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THE BASIC CLINICAL AND PATHOPHYSIOLOGICAL ASPECTS 0F THE VIBROACOUSTIC DISEASE

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SUMMARY

The effects of long term exposure to excessive levels of high intensity and low frequency noise and vibration led to the concept of "Vibroacoustic Syndrome" (J.C. Guignard, 1992). Clinical manifestations are primarily related to auditory and balanced functions, vision, epilepsy, stroke-type neurological deficiencies and psychic disturbances. Neurological examinations were normal in only 20% of men with the disease. There is an association of the psychopathological level with anxiety, depression and hostility. Patients have an increased risk of thromboembolism with lower fibrinolysis activity (low values of euglobulin time), platelet hyperaggregation and increased plasma fibrinogen and viscosity. There is a vibration-induced hyper-responsiveness of arterial smooth muscle to noradrenaline, and noradrenaline levels are elevated. Basal levels of prolactin and cortisol are depressed. All patients have some degree of permanent noise-induced hearing loss. There are changes in the retina and dentoalveolar examination reveal osteolysis. Studies with magnetic resonance imaging (MRI) demonstrate CNS lesions. Vascular lesions with predominant involvement of peripheral small arteries (intimal thickening) have been described in almost all areas of the body and all patients have some degree of mitral valve and pericardial abnormalities. In these patients, the incidence of malignancy is very high, and the frequency of sister chromatid exchange is significantly increased. There are descriptions of irreversible morphologic and electrophysiological changes induced by noise and vibration. These changes seem to be related with abnormalities of the central nervous and cardiovascular systems. There is a connection of the thalamic nuclei with the reticular activating system which influences the autonomic control center in the lower brain stem, controlling endocrine and vegetative functions of the body with relevance to cardiovascular dynamics.

INTRODUCTION

OGMA-SA (Oficinas Gerais de Material Aeronautico - Sociedade Anónima) is the leading aeronautical industry in Portugal. When the employee is hired by this company, s/he is subjected to a medical check-up, performed at the on-site medical unit, by occupational physicians, as required by law of all manufacturing facilities. Subsequently, there are annual examinations, and all medical complaints are recorded in the employee's medical file. The on-site medical unit at OGMA-SA offers the employees a variety of medical specialties free of charge, such as internal medicine, cardiology, endocrinology, psychiatry, neurology, clinical and social psychology, dentistry, orthopedics, general surgery, ophthalmology and otorhinolaryngology. If the employee requires a specialist not available in the on-site medical unit and wants to make use of the National Health Care System, then s/he must be referred to that specialist by one of the on-site general physicians. Again, all information is recorded in the employee´s medical file. Since this particular aeronautical plant has existed since 1918, the medical files of all employees are extensive and very complete. These circumstances allowed our research group to compile a large amount of data with follow-ups and periodic examinations, including relevant medical tests such as audiograms, visual physiology, spirometry, blood and urine chemistry analysis, and chest x-rays. For the past ten years, our study population, males (only recently have females begun to be employed in these workplaces at OGMA) occupationally exposed to high-intensity and low-frequency noise, has been subjected to a set of complementary tests such as echocardiograms, MRI of the Central Nervous System (CNS), and multimodal evoked potentials. Nevertheless, there are still some individuals included in our study population who have not yet received their entire range of medical tests, mainly because they are posted at OGMA-SA branches in other countries.

The goal of this study is to characterize the pathophysiology and progression of this disease, and define the various clinical stages of the VAD. In 1956 Professor Eugenia Andreeva-Galanina (4,5) developed a classification for the hand-arm vibration pathology. Other authors, namely Milkov, have also established a classification for the vibrational disease (26). Similarly, we have defined three stages for the Vibroacoustic Disease: Stage I - mild signs; Stage II - moderate signs; and Stage III - severe signs.

