Original Article

Low backache in aircrew - evaluation and disposal

Wg Cdr NN Aggarwal

ABSTRACT

Flying is a highly demanding job requiring high level of fitness. Low backache (LBA) is one of the major occupational hazards in aviators. The aviators are exposed to number of aviation stresses such as prolonged sitting in confined space, vibrations, turbulence, high 'G', rare exposure to ejection, spinal ■jar> in Tighter aircraft, high decelerative forces etc., which are potentially LBA inducing/aggravating farters. Reported cases form only tip of the iceberg. LBA is a highly subjective malady with wide (■dividual variance in pain perception and intensity. There are no easy methods to quantify pain or award aero-medical disposal. In the past few decades, the visible diagnostics on spinal disorders have improved tremendously, but the invisible LBA still eludes medical sciences. Till this day, there is, mm angle method of diagnosing all the structural and functional abnormalities of spine. Consequently, even the best available diagnostics viz., CT and MRI are also put in controversies in their diagnostic specificity. A prudent disposal is highly necessary to preserve human efficiency in the cockpit.Exclusive tests have been developed for the evaluation of the aviators with LBA, which are based on subjective, objective and job oriented functional attributes and capacities. These include good history, interview oa 10-point pain scale, identification and exclusion of congenital or acquired spinal disorders by orthopedic and/or neurosurgeon followed by detailed human engineering evaluation. The latter includes techniques of anthropometry, functional tests, spinal kinematics-range of motion, goniometry, dynamometry, vibration stress with or without surface EMG, stress tolerance to 'G' forces in human ceatrifuge and psychometry in some selected cases. Many of these tests use biomechanical simulators. The paper discusses newer evaluation procedures such as use of thermography and lumbar motion ■mitor (LMM), and the value of each test individually. The basis and guidelines on aeromedical disposal ia crew suffering from LBA with different objective presentations are forwarded.

UASM 2001; 45(2) 11 to 29

KEY WORDS : Low Backache, Human Engineering, Medical Evaluation of Aviators, Specific and Non¬specific back pain, CT/MRI Spine.

Evaluation of backache has remained as a long and lingering challenge for the associated specialties, partly because it is highly subjective in nature, and may appear in many without having any proven objective abnormality. It is accepted that after headache, low backache (LBA) is the most common painful

condition amongst human population. There is no objective gauge to measure pain; consequently with all the aids available, to quantify LBA is very difficult. Aviators suffer from LBA like any other population, nevertheless, in defense services, 100% of the aviators are screened for congenital or acquired disabilities of the spine by whole spine X-rays, as mandatory professional fitness requirement. In view of the more strenuous and demanding working environment, there are widely different reasons for causation of LBA in aviators as compared to general civil population. The aviators face unique aviation stresses, which may induce and/or aggravate LBA. Amongst these are sitting in a confined space of cockpit in 6 degree of freedom (DOF), exposure to sudden/abrupt high 'G', vibrations, turbulence and occasionally the stress of un-ergonomically designed seats, in other few by exposure to ejection from the aircraft during which a pilot may sustain injuries to his vertebrae, spinal and paraspinal soft tissues. The intensity of the symptoms may vary widely with the psychological tolerance of the individual, with some vested personal interests or as a manifestation of post traumatic stress disorder (PTSD) or lack of motivation to overt fear of flying developed under particular circumstances. In last few decades, there has been tremendous progress in more objective investigative techniques for the evaluation of LBA; however, till date no single technique has been able to give clear guidelines for the evaluation or disposal of LBA. As LBA is one of the major causes of loss of trained crew manpower hours with heavy repercussions on the operational efficiency of the service, it needs to be addressed all the more seriously. The Institute of Aerospace Medicine (IAM) at Bangalore has developed certain job oriented spinal evaluation tests, which have stood the test of time and are being used in the current practice of 'Aviation Medicine' in the evaluation of LBA. Like several other novel techniques in aviation medicine, some of these may eventually find applications in spinal evaluation in civil as well.

Low backache in Aviation - General Considerations

Both civil and military aircrew undergo stringent medical evaluation at the time of their initial entry. However, the military aviators constitute an elite group of physically fit people, who are screened for any exciting/aggravating disability of the spine by the X-Ray of the whole spine. Military aviators are also screened for congenital abnormalities of the spine, exaggerated spinal curvatures viz., the scoliosis of the spine herniated nucleus pulposus, Schmorl's node at more than one levels, incomplete sacralization, spina bifida, spondylosis or spondylolisthesis, atlanto-occipital and atlanto-axial anomalies, other exciting types of arthritis, active or chronic spinal infections, Pott's spine etc [1]. Despite this some aviators do develop LBA during their tenure of service as acquired disability, which may be related to the occupation they are in. The causes of LBA therefore range from those responsible in civil population along with those acquired due to aviation stresses along with a number of psychological stressors associated with the inherently risky profession of aviation. It has been reported that four out of five individuals have had major back pain during their lifetime [2]. The major chunk of LBA amongst military aviators is formed by those, who had been involved in high 'G' sorties such as in high performance fighter aircraft, flying in high vibration environment viz., that in helicopters, or who have been involved in road traffic accidents

(RTA) which are not uncommon amongst young mators, or during escape by ejection from disabled aircraft. Statistics reveal that about 35% of the electee pilots acquire minor or major spine injuries '}]. Out of these, approximately 52% remain symptomatic for backache, while 48% remain asymptomatic despite occurrence of spinal fracture r. some of them, which then become incidental findings on post ejection screening with plain X-ray or some more sophisticated imaging tools [4]. The symptomatic aircrew most commonly develops pain in the cervical and / or thoraco-lumbar region. The latter remains the more common of the two, both in post ejection evaluation and also in the cases of unrelated LBA. Some of the fine fractures could be detected only on CT or MRI, as many were missed on plain X-ray screening of the spine. The micro-fractures of the vertebrae are well known exciting cause of back pain. The plain X-ray spine a usually taken in three different views such as long axis side view, front to back view and oblique view *hen required. The initially normal looking X-rays may reveal abnormalities of the fine missed fractures after about 10 days or later the developing periosteal reaction or the callous formation. The CT/ VIRI have been found more revealing in comparison to plain X-ray alone.

