Assessment of Spinal Disabilities in Relation to Flying

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Introduction

THE human spine is subjected to undue stress and strain in flying. Accelerations during manoeuvres, low frequency vibrations, ejections and forced landings can contribute to spinal discomfort and damage. It is the disabilities acquired during high magnitude short duration forces which make the spinal column a focal point of anxiety. Some of the recent analyses of the results of ejections involving RAF personnel show the incidence of X-ray proven structural damage to the spine to be about 40%[1]. It is a fact that irreversible spinal damage involving the spinal cord is very rare and the commonly seen compression fractures heal rapidly and usually without residual functional disability but this is not an excuse for us to ignore the problem. Even a severely bruised back can cause considerable human suffering and loss of valuable trained man hours, not forgetting the possible arthritic sequelae.

Association of certain spinal defects or anomalies magnify the problem because some of these biologically imperfect spines might fail under ejection acceleratoins. According to Fitzgerald,[4] symptomless structural abnormalities of the spine could be demonstrated in about 25 per cent of random post-mortem examinations.

Assessment of spinal disabilities for flying fitness is a problem not infrequently encountered by the practitioners in Aviation Medicine. Our spinal ejection injury rate is comparable with the RAF figures of 40% or so. Very often, the spinal X-rays taken for the first time after ejection reveal one or more types of spinal abnormalities; and the absence of any base-line or initial X-rays in these cases, makes it difficult to predict whether these abnormalities are "the cause" or "the effect" of spinal injuries sustained. Contradictory opinions expressed in literature and the relative lack of our experience in this field does not improve matters. The introduction of the policy of taking whole spine X-rays in mid 77, both for ab initio and serving aircrew undergoing medical examination for high performance aircraft will go a long way in a better understanding of this problem.

Whatever be the state of our knowledge, there are a few important considerations which cannot be ignored. Spinal disabilities in experienced pilots require objective assessment in the interest of conservation of trained man power. This requires functional correlation between the disability and various elements of the task. The role of the vertebral column in bearing the weight and protecting the spinal cord under dynamically imposed forces must form the basis of assessing its disabilities. The ability to perform the mission with adequate safety of flight and safety of the operator has to be kept in mind. We can afford to be more rigid with the spinal disabilities detected in the new entrants, yet not too categorical, as it might lead to the elimination of keen and highly motivated individuals.

Recently a study was taken up to assess the extent and the type of spinal disabilities in IAF

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pilots or fresh candidates who reported to IAM for their medical boards. In this paper a synthesis of the problem as found in our study and a brief review of literature has been discussed.

Material and Method

Five different groups form the material for the present study.

(*a*) *Group 'A'* — Two hundred and fifty candidates who reported for initial medical examination to assess their fitness for flying branch between March 1976 and April 1977. All these cases were asymptomatic and clinically normal.

(*b*) *Group B* — One hundred and seventy five fighter pilots with 2–5 years of service who reported for High Performance Medical examination between March 1976 and April 1977. All these pilots were also asymptomatic and clinically normal. In both these groups, whole spianl X-rays were taken, for the subjects, in whom spinal disability was detected in chest X-ray. In cases where chest X-rays were normal, no further radiological exploration of the spine was done.

(*c*) *Group C* — During June–July 1977; 45 trainee pilots reported to IAM for their High Performance Medical examination. In all cases detailed spinal X-rays were taken to detect any spinal abnormality.

(*d*) *Group D* — A mixed group of candidates and serving personnel numbering a total of 289 cases between July 77 and July 78 who were symptom free and without any clinical manifestations. Whole spine X-rays were taken as a matter of policy. In all the above groups the X-rays were studied and interpreted in detail by radiologists. All anatomical variations and congenital anomalies, even if slight, were mentioned. The degree of scoliosis was measured by Cobb's method.

(*e*) *Group E* — A total of 52 serving personnel (other than Groups B, C & D) referred to IAM for spinal disability assessment between Jan 1968 and Jan 1978. These include spinal disabilities due to causes other than ejections also, *e.g.* crash landing, road accidents etc. In most of these cases detailed history and the method of assessment employed was not available.

