earlier studies on pattern of ejection injuries have revealed the incidence of spinal injuries to be 35.2% during 1960-80 and 27.5% during 1980-87 [4]. In this study the percentage of total injuries have been reported from 17 effective ejections (inc. a mid air collision involving 03 aircrew) of which spinal injuries form 41.1%, upper limb injuries 17.6%, lower limb 5.6%, fatal (multiple injuries) 23.4% and others 17.6% as shown in table IV. This study therefore shows an increasing trend of spinal injuries. This may be attributed to variance in flight profile of the aircraft at the time of ejection and individual susceptibility (discussed below) for which data is not available in earlier studies. The presence of spinal malformation/anomalies cannot be ruled out [5].

The most important factor appeared to be incorrect posture and separation from seat at the time of ejection [6]. Although most vertebral fracture occurring upon ejection have been attributed to unequal distribution of forces on the

incorrect position of the vertebrae, as a function of incorrect position, it is quite possible in many cases a combination of circumstances exists, not only position but perhaps individual susceptibility as an anatomical function and unknown phenomena of body ballistics. A case is highlighted here of a pilot who had ejected twice in a year from similar aircraft. On both occasions the pilot did not suffer from spinal injuries. The first ejection was after a mid air collision with the aircraft in a spin and pilot had no time to attain correct posture. On the second occasion he ejected in correct posture. Although difficult to explain, the pilots susceptibility and good tone of the spinal muscles and rigid practice of physical conditioning exercises may have had a part to play.

A review of the cause of nonfatal injuries indicate additional sources of difficulty in ejection seat escape. Table III indicates that bony fractures constitute the most common non fatal injury. Spinal fractures formed the majority followed by the upper limb and lower limb injuries. 11.2% of ejection were completely safe with no injuries.

The factors which have an important influence upon the success - failure rate of ejection are altitude, attitude and the speed of the aircraft at the time of ejection. Table V, VI, VII. Show analysis with regards to these factors and the injury rate.

Low level ejection with high sink rate becomes critical resulting in higher injury rate 83.5% of injuries including fatal cases were noted in this study between 0-500 M altitude as compared to 66.6% between 1000-1500 M altitude.

The advantage of been accure from straight and level flight or a climb attitude at the time of ejection, as opposed to ejection in a dive or a spin are apparent from table V, 85.7% of ejection at level or climb attitude result in major injuries. This is in comparison to 100% injury rate with ejection in spin or bank or dive attitude. Of these 33.3% in a spin and 40% in a dive attitude were fatal. Most of these injuries occurring due to safe ejections were spinal in nature but a higher percentage of injuries to other parts of the body were also noted. These were related to the higher speed at ejection, uncontrolled nature of flight and inappropriate landing. Fouling with the aircraft structure was also a possibility as in case of pilot sustaining Monteggia fracture Lt arm attributed to fouling with oxygen pressure ratio controller during the egress phase as stated in a particular COI. The difference in ejection seats (KM1M in MiG series and MB 9 in Jaguars) however did not show any significant variance.

Accidents occurring in the lower fringe of the ejection envelope provide a complete spectrum of injuries. Besides spinal injuries probably due to the incorrect posture, the injuries due to tumbling in the aircraft, wind blast and landing are exaggerated. In one such pilot who ejected 4.5 sec before the aircraft hit the ground suffered from elbow injury within the cockpit due to fouling with cockpit structure, spinal fracture during egress, windblast injuries and compd communitted fracture both bones Rt leg with 10th and 11th rib fracture on landing. These injuries are all attributable to higher indicated air speed, nose down attitude (although the aircraft was wing level) higher sink rate resulting in uncontrolled egress and higher landing speed as the parachute had yet to attain the free fall velocity and the desired stability.

Lateral and partial multiple compression of the spine have been attributable to ejection in a bank attitude. Lateral bending forces or angular rotation about X-axis cause lateral compression fracture [7]. When the pilot ejects with the

incorrect position of the vertebrae, as a function of incorrect position, it is quite possible in many cases a combination of circumstances exists, not only position but perhaps individual susceptibility as an anatomical function and unknown phenomena of body ballistics. A case is highlighted here of a pilot who had ejected twice in a year from similar aircraft. On both occasions the pilot did not suffer from spinal injuries. The first ejection was after a mid air collision with the aircraft in a spin and pilot had no time to attain correct posture. On the second occasion he ejected in correct posture. Although difficult to explain, the pilots susceptibility and good tone of the spinal muscles and rigid practice of physical conditioning exercises may have had a part to play.

A review of the cause of nonfatal injuries indicate additional sources of difficulty in ejection seat escape. Table III indicates that bony fractures constitute the most common non fatal injury. Spinal fractures formed the majority followed by the upper limb and lower limb injuries. 11.2% of ejection were completely safe with no injuries.

The factors which have an important influence upon the success - failure rate of ejection are altitude, attitude and the speed of the aircraft at the time of ejection. Table V, VI, VII. Show analysis with regards to these factors and the injury rate.