Specific and Nonspecific Low Backache

There are two categories of patients with LBA. one with specific diagnosis, others with non¬specific diagnosis. The specific diagnosis is easier :o identify and dispose, because of its obvious relationship with trauma, infection, neoplasm and significant neurologic deficit. The difficulties arise »ith non-specific diagnosis, where only history of pain is available or is primed with an old insignificant injury. The relationship between the abnormality of the components of the spine and LBA has long been postulated. Although Mixter and Barr [5]. developed relationship of LBA with vertebral bodies, the interposed intervertebral disc, the bony arch, pedicles and the facets and the contained nerve root, it has not always been possible to establish the same. In fact, the concept of sustained nerve root compression producing pain is not tenable [6]. There may be pain on initial impact, however, if the compression is sustained it would be associated with sensory, motor deficits with loss of related reflexes, but there would be no pain in long term. Therefore, the pain must originate from some other structures. In absence of any obvious lesion, it becomes very difficult to identify the exact origin of the LBA, even when its characteristics point towards particular structure. In most cases, one finds the history of pain only; there is no clinical disclosure of neurologic deficits or physical findings. In patients with obvious lumbar disc disease, one may present with LBA consisting of stiffness in the back and pain radiating down to the thighs, calves, and feet associated with paraesthesia, weakness and reflex changes. The pain from intervertebral disc disease is often exacerbated by coughing, sneezing or physical activity. Pain is usually worse when sitting and with straightening or elevating the leg. Disc herniations occur most often at the lower lumbar levels, 90% at L4-5 and L5-S1,7% at lumbar 3-4 and remaining 3% at the upper two levels [7]. Despite good radiological screening at entry, the affected crew population shows almost similar trend. There are no current diagnostic techniques that images soft tissue with certainty, though ultra¬sonography has improved the outlook. In this instance, the imaging is directed towards the myofascial system which binds the spinal segments

together and without exception is involved with LBA. In the past, the aero-medical evaluation of the LBA was oriented only towards bony lesions of the vertebrae. With improved diagnostics, it has now been centered on the nerve/disc/bony relationships, leaving somewhat the soft tissue integument and the supports, where all the causal factors could be found. These consequently interact to produce the stimulus of pain. In non¬specific cases, it has now been increasingly accepted that the myofascial system is the major responsible element in producing LBA. Clinically, the majority of LBA would remit spontaneously within first 4-8 weeks of time from the appearance of symptoms of LBA, however, some may continue as radiological, imaging studies and further testing of the patients in the periphery may fail to find definitive contributory lesion.

Problem Areas in Evaluation

The perception and intensity of pain much depends upon particular personality type and general mental make-up. Some people tend to ignore the pain while others exaggerate the same. Most of the cases of LBA recover and stabilize within two months of occurrence of pain. However, evaluation problems pertain largely to those, who despite adequate rest fail to exhibit any recovery when they do not have any organic lesions, albeit give history of some injury in the past. In these cases, in particular, the precise diagnosis of the cause of LBA could be a frustrating, expensive and low rewarding experience. Often their motivation seems to be low either because of injury or persistent pain or other related events. Such cases need detailed subjective, objective and psychological workup. Thereby, in addition to the conventional and job oriented functional test, they need to undergo relevant psychometry. In all cases of LBA however, the attention is more focused on the serious causes, the residual functional capability and the prognosis.

Status of Radiography and Special Imaging Investigations

Human engineering evaluation is essentially preceded by detailed radiological review, to ascertain the safety of the number of tests/

simulated stresses given. Plain radiographs of the spine are of little or no help in the diagnosis of nonspecific LBA. Reduced IVDS in no way indicates nerve root compression. A normal X-ray gives no indication of discal protrusion as well. Nevertheless, it shows gross extent of bony vertebral injury, which could have been sustained during RTA, ejection, high 'G' effects, crash landing, improper escape and landing. The additional studies such as MRI or CT scan are required to be done for finding the details of bony and neural damage. Reformatted 3-D images of the bone column require MRI images of the spinal cord. Compression of the spinal nerve root cannot be reliably confirmed with specific imaging procedures such as Computed Tomography (CT), myelography, discography, sonography, venography, magnetic resonance (MRI) or EMG, nerve blocks etc., because all of these exhibit relatively low specificity. The disposal is complicated by the fact that 20-30% of asymptomatic subjects have a disc protrusion as demonstrated with myelography, CT/ MRI. Other studies indicate it to be present in about 70% of the subjects [7].

Despite above, the MRI has come to stay as the corner stone of exquisitely detailed anatomic visualization with non-invasive and non-radiating

Irraging technology, so often required in the periodic evaluation of the cases of LBA. Bone and SPECT-scanning are useful for the evaluation of degenerative or destructive processes. They help dating of the old injuries, which may be mistaken so be responsible for the currently existing LBA. The pulse sequence and the specific protocols vary among different MR sites of the spine. The seme, needs to be imaged in at least two planes. L= the cervical and the thoracic regions, a T2 weighted sequence is mandatory to assess the inmge to the spinal cord. Thin sections are required to visualize the neuro-foramina. The pulse sequence is required to be tailored to counteract CSF flow and its physiologic motions. Fortunately, ±e imaging requirements for the lumbar spine are -ruch less, as its anatomic parts are larger. Most protocols include a Tl weighted sequence and souk type of T2 weighted sequence to give a =r»ek>graphic effect. Fast spin echo (FSE) is fast replacing the conventional spin echo for T2 of the spine. Three-dimensional gradient echo iGRE) is able to achieve less than 1 mm slice tnckoess to facilitate visualization of finer lesions.