Observations and Findings

For Group A — Out of a total number of 240 fresh candidates only nine cases showed spinal abnormalities in chest X-rays. The details regarding type of spinal abnormalities detected and disposal recommended is given in Table I. All these nine cases were declared unfit for aircrew duties because of the existing spinal disabilities.

Table I

Types of Spinal Disabilities in Group A (N—240)

Type of disability	Total No of cases	Disposal recommended
Scoliosis	8	All declared unfit for entry to IAF for aircrew duties
Kyphosis	1	
Other associated spinal abnormality		
– Reduced IV space	2	
– Loss of normal cervical lordotic curve	1	

For Group B — Out of 174 pilots who reported for High Performance Medical examination, a total of ten cases showed evidence of spinal abnormality in chest X-rays. Table II shows the details of types of abnormality detected. Out of these 10 cases five were declared unfit for flying aircraft fitted with an ejection seat. However, these cases were considered fit for Transport and Helicopter flying.

For Group C — Twenty four out of 45 of these cases showed spinal abnormalities. Breakdown of these abnormalities with disposal recommended is given in Table III. Out of 24 of these spinal abnormality cases, 14 were declared unfit for ejection seat flying. However, they were considered fit for Transport/ Helicopter flying. It is interesring to note that in many of these cases multiple congenital abnormalities co existed. The details of such findings are shown in Table IV.

For Group D — Out of 283 cases 146 showed one or more spinal abnormalities. Table V gives the detailed breakdown. The largest number was those

of scoliosis with or without other malformations. Other common abnormalities were: spina bifida and sacralisation of LV5. Scoliosis of more than 7° (by Cobb's method), spina bifida other than that of SV1 and unilateral sacralisation of LV5 were not accepted into flying branch of Air Force amongst candidates.

For Group E — Spinal disabilities in this group are shown in Table VI. Out of these, 31 cases (over 60%) were those of vertebral fractures, a large majority involving the thoraco-lumbar hinge (DV_{10} to LV_2), and a lesser number involving the mid

TABLE II

Types of Spinal Disabilities in Group B (N—171)

Total No. of cases with spinal disability — 10

Types of disability	No. of cases	Disposal recommended
Scoliosis of spine alone	7	—3 cases where scoliosis was more than 10° by Cobb's method were made unfit for ejection seat flying.
Scoliosis and other deformity	2	—Unfit for ejection seat flying — Fit for Transport/Helicopter flying.
Lumbaralisation with spina bifida LV6	1	—Unfit for ejection seat flying but fit for Transport/Helicopter flying.

TABLE III

Spinal Abnormalities in Group C (N—15)

Total No. of spinal abnormalities cases — 21

Type of spinal abnormality	No. of cases	Disposal recommended
Scoliosis alone	16	—In 6 cases scoliosis was more than 10°, so made unfit for ejection seat flying.
Scoliosis and other spinal congenital abnormality	6	—Unfit for fighter flying and ejection seat flying.
Other congenital spinal abnormality	2	—Unfit for fighter flying and ejection seat flying.

TABLE IV

Details regarding types of congenital abnormalities detected in Group C

Total No. of cases — 24

Type of spinal abnormality	No. of cases
Scoliosis	22
Kyphosis	1
Presence of LV_6	3
Spina Bifida	8
Sacralisation	
(*a*) Unilateral	2
(*b*) Bilateral	4
Unfused epiphyses	3
Blocked vertebrae	1
Reduced IV space	1
Cuniform vertebrae	2

NOTE : In majority of cases a combination of more than 2 or 3 abnormalities were detected.

thoracic vertebrae. Many amongst these had multiple vertebral fractures. Fives cases were made unfit for flying as they had more than one disability. Amongst the cases of scoliosis, those made unfit for flying had between 17° and 38° of lateral bending of the spine. Others with spinal deformities like spina bifida, spondylolysthesis, hemivertebra and sacralisation were unfit only for ejection seat flying. Both the cases of spondylosis were declared unfit for flying duties.