MATERIALS AND METHODS

We carried out medical examinations of 140 males, who perform daily engine run-up procedures as part of aircraft maintenance programs, along with a comprehensive and chronological review of each individual medical file. Simultaneously, family and friends were interviewed by a sociologist and a social worker in order to obtain additional information on the

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individual's behavior outside his professional activity. The information was compiled and statistical analysis was performed on the results. The average age of the population is 42 years (SD = 10.4).

The criteria for exclusion of patients from the study population are shown in Table I. Using these criteria, we eliminated 166 patients leaving a study group of 140 workers.

TABLE I : Exclusion criteria for the Study Population.

CONDITIONS	COMMENTS
Streptococcal Infections (by history)	Due to their propensity to induce extracellular matrix changes.
Pre-existing Cardiovascular Disease	But not labile hypertensives (discussed elsewhere in this Supplement).
Tobacco Abuse	Smokers of more than 20 cigarettes a day.
Alcohol Abuse	Drinkers with more than a liter of wine per day. (10-12% alcohol content)
Drug Use	Users of any recreational or psychotropic drug.

RESULTS

Tables II, III and IV list the mild, moderate and severe signs of the VAD, respectively. Exposure time refers to the average number of years it took for 50% of the study population (140 subjects) to acquire the corresponding sign and symptom.

Stage I - Early Signs

In a first stage, and based on reports from family and friends, the individual begins to have mood swings. His behavior changes primarily by avoiding remaining in noisy environments such as clubs, cafés and parties. He becomes irritable and begins isolating himself. Family and friends also report memory lapses, but statistically significant cognitive changes were only found in Stage II.

TABLE II : Clinical Stage I - Early Signs.

Clinical Stage	Signs, Symptoms and Diagnostic Disorders	Exposure Time (± SD) (years)*
I	slight mood swings	2(±2.1)
MILD	slight gastrointestinal dysfunction	2(±2.2)
SIGNS	oropharynx infections	2(±2.3)
	bronchitis	2(±2.4)

* The exposure time required for the sign/symptom to manifest itself in 50% of the workers.

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Chronologically, as corroborated by evaluation of the medical records right after they begin their occupational activity, there are complaints of non-specific stomach aches, flatulence and colic.

On average, two years later, more than 50% initiate frequent and repeated visits to the on-site physician, complaining of oropharynx infections and bronchitis.

Stage II - Moderate Signs

[*Table III : Clinical Stage II - Moderate Signs.*

Clinical Stage	Signs, Symptoms and Diagnostic Disorders	Exposure Time (± SD) (years)*
II MODERATE SIGNS	chest pain	5(± 5.8)
	definite mood swings	6(± 4.5)
	back pain	6(± 5.9)
	fatigue	7(± 5.9)
	fungal, viral and parasitic skin infections	7(± 6.2)
	gastritis	7(± 6.8)
	pain and disuria	8(± 7.1)
	conjunctivitis	9(± 7.0)
	allergies	9(± 7.2)

* The exposure time required for the sign/symptom to manifest itself in 50% of the workers.

After 5 years of occupational exposure, 72 individuals complain of chest pains. The characteristics vary for each patient. Pain was bilateral in only 10 patients; 48 complain of the left thorax more than the right, and most of the descriptions are like pleurodynia.

Behavioral changes become more pronounced after about 6 years of occupational exposure. They claim that they "hear too much", but they already have some hearing loss even though the Metz test is negative. Their social isolation increases and becomes an active process. Hearing loss causes a decrease in social contact; but sound intolerance causes social incompatibility. They cannot even stand music (19).

Back pain is one of the most common complaints in this Stage. There are no imaging diagnostic methods to identify the cause. Even other neurophysiological methods are useless for diagnostic purposes. Later in Stage III, imaging of bone and disk pathology, and electrophysiological parameters provide the evidence for the organic nature of these complaints. It should be noted that when these workers complain of their pains to the physician, and in the absence of any radiological lesions or other signs of definitive pathology, they are regarded as malingerers who are looking for a way to get sick leave.

After about 7 years of exposure, they complain of fatigue often appreciable and which they cannot adequately explain. Twenty-seven of these asthenic individuals refer to anorexia that in 2 cases was accompanied by selective appetites.