Hunan Engineering Evaluation

A detailed human engineering (HE) evaluation x ;amed out in order to find the potential of the m±rv»dual to reflight him back on the type of the ~~nr.i~~ ~~a~~ft that he was flying before the onset of LBA. **Tx** patient arrives at the HE department through iae Medical Evaluation Center (MEC), after seeing i&k orthopedic/neurosurgeon, confirming the pfeyscal status of the case clinically and adiologically. The surgeon assesses the patient of LBA through history, clinical examination and supplementary examination if required and opines gee the extent of the lesion and disability. At the department of human engineering, quantitative and qualitative assessment of back pain and the functional disability is carried out. At the outset, the crew is rated on ten-point pain rating scale. In the event of this being symptomatic, only minimal baseline functional evaluation is done. In case some discrepancy is observed between the pain scale

inferences, interview and the functional tests, he is subjected to psychological evaluation. In case he is asymptomatic at the time of evaluation, he is subjected to various objective tests, evaluating him on simple and basic functional tests, relevant spinal anthropometry, goniometry and dynamometry. In case, he continues to remain asymptomatic, he is subjected to uniaxial vibration test and human centrifuge tests in step rising fashion, to evaluate his simulated stress tolerance in aviation and optimal employability. All the tests are usually explained to him on arrival to the dept of HE during face-to-face interview and a general verbal consent is obtained.

Evaluation on Pain Scale

The crew with LBA generally arrives at IAM/ other tertiary aero-medical evaluation centers after 6-8 weeks or longer of duration from the onset of pain due to any of the reasons. By this time the crew is fairly stabilized from acute LBA. The patient is therefore given one of the commonly used chronic pain rating scale. The pain rating scales are designed to find out the perception and intensity of pain as felt by the patient. Most of the pain scales use the traditional range of 0-10. Several pain scales are available such as Randall Chronic Pain Scale or Mankoski Pain Scale, and are administered before the patient enters the formal evaluation by the Aviation Medicine Specialist, the scales usually provide quantitative

data on patient's symptoms and magnitude of interference with daily activities. The output may however remain only partly reliable, on account of the patient being guarded, or attempting to feign, also his subjective pain threshold could influence the response, which may be either high or low. Nevertheless, its importance cannot be underestimated in understanding the patient a little better, deciding the range of investigations needed, the need of psychometry and higher rationalization of the disposal. Some orthopedic centers in Europe, such as Basildon Hospital, London uses 'yes or no' questionnaire on spinal pain with the assistance of micro-computers, so called the 'computerized interview system' [8].

Subjective and Objective Physical Evaluation

At the department of HE, every case of LBA undergoes subjective as well objective tests. Irrespective of the clinical history taken earlier by the clinicians, the history is retaken with particular reference to aviation stresses and dynamics of injuries. The objective test begins with critical observations as the case enters. His spinal curvature is examined clinically. In case of spinal ejection injuries, vertebral point tenderness is occasionally illicitable. Affected crew often reports the paraspinal pain at lower lumbar vertebrae, however overt limitations of spinal movements may not be found. Absence of physiological curves in the back, lumbar hyperlordosis, scoliosis and other asymmetry of trunk and back are recorded before administering objective and functional tests.

Postural & Functional Assessment

Sitting for long times in a seat is responsible for muscular aches, pressure on discs, orthopedic disabilities and other circulatory problems. The vertebral discs are the pressure absorbers, but imposition of unnatural postures putting pressure on the discs squeezing out the fluid results in excruciating pain. Many crew tend to suffer from LBA due to this contributory reason.

The patient is examined for his attitude, gait and stance as soon as he enters for examination. The functional anatomy including the altered posture is observed carefully. Special focus is given on his functional attitude, limping or coordination problems as these may be indicative of neurological or myofascial syndromes. Clinical scliometry is being introduced shortly to add objectivity to the test and avoid observer's errors. He is then subjected to the basic functional tests. These tests are well oriented towards his primary job requirements, and include tests such as on the spot jog test; squat test, 4 feet jump test and run tests. Such eventualities may occur during launching operation readiness platform (ORP) or emergency escape from aircraft. These are carried out only after clinical / investigative clearance by the orthopedic / neurosurgeon. The tests are stopped in case the crew gets symptomatic, while carrying out any of the tests.

Following satisfactory qualification on these preliminary tests, the subject undertakes other tests, which include spinal anthropometry, goniometry and dynamometry, and certain stress tolerance tests such as pre-defined limited vibration and accelerative stresses.

Spinal Anthropometry

The anthropometry is an art and science of taking various body measurements. This constitutes an essential component of any spinal examination. Under this evaluation the stature height, the sitting height, mid and shoulder tip heights on either side are measured. The two can be compared to bring out any effectual asymmetry due to postural compromises. The other parameters are recorded for future comparative study for recovery or deterioration. The postural asymmetry in cockpit environment may be nonconducive towards aircrew-aircraft compatibility. Postural compromises may enhance ejection injuries. Very tall or very short occupant of the cockpit may acquire backache due to compromised posture and demands on the controls.

Spinal Movements

Evaluation of spinal movements constitutes a very important part of aero-medical examination for LBA. The spinal movements constitute 5 major movements viz., ventral flexion, lateral flexion on either side, extension and circumduction. Spinal rotation of lower spine is measured by disc goniometry. The movements are evaluated on specially designed 'Spinal board' fitted outside with metallic reverse measuring scales on its closed three sides, and the efficacy of the spinal movements is gauged where the tip of the middle finger of the individual is able to reach down on the reverse scales. Any reading short of two SD of the normal is considered abnormal.

Normal variations in these tests do occur in view of the different stature heights and the arm lengths of the subjects. However, in these cases the symmetric reach on either side offers decisive clue. The quantitative value of the spinal extension of the spine cannot be assessed at present, objectively and is evaluated subjectively only. Rapidity of movements and freedom from pain are taken to be indications of normal spine.