DISCUSSION

Major spinal deformities, whether acquired disabilities or congenital malformations with clinical disorders or obvious modifications of posture made an individual unquestionably unfit for flying duties.

The problem arises with cases in which minor degree of congenital irregularities exist without any clinical evidence. These are demonstrated on radiological examination only and some may constitute what we refer to as "fragile spines" or biologically imperfect spines which may fail under ejection loads. Delahaye et al[1] who studied 6687 spines found that congenital abnormality figured in one individual

TABLE V

Types of Spinal Abnormalities in Group D (N—283)
Total No. of cases in which spinal abnormality detected — 146.

Types of spinal abnormality	No. of cases	Remarks
Scoliosis alone	80	Scoliosis of more than 7° by Cobbs method was found in 18 cases.
Scoliosis with other congenital abnormalities	15	Considered unfit for entry into flying branch of Air Force.
Spina bifida LV_5	9	Spina bifida other than SV_1 is considered unfit for entry into flying branch of Air Force.
SV_1	9	
CV_6-CV_7	1	
CV_7-DV_1	1	
Blocked CV_5-CV_6 Vertebrae	2	
CV_2-CV_3	1	
CV_6-CV_7	2	
Sacralization LV_5 Unilateral/ bilateral	9	Unilateral sacralisation seen in 3 cases — considered unfit for entry in flying branch.
Cervical ribs bilateral	12	
Loss of spinal curves	5	

out of ten. In our study of limited number of cases (N—328, Groups C & D) about 50% individuals showed presence of congenital abnormalities. However, very few were made unfit for any kind of flying duties. 14 out of 45 individuals in Group C were not considered fit for flying ejection seat aircraft. Other spinal deformities were considered insignificant in relation to flying.

The policy on assessment and disposal of such cases cannot be rigid. The yardstick applied earlier was (as recommended by Verma and Sharda[3]) that no degree of scoliosis, postural or structural was acceptable at the time of entry. In the serving aircrew an uncomplicated scoliosis of more than 10° was not acceptable for flying aircraft fitted with ejection seat. Similarly, if more than one congenital abnormality existed the case would not be considered fit for ejection seat flying. According to Delahaye et al[2] the scoliotic limit angle compatible with conditions of ejection seat flying is fixed at 15°, in the French Air Force. According to these authors[1,2,3] some congenital malformations, not modifying the resistance of the spine should not involve rejection. The rejection criteria should be pronounced only after the study of malformation and its localisation in relation to the region of "Calling" traumatism. This seems a logical approach to the assessment of the spine of serving aircrew considering that ejection itself is a very rare accident in the life of a pilot. For fresh candidates, scoliosis of more than 7° is considered as a cause of rejection for entry into the flying branch.

PHYSIOLOGICAL VARIANTS OF SPINE

Certain authors (as quoted by Delahaye[2], Testut, Schmorl and Junghans) consider that frequent and slight dorsal inflexion with scoliosis to right is a physiological variation. Same views are also held by Hollinsheed[6]. According to some workers it is a result of muscular pull, the musculature of the trunk being more developed on the right with right handedness, while others feel that it is due to pressure on the vertebral column by the arch of the upper part of the ascending aorta.

Another frequently encountered morphological variant[1] is a wedge shaped tendency of vertebrae (cuniform vertebrae). These are found in the centre of physiological curvatures such as D_6 for the Thoracic column and D_{12}-L_1 at the lumbo-thoracic hinge[2]. According to Brocher[1] these are purely physiological variants. At present cuniform vertebra is considered fit for ejection seat flying[1,2].