Skin infections after this same exposure time affect almost the entire population. In approximately 30% of the cases, simultaneous fungal and viral infections appear in the oral cavity.

Dyspeptic complaints are very frequent after 7 years of exposure. Inflammatory and peptic lesions of the stomach and duodenum are confirmed by radiological and/or endoscopic studies.

Urinary tract complaints including pain, disuria and renal colic, emerge after 8 years. Usually, this pain disappears with vacation and rest. Uroanalysis reveals microscopic hematuria and in the majority of the cases (approximately 80%) there is no associated infection, including alcohol- and acid-resistant bacilli. There are no symptoms of any prostate pathology. Thirty-two patients had kidney stones, 30 were calcium salts and the remaining 2 were uric acid salts. It is interesting to note that when the individual performs a prolonged run-up procedure (more than 2 hours), even if he has just begun his professional activity, he too will present hematuria without infection.

Conjunctivitis is another very frequent clinical finding, affecting 71 patients after 9 years of exposure. Conventional treatment is useless. With corticoid therapy, there are short-lived periods where the inflammation disappears, but the rate of relapse is high. These symptoms disappear during vacation. In 6 individuals who changed workplaces (within OGMA) for other reasons, these symptoms disappeared entirely.

Also after about 9 years of exposure, allergic reactions are very common, the most frequent being skin rashes, urticaria and allergenic rhinitis.

Stage III - Definite Signs

***Table IV** : Clinical Stage III - Definite Signs.*

Clinical Stage	Signs, Symptoms and Diagnostic Disorders	Exposure Time (± SD) (years)*
	psychiatric disturbances	11(±7.1)
	hemorrhages of nasal, digestive and conjunctive mucosa	12(±9.0)
	varicose veins and hemorrhoids	12(±7.2)
III	duodenal ulcers	12(±7.5)
SEVERE	spastic colitis	13(±7.0)
SIGNS	decrease in visual acuity	13(±7.3)
	headaches	13(±7.4)
	severe osteoarticular pain	13(±7.7)
	intense muscular pain	14(±6.7)
	neurological disturbances	15(±7.9)

* The exposure time required for the sign/symptom to manifest itself in 50% of the workers.

After 11 years of exposure, over 53% of the population have been to psychiatric counseling referred by the on-site general physician at OGMA. The most frequent diagnosis is anxiety, depression, and in five cases, suicidal tendencies. There were 5 suicidal attempts, 4 unsuccessful. These suicidal individuals do not feel shame for their attempted suicide, nor do they really know what happened during the incident. This is not the usual behavior for most suicidal individuals. Simultaneously they over-react violently and aggressively to a variety of stimuli, especially sudden and intense noise. They have frequent memory lapses with the expected cognitive deficit (7,20).

Nasal, digestive and even conjunctive mucosal hemorrhages appeared in individuals after 12 years of occupational activity. Beyond the hemorrhagic lesions, vascular pathology with a constitutional component is frequent. Varicose veins and hemorrhoids occur in over 50% of the population after 12 years of exposure.

At the same time, major gastrointestinal pathologies appear, namely duodenal ulcers and spastic colitis. Other kinds of pathologies that usually arise after this period of exposure are esophagitis (in 19 individuals), esophagus diverticula (in 4 individuals), appendicitis (in 17 individuals) and colon diverticula (in 5 individuals). Gallbladder dyskinesia was diagnosed in 17 individuals.

Slight visual changes are also frequent. After 13 years of exposure, over 50% of the individuals have a significant decrease in visual acuity, which in some cases is non-correctable (39).

Over 50% of the entire population frequently complain of headaches after 13 years of exposure. These are difficult to characterize and relatively resistant to normal therapeutics.