Spinal Goniometry

Goniometry is the science of measuring the angular movements at joints. Spinal goniometry is a very good tool in the evaluation of the spine, especially in the assessment of LBA. The

Table - 1

Finger - Board Distance on Spinal Flexion Board - Normal Subjects

Movement	Mean (cm)	(cm)
Ventral Flexion	4.31	138
Lt. Lateral Flexion	39.14	2.85
Rt. Lateral Flexion	39.73	2.60
Extension	Subjective assessment > 35°	-

restriction of the spinal movement for any one or more parameters is the pointer towards the underlying pathology. The rotation of the low back is measured as combined lumbo-pelvic rotation over a rotating disc against preset resistance of 20 kg over two pulley system affixed on a multi-gym system. Spinal movements at the waist can also be measured on fixed base through circumduction. The normal values on the spinal goniometry are given below. [Table 2]

Spinal Dynamometry

Dynamometry on humans is concerned with the measurement of load tolerances by an organ or a particular tissue. Hand and limb dynamometry are already in extensive practice. The spinal dynamometry is primarily concerned with measurement of strength of flexor and extensor groups of spinal muscles. For LBA, the flexors and the extensors of the lower back are evaluated for their load tolerance. The loads tolerated / pulled are measured through electronic load cells and the values are obtained in terms of kgf or Newtons. The following table gives the mean values for flexor and the extensor group of the spinal muscles. [Table 3]

The lower limb functional dynamometry over the 'Cockpit Controls Digital Dynamometer1 gives useful information on the residual / functional capability of the crew to operate aircraft controls viz., the rudders, toe brake etc. Some of these functions may get compromised with neurological involvement, clinically presenting as LBA and / or Sciatica.

Uniaxial Vibrations Stress Test

Having qualified the earlier tests, the patient is subjected to the vibration stress test. The total duration of the stress is 25 minutes, during which the subject sits in a uniaxial vibration simulation non damping chair mounted on a vibrating platform. The subject needs to be asymptomatic before he is subjected to the vibration test. The typical profile given to the asymptomatic subjects with LBA irrespective of having prolapsed disc or compression fracture is given below. [Table - 4] The profile is pre-designed considering the natural resonance frequency of particular musculoskeletal system to be evaluated.

The human body has resonance bands around 5 Hz, which is mainly related to the shoulder girdle and thoraco-abdominal system. At these frequencies, there is amplification in the body of the energy transmitted by the vibrations, and the tolerance is the lowest. These frequencies are similar to those experienced in the helicopter flying. Exposure to these frequencies, even at smaller amplitudes, tends to evoke latent pain particularly in lumbar spine. The test is preceded and followed by clinical assessment of spinal and paraspinal spasm and limitations of spinal movements. The test exhibits the vibration stress tolerance in simulated aviation environment.

Surface Electro-Myography (sEMG)

EMG has often been used as a useful tool in the evaluation of LBA, independently or under vibratory stress. The effects on the musculoskeletal system can be evaluated non-invasively by using EMG power spectrum analysis shows raw EMG data in conjunction with the force data manifested by the muscle contraction. The delta time periods (Tl to T2) and (T3 to T4) are analyzed separately and compared using FFT (Fast Fourier Transform

Table - *2* Kinematics of Lower Spine

MOVEMENT	NORMAL ROM	Below Satisfactory ROM
LUMBAR SPINE		
Flexion	60°	53°
Extension	25°	12°
Lt Lateral Flexion	25°	21°
Rt Lateral Flexion	25°	21°
Circumduction	Subjective^ assessment	
- Clockwise	Full, symmetrical 130 degrees	
- Anticlockwise	Full, symmetrical 130 degrees	
THORACO - LUMBAR SPINE		
Flexion	80°	52°
Extension	50°	20°
Lt Lateral Flexion	50°	30°
Rt Lateral Flexion	43°	30°
Lt Rotation	42°	35°
Rt Rotation	42°	35°
SPINAL GONIOMETRY		
THORACO - LUMBAR PELVIC SPINE		
Flexion	150°	110°
Extension	60°	22°
Lumbo - Pelvic Rotation (Clockwise)	146.0°	9.0°
LP Rotation (Anti - Clockwise)	146.0°	9.0° .

Table-3 SPINAL DYNAMOMETRY

Croup of Muscles	Mean (kgf)	SD (kgf)
Flexor group of spinal muscles of **LS** Spine	16.5	1.5
Extensor group of spinal muscles of **LS** spine	21.2	3.2

Table - *4*

Uniaxial Vibration Stress Profile For LBA

DURATION (min)	**FREQUENCY (Hz)**	**AMPLITUDE** (m/s^2)
5	4	1.00
5	5	1.10
5	6	1.15
5	7	120
5	8	125

function). The EMG does not turn positive until 3 weeks after the onset of symptoms, so that an early negative study can be misleading. To avoid interference, active electrodes may be used. They are available in two configurations, wide and narrow. Each may be used as surface electrode or a fine wire electrode. They are very small and will fit to most parts of the body. When combined with vibration test, EMG can enhance the specificity of the latter. For the spine and the discs, an erect posture is advisable, while for the muscles of the back, a forward inclination is advisable.

Evaluation on Human Centrifuge

The crew of fighter stream having LBA are evaluated on Human Centrifuge (HC) before reflighting, as to ensure acceleration tolerance and that the symptoms do not reappear by exacerbating the residual pathology while pulling G during actual flying. The test is carried out over two consecutive days, as follows :

(a) Day-1: Evaluation of the relaxed tolerance to 'G' stress.

(b) Day-2 : Rapid Onset Rate (ROR) exposure to 'G' and SACM (Simulated Aerial Combat Maneuver)

ROR-5 'G' for 30 sec. ROR-6 'G' for 30 sec. ROR-7 'G' for 15 sec. SACM-4-6.5 G for 2 peaks.