Absence of union of the vertebral corners is a developmental disorder. According to certain authors[2] this anomaly, even isolated will make the disc more fragile and involves an early degeneration. However, this opinion is not accepted by numerous radiologists

TABLE VI

Spinal Disabilities in Group E (N—52)

Sl. No.	Types of spinal disability	No of Cases	Description		Disposals Recommended	Remarks
1.	Fracture Vertebrae	31	Cervical (C_3)	— 2	18 went back to full flying after varying length of time.	1. 13 cases had fracture of more than one vertebra.
			Dorsal (D1 D9)	— 6		
			Dorso Lumbar (D10–L2)	— 20		
			Lumbar (L3–L5)	— 2	8 Unfit for ejection seat, fit for transports/ helicopters.	2. All the cases made unfit for flying had either fracture of more than one vertebra or other disability like scoliosis or kyphoscoliosis.
			Spinous process D_{11}	— 1	5 unfit for flying duties.	
2.	Scoliosis spine	13	Cervical	— 2	6 cases were made unfit due to scoliosis alone.	All the 6 unfit cases had scoliosis of 17°–38°.
			Dorsal	— 9		
			Dorso-lumbar	— 2		
3.	Spina bifida	3	LV_5	— 2	1 made unfit for flying.	The case made unfit for flying had spina fibida of C_7 in addition to L_5.
			S_1	— 1	1 made unfit for ejection seat flying.	
4.	Spondylolysthesis	1	L_5–S_1		Unfit ejection seat flying.	—
5.	Hemi Vertebra	1	D_1		Unfit ejection seat flying.	—
6.	Sacralisation	1	L_5		Fit full flying.	—
7.	Spondylosis	2	Cervical	— 1	Both unfit flying.	—
			Dorsal	— 1		

and rheumatalogists. The fact to be remembered is that since the union of the anterior corner of the vertebral disc occurs physiologically around 21–23 years, its presence in a young entrant should not be a cause for rejection.

The transitional anomalies are also frequently observed and usually these are present at the level of lumbo-sacral hinge. These can be in the form of the sacralisation of L_5 (which can be unilateral or bilateral) and lumbarisation of S_1. Since lumbo sacral hinge is not the 'area of traumatism' during ejection, these should not be a cause for rejection. Our views are in agreement with policy followed by French Air Force[1 2 3]. However, unilateral sacralisation in fresh candidates is considered a cause of rejection for entry into flying branch of IAF.

The presence of spina bifida or the dehisence of the posterior arch is another common congenital anomaly. This basically results from disorders in the development of the neural canal. It usually involves L_5 or S_1. Verma and Sharda[7] are of the opinion that such cases are unacceptable for any flying where high 'G' loads exist. However, Delahaye et al[1] consider that this does not change the solidity of the vertebral column and it should not be cause for rejection. They have actually observed the results of ejection of pilots with this congenital malformation[1]. The fact that some of these pilots ejected

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2.	Scoliosis spine	13	Cervical – 2 Dorsal – 9 Dorso lumbar – 2	6 cases were made unfit due to scoliosis alone.	All the 6 unfit cases had scoliosis of 17°–38°.
3.	Spina bifida	3	LV_5 – 2 S_1 – 1	1 made unfit for flying. 1 made unfit for ejection seat flying.	The case made unfit for flying had spina fibida of C_7 in addition to L_5.
4.	Spondylolysthesis	1	L_5 S_1	Unfit ejection seat flying.	—
5.	Hemi Vertebra	1	D_1	Unfit ejection seat flying.	—
6.	Sacralisation	1	L_5	Fit full flying.	—
7.	Spondylosis	2	Cervical – 1 Dorsal – 1	Both unfit flying.	—

and rheumatologists. The fact to be remembered is that since the union of the anterior corner of the vertebral disc occurs physiologically around 21–25 years, its presence in a young entrant should not be a cause for rejection.

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without any injury resulted in cancelling the regulation of unfitness on the basis of "spina bifida" for French Air Force. Spina bifida except that of SV_1 is considered a cause for rejection for fresh entrants into IAF.

Congenital vertebrae blocks (fused vertebrae) with the absence of intervertebral disc spaces are another form of congenital anomaly often detected during spinal X-rays. These are usually the result of a flaw in the segmentation or a disorder of the vascularisation. These represent partial or complete fusion of two or several vertebrae. Most frequent site is C_2—C_3. If isolated, they do not modify the height or the basic curvature of the spine. Since the lesions of the cervical spine are very rare (exceptional) in aviation [1,2,5,6]; we consider that an isolated cervical vertebrae block should not be a cause for rejection.