Severe osteoarticular pain is very frequent after 13 years of exposure and generally occurs unilaterally and in the large joints, e.g., scapulo-humeral, elbow and knee. In 59 cases of severe joint pain, only 8 are bilateral and these are all in the knee. Pain in the knee joint is the most frequent (31 individuals), in 21 the pain in located in the scapulo-humeral joint and in 7, the pain is located in the elbow. In most cases there are visible radiological lesions. Of the 21 individuals who have elbow pains, 17 complain of the right elbow and the remaining 4 of the left elbow. These 4 individuals are the only left-handed subjects of the group. Osteo-articular lesions caused by noise and vibration are well-known (15). Even though our group has not given much attention to this type of pathology, the study we performed on the dento-aveolar structures of these patients revealed the presence of considerable lesions (12).

Of the 140 individuals, 71 complain of very intense muscular pain, 44 of whom get severe neck stiffness, after 14 years of exposure. Later, muscle contractions are sustained and very painful.

There are neurological changes in 70 patients, the most frequent being the archaic palmo-mental reflex. Four individuals presented facial dyskinesia triggered by auditory stimulus, also after 14 years of exposure (24,32). Some individuals are currently being evaluated with electromyography, revealing permanent contraction of a group of muscles on one of the sides of the chin. We believe that these two phenomena are interrelated in that both represent an inhibition of the upper cortical control on the lower pontine centers.

Late epilepsy was diagnosed in 22 individuals (13,17, 23). Balance disturbances are one of the most common findings in over 50% of the patients, although the severity of the balance disturbance range from dizziness to severe vertigo. One patient falls each time he closes his eyes. The entire study population received brainstem auditory evoked potential evaluations. In the individuals suffering from balance disturbances, we identified an asymmetry of the brainstem evoked potentials that was correlated with MRI hyperintensities in T2, located in the deep white matter and the basal nuclei (13).

Unique and sudden episodes of non-convulsive neurological deficit occurred in 11 individuals. These were diagnosed as cerebral ischemic vascular accidents, which is compatible with the imaging studies. EEG and multi-modal evoked potentials showed considerable power changes that are in agreement with the neurological clinical evidences (7,18).

Some kind of respiratory insufficiency was found in 24 of the 140 patients, 11 of which were smokers. In 10 cases all it took to manifest itself was some light physical effort. It should be noted that only 45 of the 140 individuals are smokers. The lung pathology observed in our human study population has been successfully reproduced in rats exposed to occupationally simulated, high sound pressure level and low frequency noise (21).

Other important pathologies have been found in these 140 individuals, and in spite of not reaching 50% of our study populations, their incidence is clinically important, e.g., endocrine disorders the most common being thyroid dysfunction (18 cases) and diabetes (16 cases). It should be noted that the average age of the subgroup which has diabetes is 39 years (SD = 7.8). The overall rate for diabetes for a similar age-group is 4.6% (22) while in our subgroup it is 11.4%. Additionally, the overall rate for adult thyroid dysfunction is 0.97% (33), and our subgroup has 12.8%.

Lastly, the highly sensitive subject of malignancy. In these 140 individuals, 28 had malignant tumors with peculiar characteristics. Since the first autopsy performed eleven years ago on one of our patients, we realized that malignancy can be a serious problem in the VAD. The cause of death of this first autopsied patient was cardiac tamponade from a ruptured myocardial infarct. The necrospy study revealed the existence of two previously unsuspected malignant tumours: a microchystic astrocytoma (grade I) and a Grawitz tumor in the left kidney (8). In the 28 cases, 5 had simultaneous tumors of different types. In 3 of these 5 cases one of the simultaneous tumors was a Grawitz. All the CNS tumors (5 cases) were malignant glyomas. Other tumors were found in the stomach (10 cases), colon and rectum (9 cases), lung (5 cases), larynx (1 cases), soft tissue (1 case), bladder (1 case). Up until now (December 1997) of these 28 individuals, 8 are deceased. One of the features appears to be a good survival rate after therapy, even in cases with large tumors and some with regional metastasis. An epidemiological study is underway to further and more fully characterize this important area. The mutagenic effect of occupational exposure to low-frequency noise was confirmed by assessing the frequency of sister-chromatid exchanges in lymphocytes of workers (38).