The tests are preceded and followed by clinical examination of the back, during which the spinal and paraspinal regions are checked for local tenderness and the muscle spasm.

Psychological Evaluation

A battery of tests is carried out along with face-to face interview with a questionnaire to find out attributing psychosomatic elements, if any. Somatoform pain disorder is a conversion reaction that has the essential features of preoccupation with pain in absence of adequate physical findings to account for pain or its intensity. For example the 'Fibrositis syndrome' is considered to be the somatic expression of internal tensions and the suppressed anxieties, which the patient cannot verbalize. There could be number of psychological factors, which could affect the illness in an exacerbated form viz., anxiety, somatic preoccupation, air sickness, fear of flying, bad event in flying etc. The factors, which need to be isolated, are lack of motivation and / or malingering. The tests include both 'Projective' as well as the Objective Test'. The latter are in the form of questionnaire and when truthfully done, their results seem to be high on reverse validity scale. However, most of the affected are quite guarded on their visit to the evaluation centers, also most of the pilots have very strong defense mechanism of denial, thereby expressions of ignoring pain or an overt denial despite visible / ra'diologically visible injury are not uncommon. Modified Somatic Perception Questionnaire and the Jung Depression Scale have been found to be the most discriminating

;io].

Executive Report

The executive report on flying has important value, especially in cases of demotivation, weakness in flying capability, reflighting after long duration and while advising on change of stream. The aviator is judged in the cockpit environment by an independent, mature and well-qualified supervisor on the recommended type of aircraft, for his ability and ease to fly and sustain the aviation stresses, as he would be actually facing when granted flying fitness for reflighting purposes. Unfortunately, most of the executive reports are only flight oriented, and most motivated pilots ignore their LBA during few sorties done for the purposes of executive report. Therefore, in any such report the human factor aspects must also commented upon for its better significance towards disposal.

Newer Supplemental Technique

Ultrasonography

Ultrasonography techniques have advanced in recent years, with resolution greatly improved. The technique has been applied to find out the fractures in the fibers of muscles and ligaments. These tears otherwise cannot be visualized by any other imaging techniques clearly. USG has also been found of value in determining paraspinal haematomas in various phases of resolution.

Thermography

Though quite popular in the west, this diagnostic modality is not yet available for evaluation of the LBA related lesions amongst aviators in India. It is especially helpful in diagnosing myofascial syndromes as well as

nervous system conditions. The active lesions are readily picked up by this non-invasive technique. However, thermography may be found abnormal in substantial proportion of asymptomatic subjects without having back problems.

Lumbar Motion Monitor

LMM is a new reliable tool designed for on job spinal evaluation in or outside the laboratory. A complete evaluation can be accomplished in just two minutes. Patients are more compliant as they don't have to maintain any specific position. As the patient gets pain while walking or doing some work, he presses the button. Thereafter, it automatically marks the onset of pain on the graph and records its effects on the ranges of motion (ROM) and the movement velocity, Measuring true lumbar spinal angles quickly and accurately makes the evaluation more relevant'and realistic. Activity in each plane in isolation or combined can be measured, while the subject is in specific activity. The subject wears the equipment on his back, one can isolate the ergonomic factors and faulty body mechanics.

Discussion

Low Backache (LBA) is one of the commonest maladies in humans, most of which is attributable to postural compromises and / or the effects of external forces. Despite tremendous advances in diagnostics, the current medical science's understanding of the complex nature of LBA is still limited. Its incidence seems to be higher in more developed countries. Its relationship has been coined with some specific occupations, having potential to cause direct or indirect trauma to the spine. Under normal circumstances, it is estimated that between 30-40 persons per million population suffer from spinal injuries every year all over the world. The injuries often tend to involve young adults between the age group of 20-30 years. In technological advanced world today, the identified most common causes amongst young adults include the motor vehicle accidents (45%), followed

by fall from height (25%), sports injuries (15%) and act of violence (15%) [11]. Amongst military aviators, usually the LBA is due to two major factors viz., the 'Road Traffic Accidents' (RTA) amongst relatively young and the repetitive spinal stress over a period of time in more experienced. While, the vibrations and the poor posture have been identified as the common causes in the helicopters, prolonged sitting, turbulence, sudden decelerations viz., on crash landing etc., are the reasons of LBA in transport aircraft, which is by far are less than that in helicopters. The incidence again rises in the fighters, due to exposure to short or sustained high 'G' forces, compressing the contents of intervertebral discs, maintenance of posture under high agility maneuvers, high accelerative forces of ejection or high decelerative forces of crash landing etc. It is very interesting to note that there are lesion site similarities between aviation spinal injuries and RTA injuries as both involve high decelerative forces in their causation and involve dorso-lumbar region DV12-LV1 (40% in RTA) [12]. Rimoldi reported involvement of DV12 in 32% cases, and LV1 involvement in 27% cases of RTA. [13].

In aviation, the reported cases form only the tip of the iceberg; although the unreported incidence may be quite high. The reported incidence tends to vary with the sophistication of the diagnostic modalities being used. In the past,