FRACTURES OF VERTEBRAE

Fracture of vertebrae can occur in aircrew as a result of high G impact forces. In the assessment of flying fitness after such injuries the decision taken depends on the type of fracture. The commonest area of involvement is the dorsolumbar spine.

Comminuted fracture of a vertebra invariably disrupts the disc annulus and damages the interspinous ligaments and inter articular joints. The superior and sometimes the inferior intervertebral discs are damaged. These fractures are the unstable type. Even when healed and symptomless, these cases are not fit for fighter flying as their spine is no longer capable of withstanding the forces in case of ejection or crashlanding. Moreover, such people frequently suffer in normal conditions of life because of arthrosis. The same is the case of dislocations or fracture-dislocations.

Simple fractures due to compression, heal rapidly and may leave no evidence of vertebral deformity and the disc space may remain unaltered. Such cases are normally assessed fit for full flying at the end of a three month, post hospitalisation period, provided they are symptom free. However, if the compression is more than 1/3 of the total height of the vertebra, the spinal curve gets usually affected and additional, undetectable damage to other components cannot be ruled out[8]. Such cases are considered under the category of "unstable fractures." Similarly, multiple fractures indicate damage to vertebral end plates and in the presence of change in the thoracic curve the individual is unsuitable for further fighter flying.

Fracture of the cervical spine is a rare injury in Aviation. In general they involve dislocations most frequently seen in the last five cervical vertebrae[2]. Such cases are considered unfit for fighter flying. However, fractures of transverse apophysis when healed and symptom-free should permit normal aviation activity.

In cases of trauma without fractures, arthrosis and osteoarthritis (other than tuberculous) require a thorough assessment. Delahaye et al[2] feel that certain cases can be retrieved to full flying by taking into account the region affected.

Recognisable degree of Kyphosis exaggerates the flexion compressive stresses and is considered unfit for fighter flying.

Any surgical intervention done on the spine leaves behind instability, and the cause for such surgery should itself be a reason for unfitness.

RECOMMENDATIONS

(*a*) A reference dossier of the Basal spinal X-rays taken during initial medical examination, should be maintained. Comparison of this reference dossier after any spinal injury may be useful in protecting the interest of the aviator or the state on a medico-legal interest.

(*b*) Considering the fact that ejection by itself is a rare accident, rules regarding such spinal defects can be relaxed. The disposal policy towards congenital anomalies must take into account the —

(*i*) Vertebral element affected.

(*ii*) disco-somatic anomalies.

(*iii*) anomalies of posterior arch and

(*iv*) certain morphological variants.

Certain spinal segments, *e.g.*: dorso-lumbar hinge, are more vulnerable to ejection trauma and any anomaly of this region should be a cause for concern in an aviator. Cervical and lumbo-sacral

segment lesions are rare in aviation, and as such isolated congenital deformities of these regions should not be a cause for rejection.

(*c*) Assessment of spinal column that has undergone spinal injury should be based on :

(*i*) Absence of any symptoms and signs.

(*ii*) Maintenance of shape of vertebral bodies.

(*iii*) Normality of intervertebral spaces.

(*iv*) Normality of spinal curvatures.

(*v*) Use of discographic and laminographic X-ray techniques to ensure integrity of inter-vertebral disc.

(*d*) All the cases of spinal anomalies in service (detected during initial X-rays and accepted for flying) should be followed up for next 10–12 years. This will be a study in occupational pathology.

(*e*) Since the number of cases of our present study are very small it is recommended that a survey should be carried out for 400–500 pilots with 10–12 years of flying experience. Anomalies noted in their spinal X-rays should be correlated with their flying history *i.e.* : total fighter flying, ejection, crashlanding etc. This will give us better idea regarding statistics of congenital abnormalities in our population and effects of various aviation trauma to such anomalies. This may be taken as a quick retrograde study which will be of great help in formulating future guide-lines for such cases.

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