Low level ejection with high sink rate becomes critical resulting in higher injury rate 83.5% of injuries including fatal cases were noted in this study between 0-500 M altitude as compared to 66.6% between 1000-1500 M altitude.

The advantage of been accure from straight and level flight or a climb attitude at the time of ejection, as opposed to ejection in a dive or a spin are apparent from table V, 85.7% of ejection at level or climb attitude result in major injuries. This is in comparison to 100% injury rate with ejection in spin or bank or dive attitude. Of these 33.3% in a spin and 40% in a dive attitude were fatal. Most of these injuries occurring due to safe ejections were spinal in nature but a higher percentage of injuries to other parts of the body were also noted. These were related to the higher speed at ejection, uncontrolled nature of flight and inappropriate landing. Fouling with the aircraft structure was also a possibility as in case of pilot sustaining Monteggia fracture Lt arm attributed to fouling with oxygen pressure ratio controller during the egress phase as stated in a particular COI. The difference in ejection seats (KM1M in MiG series and MB 9 in Jaguars) however did not show any significant variance.

Accidents occurring in the lower fringe of the ejection envelope provide a complete spectrum of injuries. Besides spinal injuries probably due to the incorrect posture, the injuries due to tumbling in the aircraft, wind blast and landing are exaggerated. In one such pilot who ejected 4.5 sec before the aircraft hit the ground suffered from elbow injury within the cockpit due to fouling with cockpit structure, spinal fracture during egress, windblast injuries and compd communitted fracture both bones Rt leg with 10th and 11th rib fracture on landing. These injuries are all attributable to higher indicated air speed, nose down attitude (although the aircraft was wing level) higher sink rate resulting in uncontrolled egress and higher landing speed as the parachute had yet to attain the free fall velocity and the desired stability.

Lateral and partial multiple compression of the spine have been attributable to ejection in a bank attitude. Lateral bending forces or angular rotation about X-axis cause lateral compression fracture [7]. When the pilot ejects with the

aircraft in a spin or in a vicious bank these forces come into play in addition to the vertical G load on the spine.

Dive or spin attitude have resulted in fatal injuries. At most occasions the pilots have had insufficient time to initiate ejection or the seat has not fired. The element of incapacitation in all cases have been ruled out by COI. Most of them are human error and the ejection have been initiated outside the safe envelope or more appropriately below the Mean Safe Ejection Altitude (MSEA) resulting in multiple fatal injuries due to the impact forces. In two of the cases the aircraft had levelled out at impact and in one the impact was in vertical attitude.

Search and Rescue operations were also studied by reviewing the COI. Kapur et al (1990) [8] in their earlier study have reinterated the advantage of quick rescue of the pilot on ejection. Although their study had revealed nil usage of the survival packs nevertheless, the importance of same in survivable condition is unquestionable. This study revealed the time taken for rescue which was 58 ± 5.6 min. There was no reported usage of survival pack. Most of the cases were rescused by SAR helicopter and occasionally by he ambulance. However two pilots reported to the base after taking lift from a scootrist both. Later were detected to have spinal fracture. Such practise is against all medical norms and the aircrew should be indoctrinated to avoid aggravation to injuries which may result in neurological deficit. No significant problems were highlighted. At most of the bases Cheetah helicopter are used for SAR purposes. Difficulty has been envisaged especially while carrying lying casualty. Chetak or Mi-17 helicopters are relatively better to evacuate lying casualty.

In conclusion, it is revealing that there is a noticable incidence of ejection related major injuries even though ejection has occurred in the safe envelope. Indicated air speed and attitude of the aircraft at the time of ejection play a major role. Indoctrination to attain a correct posture before ejecting to ascertain extent will bring down the percentage of spinal injuries though individual susceptibility and physical conditioning of the spinal musculature will also play a role. It is suggested that future evaluation of vertebral injuries would be greatly facilitated by the usage of modern imaging techniques (CT scan, MRI) soon after injury.

References

1. Roy Chowdhary, RR Kapur. Incidence of spinal disability amongst IAF pilots. *Ind J Aviation Med.* Dec 1978.
2. Kuldip Rai, G Gurusiddapa. Spinal injury pattern due to ejection. *Ind J Aviation Med.* June 1979.
3. MM Dogra, RR Kapur. An analysis of spinal injuries after ejection and crash landings in IAF. *Ind J Aviation Med.* June 1982.
4. MM Dogra JK Gupta. Analysis of ejection spinal injuries in IAF (1980-1989). *Ind J Aviaiton Med.* June 1988.
5. S. Bhargava, MB Dikshit. Radiological spinal abnormalities amongst aspiring pilot candidates. *Ind J Aviation Med.* Dec 1992.
6. Randhir Singh. Hazards of loose harness during flying. *Ind J Aviation Med.* June 1983.
7. Randhir Singh. Injury dynamics in aircraft accidents *Ind J Aviation Med.* Dec 1979.
8. RR Kapur. Aircrew survival experience in IAF - A retrospective study. *Ind J Aviation Med.* Dec 1990.