the mainstay of diagnosis was the plain radiograph of the spine in various views. In modern times, the value of plain radiographs in the diagnosis of LBA has gone in to lower importance, as its specificity over physical examination is 1:2500 adults under 50 years of age, to which almost all of the active aircrew belong. Hitherto, large emphasis was laid in the involvement of the bony constituents in terms of fracture / dislocation and congenital abnormalities if any. The reduction in the height of intervertebral disc was the only cue for a variety of IV disc disorders. Facet joint degeneration, which begins from the first two decades of life in almost 100% population, had been relatively less looked for, It is now known, that between 4-28% of the asymptomatic general population shows changes of lumbar canal stenosis [14]. Similarly, age related spondylotic changes are very common and are seen in 60-80% of population aged more than 50 years. It had been reported to be higher ui the people involved in heavy physical labor and activities causing stress to the spine. [15]. Would it therefore mean that the aircrews show more such changes in the spine as compared to general population under repetitive stresses of acceleration and vibrations? One such study attempted to co-relate the two when X-Ray spine was the only tool available in India [16]. More recently it is established that the existing superior and sophisticated modalities like the CT/MRI reveal multiple findings in both symptomatic and asymptomatic flying individuals, which may have some bearing not only on LBA> but the very ntness for flying at least the high performance aircraft. Higher numbers of findings on these investigations have also been found amongst F-15 and F-16 pilots [17]. The spinal pain amongst fighter pilots due to high sustained acceleration in advanced jet fighters such as MiG-29, Mirage 2000 and other fighter aircraft in IAF was found to be 63.6%, 80.76% and 54.2% respectively with occurrence found above +6Gz of acceleration, mainly in the cervical region [18]. In fighter trainers, the occurrence was still higher in the pilots in the rear seat. Cervicalgia was found to be directly related to the weight of the helmet used. If the head weighs 3.5-5 kg with the weight of the head gear 1.8-2.2 kg, it would generate a load on the cervical spine equivalent to 48-65 kg at 9 G. Neck movements during high G were found to be the most significant cause of cervicalgia. 82% pilots gave history of upward or lateral movement of the neck while pulling G. The aviation cervicalgia is not uncommonly associated with LBA. The mechanism however is somewhat different over the lower back, wherein the intradiscal pressures under the increasing loads of entire head, and neck and thorax rise tremendously albeit proportionate to the amount of G pulled. Nachemson has worked out the intradiscal pressures in the lumbar region under 1 G condition in 70 Kg man at L 3 disc level. [19]. The IV disc pressure in standing posture was taken to be 100%. The IV discal pressures while standing was found to be 100 Kg, while sitting these increased to 140 Kg. That is IVD pressure while sitting in erect posture was 140%. With trunk forwards, it was found to be still higher as 190%, a common occurrence in aviation. Even the routine activities in normal influence the intra-discal pressures. For example on raising the upper body while getting up from the bed, the weight-bearing flexion was found to exert about 250 Kg of force on IV disc. Otherwise during lying down posture, the IVD

pressure is only 24%. In any such situation, the disc material is pressed against its capsule and especially towards any radial tear if pre-existing from previous trauma. On leaning forward, as in helicopter flying or anti-G straining maneuver the disc exerts a fulcrum effect. The intradiscal pressures may go well beyond 150 kg under 1G itself. As the remaining band of annulus fibrosus rupture, the central disc material is squeezed towards the edges of the vertebral bodies, pushing against its thin ligamentous capsule with all its delicate nerve endings herniated into and prolapsing the disc. Not uncommonly, in absence of any obvious neurological deficit a diagnosis of 'muscle strain' is given. Yet, the herniated disc continues to impose a mechanical problem.

Backache localized in the lumbar area of the helicopter pilots is a well known occupation related hazard. Helicopter pilots have been reported to have comparatively higher incidence of LBA tl on other variants of aircraft. In sitting position, pelvic rotation is effected, bringing the to weight on to the ischial tuberosities and thig The upper edge of the pelvis is rotated backwa resulting in the lumbar and part of the thora vertebral column from lordotic (curved inwards^ kyphotic (curved outward) shape. The bod postures have profound effect on disc pressv. Internal pressure on discs is due to overload resulting in early wearout. Apart from this ejection injuries sustained before conversion fr the fighters in some, may also be responsible. IBA. Several studies have been done in India i abroad on the higher incidence and mechanism backache amongst helicopter pilots. This back p has often been related to helicopter vibrations < poor posture during flight. However, one of recent studies [20] on three different helicor. types Sea King, Bell 412, and Lynxconcluded

Intradiscal Pressure With Change of Posture - Nachemson (1964)

(Total load on L3 disc in different positions of the body in 70 Kg man under I 'G')

S.No.	Position and attitude of the body	Intradiscal pressure in Kg/cn
1.	laxed supine	25
2.	clining lateral decubitus	75
3.	anding upright	100
4.	anding and 20° forward leaning	150
5.	tting upright, arms and back unsupported	140
6.	tting and 20° forward leaning	180
7.	eight lifting *	t
8.	eight lifting with forward leaning of trunk *	tt
9.	raining **	tt

Situations found similar under high 'G' maneuvers-* Involuntary,** Voluntary

the back pain amongst helicopter pilots is related to poor posture, whereas vibrations play a minor role, if at all any. It is well known that during long duration flying, the seat and the helicopter controls force the pilot to assume an asymmetric posture [21]. The helicopter crew continues to balance his body during various phases of flying. The repetitive nature of the trauma bears pathological changes in the spine after a period of time.

Disposal

LBA offers unique challenges in awarding aero-medical disposal. Unlike, those for ground duty personnel any disposal needs to consider the biomechanics of various aviation stresses, which affects the spine adversely. The recommended new aviation environment and the change of stream must consider, what would be his prognosis in new environment. The main aggravating stressors include the vibrations in the helicopters and transport aircraft and the high 'G' conditions in fighters. Bio-mechanical models reveal that a 77kg man holding 90.7 kg of weight in a stooped posture leads to a predicted reaction force of 66 kN at sacrum [22], which is comparable with fracture strength of the end plates of the vertebral body, whose isolated bearing strength is 5-8 kN. The disc pressure increase with increased intra-abdominal pressure in standing and upright posture. However, it reduces with increased intra-abdominal pressure in stooping and leaning postures [19]. Excessive localized loading situations are frequent in aviation. The various anti-G protective maneuvers would raise high intra-abdominal pressure. Under the maneuvers, with external and internal forces acting, die load distribution in human spine becomes very complex. The load factors at a particular site can be visualized as concentrated or distributed in spine, due to body weight itself, increasing external loads; muscle forces, ligamental forces, abdominal pressure etc., as internal loads. All of these would increase under high loads of 'G' as well as vibrations. Compressive forces along the spinal length transmit the loads on the spine. Usually, the compressive damage to the vertebrae and the discs does not lead to the collapse of the spine as the forces remain normally lower than the crushing strength of the vertebrae and discs. Due to sufficient strength of the spine to resist shear forces, the sliding failure of the spine does not occur.

Irrespective of other subjective and objective tests, the visible investigative tools such as imaging tools strongly affect the outcome of the disposal significantly. Unfortunately, over a period of time there has been growing controversy over the findings and interpretation of some of the modern radiological (CT) and other non-radiological imaging investigations like the MRI. It is because 20% of the normal 30 years old undergoing CT/ MRI show asymptomatic presence of herniated discs [15]. This finding lead certain people to misuse them as well support evidence that herniated discs bear no equation with pain or disability. It may require to be taken otherwise in that the presence of any herniated disc in imaging produces strong evidence of previous or fresh unnoticed/ignored injury to the disc system. In case, no other cause is found, the herniated disc still remains the most likely cause of the pain. The presence of herniated disc in many asymptomatic means that in actuality far more people suffer from disc injuries, than is apparent. It also shows that probably, the disc disease was not diagnosed at the time of its occurrence, and the individual had

become asymptomatic by the time he was examined. It is because either the individual gets so accustomed to the pain and the limitations of the movements or the area has become scarred and therefore physiologically/spontaneously stabilized. Both these conditions have relevance in disposal, although the lesion appears quiescent it may continue to keep the potential at becoming symptomatic later even on a minor insult.

Irrespective of the controversies in the interpretation of X-rays, CT and MRI, the fact cannot be denied that the aviators are at high risk as far as the day to day stresses on the spine are concerned. Consequently, any vertebral or discal derangement becomes the issue of high concern while giving disposal. A proper understanding and grading of disc derangements need to be appreciated quite well.

(a) *Disc bulge :* It is the circumferential enlargement of the disc contour in symmetric fashion.

(b) *Disc protrusion :* A bulging disc that is eccentric to one side but is < 3 mm beyond vertebral margin.

(c) *Disc herniation :* Disc protrusion that extends > 3 mm beyond vertebral margin.

(d) *Extruded disc :* Extension of nucleus pulposus through the annulus into the epidural space.

(e) *Free fragment :* Epidural fragment of disc no longer attached to the parent disc.

Disc injury presenting as disc desiccation on MRI is perhaps one of the commonest findings amongst affected aviators reporting for spinal evaluation.

As the disc loses water, which in health is 80% in nucleus pulposus, the MR signal decreases on gradient echo and T2 weighted images. With more advanced degeneration, the disc collapses and gas may form within the disc. Calcification is not uncommon in chronic degenerative disc disease. The degenerative disc may incur three different types of tears viz., concentric, radial and transverse resulting from the rupture of the fibers. Any radial tear of the annulus is potential site for herniations of nucleus pulposus. Most disc herniations occur in a postero-lateral direction into the spinal canal. A herniated disc usually impinges on the nerve root as it comes inferiorly towards the foramen at next lower level. It is important to realize that the herniated disc need not compress the nerve root directly to cause radicular pain. Fragments of nucleus pulposus within the epidural space induce a focal inflammatory reaction that can secondarily irritate the nerve root. Complete disruption of annulus exposes the nuclear material to the epidural tissues, inducing a focal inflammatory reaction.

Appearance of desiccation on any of the imaging systems poses disposal problems. The disc desiccation may occur under the stresses of high 'G' forces. Kramer J studied the nutritional requirements of the inter-vertebral discs. There is no blood supply in the inner disc. The disc is nourished by the diffusion from the outer fibrous tissue. Pressure on the disc, such as under high 'G', would create a diffusion gradient from the interior to exterior resulting in leaking out of the tissue fluid. The opposite happens when the pressure is reduced. Thereby, the repeated

change in posture is beneficial, such as from bent posture to erect and vice versa.

Therefore, the disposal needs to be given on individual merits of the case with due consideration of both subjective and objective tests. When the case is symptomatic with positive objective findings, he is awarded ground category for further recovery and sheltered service. Occasionally, the patient may need rehospitalization for further observations or recovery. When the case is symptomatic without any objective positive findings, or there exists gross incongruity between the pain scale, the objective tests, psychometry with evidence of situational depression, post-stress traumatic disorder etc., he may require to be counseled and treated. Cases having LBA due to low motivation, and or other vested interests are returned to the unit in full flying category for further disposal by administrative channels. Under these circumstances, the flying units may not allow him to fly till his disposal is confirmed and communicated by the latter. The affected needs to be kept under vigilance of supervisor for appropriate time to maintain flight safety.

Disposal of the cases of obvious spinal injury pose lesser difficulties. Cases having chronic LBA attributable to the past spinal injuries sustained during ejection from fighter aircraft, might be found unfit for the ejection seat. Such cases may be considered for changes of stream preferably to fixed wing transport aircraft, wherein the vibrations are less. The helicopter pilots developing backache due to vibrations may be given adequate rest, advice on spinal hygiene, a ground tenure or a change of type in case his overall condition merits that. For reflighting, a gradual exposure to aviation environment is advocated such as observation in low medical category A3G2 with limited flying with qualified crew on type, to observe the performance inflight, to render him more confidence and to induce him gradually back till he gains the required performance levels, without risk of recurrence in the cockpit. After the required period of observations, the crew can be awarded full flying category. Crews having degenerative disc disease pose several problems. The degenerated discs are unlikely to recover and regress within short observation period, as it would take very long time for stabilization and regression. The degenerated disc could become an exciting factor subsequently. With uncomplicated disc desiccation and in absence of any associated disc herniation, the case could be considered far restricted flying when he is found asymptonnbc In all cases of disc bulges and disc protruaoas, if he is able to do all the functional less uneventfully, qualifies goniometric, dynamomcaric, vibration tests etc., he may be given mmm observation and restricted flying, asymptomatic cases, turning symptomatic of the above tests may be grounded for further recovery. Cases with neurologic deficits would be grounded | Cases with reversible neurological deficits i observed and treated in temporary ground category. Almost all the require active follow up and repeated invt Under such circumstances, excessive radiation must be avoided by using investigations. It may be realized that car CTm of lumbar spine exposes a person to >5-M 9Mi of radiation. Care must be taken in suffering with LBA. Bone scan is

especially during pregnancy and is largely avoided in women pilots of reproductive age.

The other challenging factor in awarding disposal is the finding of spinal stenosis on CT/ MRI. The original description of 'Spinal stenosis' is that of non-painful condition with loss of neurological function triggered by physical activity and not by pain per se. [23]. Electrostimulating techniques (F-wave, H-wave) can be used to detect radicular lesions. Asymptomatic cases of spinal stenosis should not be employed in high-'G' or high vibratory environment.

Conclusions

1. Low backache amongst aviators is an established occupational hazard.
2. Acute LBA usually remits within a short period of time; it is the persistent pain beyond usual observation parameters that require major diagnostic studies and evaluation to avoid or limit further chronicity and to give suitable employability.
3. LBA is a multi-diagnostic and multidisciplinary issue. The efficacy of plain X-ray spine is very limited.
4. Most cases of LBA do not require surgical intervention; nevertheless surgical (orthopedic and / or neurosurgical) evaluation is necessary.
5. The disposal requires professional seriousness to avoid overwhelming cost on LBA, loss of trained manpower, adverse psychological effects, personality changes in the affected and the implications on flight safety.
6. The disposal of LBA cases requires holistic and balanced approach. In most cases, it is the residual functional capability in asymptomatic, job related stress tolerance and the existing status of healed / unhealed lesions which decide the final outcome and the employability back in aviation.

Recommendations

1. Preventive programs against occupational LBA need to be initiated for all aviators starting at the basic training level and continued at working levels.
2. As LBA still remain elusive, the infrastructure at evaluating centers requires to be upgraded.

References

1. IAP 4303, 2nd Ed. 1987, Amendment No 35 and 40.
2. Amaresh NB, Sikdar, J, Joshi A, Pandey LC. Stabilization of Thoraco - Lumbar Spinal Injrues. MJAFI 2000; 57: 3-7.
3. Gopal P, Nayar GS, Singh G. Spinal injuries in ejection from aircraft - Indian experience: UASM 1994; 38(2): 170-5.
4. Alam A, Ghosh PC, Aggarwal NN, Gupta JK. Post ejection CT / MRI spine : an appraisal. UASM 2000; 44(2): 7-11.
5. Mixter WJ, Baa JS. Rupture of the intervertebral disc with involvement of the spinal canal. N Eng. J. Med 1934; 211: 210-5.
6. Rossomff HL. Do herniated disks produce pain? Clin. J. Pain. 1985; 1: 91-3.
7. Boden SD, Davis DO, Dina TS. Abnormal magnetic resonance scans of the lumbar spine is asymptomatic subjects. J Bone Joint Surg Am. 1990; 72: 403-8.
8. Gardner AD, Pursell LM, Murty K, Smith DG. The

management of the clinical problem of spinal pain with the assistance of a micro-computer. In Hukins DWL, Mulholland : Back pain. Methods for clinical investigation and assessment. Manchester University Press 1986; 4: 23-41.

9. Ehni G. Significance of the small lumbar canal, Cauda equina compression syndromes due to spondylosis. J Neurosrg 1969; 31: 490-4.

10. Greenough CG, Fraser RD. Psychomertric instruments in low back pain Spine 1991 ; 16: 1068.

11. Pathania VP. Role of surgical management in injuries of thoraco-lumbar spine. MJAFI 2001; 57 : 01 - 02.

12. Bums JW, Loekr TH. Prevalence and significance of spinal disc abnormalities in an asymptomatic acceleration subject panel. ASEM 1996; 849-53.

13. Rimoldi RL, Zigler JE, Capen DA, Serena SH. The effect of surgical intervention on rehabilitation time in patients with thoracolumbar and lumbar spinal canal injuries. Spine 1992; 17(12): 1443 - 9.

14. Kent DL, Haynor DR, Larson EB, Deyo Ra. Diagnosis of lumbar spinal stenosis in adults, analysis of the accuracy of CT/MRI and myelography. AJR 1992; 158: 1135-44.

15. Renick D. Degenerative diseases of the vertebral column. Radiology 1985; 156: 3-14.

16. Aggarwal NN. Cervical Spondylosis following cervical spinal injury - Mirage 2000. A case study. Presented in ISAM annual conference. 1991 (Unpublished).

17. M Petren-Mallmin J Linder. MRI cervical spine findings in asymptomatic fighter pilots. ASEM, 1999; 1183-7.

18. Gupta SK, Mogra AL. Cervicalgia under high sustained G. UASM 1994; 38(2): 3.

19. Nachemson AL. Valsalva maneuver biomechanics -Effects on Lumbar tensile loads of elevated intra¬abdominal pressure. Spine, 1986; 5 : 476-9.

20. Hansen OB, Wagstaff AS. Aetiological factors of back pain in helicopter flying. 42nd ICASM Proceedings, Pub UASM 1994; 38.

21. Vellejo P, Lopez J, Riso F, Jimenez J, Garcia-Alcon,
Velasco C, Azofra J. Helicopter Back pain - Assessment and Evaluation by Surface Electromyography. Presented in AsMA 2000 Scientific Meeting, Houston, TX.

22. Morris JM, Lucas DB, Bresler B. Role of the trunk in stability of the spine. The Journal of Bone and Joint Surgery. April 1961; 43-A: 327-1.

23. Rosomoff HL. Low back pain. Evaluation and Management in the Primary Care Setting. Med.Clin.North Am. 1999; 83 (3): 643-2.