Pathologies that may appear at any time

Thickening of Cardiac Structures

Echocardiography evaluation revealed thickening of cardiac structures, large and small vessels, in 100% of the study population. This is the object of an independent study.

Prof. T. Matoba was the first to describe thickening of cardiac structures in some patients working with chainsaws (25). There is no correlation of cardiac structure thickening with age, nor with exposure time (6, 31). Some susceptible individuals presented very evident thickening after only 2 or 3 years of occupational exposure to high-intensity and low-frequency noise. Of the 140 individuals, 130 (98%) present pericardium thickening and the remaining 4 have thickening of the mitral and aortic valves. Morphological changes of the extracellular matrices of cardiac structures are much more frequent than auditory changes obtained through audiograms. This indicates that the diagnostic and follow-up tool of choice is the echocardiogram. Until now there are no published studies relating the thickened cardiac structure to echocardiography findings. There are descriptions of intimal artery thickening (2). Two studies are currently underway in order to establish a specific correlation between the echocardiography imaging and the gross anatomy of the pericardium. One involves 5 human pericardia obtained from patients of our study population, and who were submitted to cardiac surgery for other reasons. The other study is being performed on sheep.

Professional Hearing Loss

The most frequent auditory deficit is in the 250 Hz and 500 Hz bands. Only 4 individuals of the 140 had a hearing deficit at 4000 Hz. The asymmetries of the auditory deficit are associated with the balance disturbances. The Metz test does not confirm that the noise intolerance observed in this population is due to recruitment. The recruitment-like phenomena is most probably of a central origin. There is a positive correlation between the thickness of the mitral valve and auditory deficit at 250 Hz, and between the thickness of the aortic wall and auditory deficit at 500 Hz. This is the object of an independent study.

Disabilities resulting from On-The Job Accidents

Accidents serious enough to involve leave of absence were documented in 75% of the population (3). Of these, only 29% had only one accident, while 71 % had more than one accident. Some had over 3 accidents. The first accident occurred during the first 3 years of professional activity for 48.5%. We found these numbers are much higher than in any other population employed by a manufacturing plant that does not have high sound pressure level and low-frequency noise environments. Even though our population is more prone to having on-the-job accidents, there is no association between accident frequency and the clinical stages.

Discussion of The Vibroacoustic Disease

Other Studies

The pathologies associated with the Vibroacoustic Disease have been identified by many authors in the past. In 1946, Dart describes a similar clinical picture in workers employed by the Ford aeronautical factory in Detroit (14). In 1961, Rumancev also describes a similar clinical picture in workers employed by a concrete factory in the Soviet Union (36). Sanova, in 1975, studied workers of compressor shops, where noise is characterized by high sound pressure level (87-98 dB) and low-frequency (16-31.5 Hz). This author found essential changes of the external respiratory function and changes of the vegetative nervous system (37). In 1991, Ostapkovich claimed that intensive industrial noise induces an independent nosological form of pathology, characterized by hypoacusis, neurodynamic and neurocirculatory changes, and a combination of disorders of the cardiovascular and central nervous function (30). Also in 1991, Podolskaia studied the morbidity of workers employed in the main shops of a machine-building plant. The leading cause of death was attributed to acute respiratory and cardiovascular pathology (34).

Primary Category	Diagnostic Disorders	Symptomatic Complaints
Neurological	Acute anxiety, Neurosis, Sciatica, Radiculoneuritis, Hemiplegia	Headache, Dizziness, Numbness
Digestive	Ulcer (duodenal and peptic), Gastritis, Diverticulosis, Acute gastroenteritis, Appendicitis	Stomach cramps, Nausea, Diarrhea, Heartburn
Cardiovascular and Circulatory	Tachycardia, Angina pectoris, Hypertension, Hypotension, Coronary sclerosis	Pain in chest and arm (with history of heart disease)
Otological and Audiological	Blocked eustachian tube, Ear infection, Otosclerosis, Suppurative ear	Ear bleeding, Earache, Ringing ear, Difficulty in hearing
Allergenic and Dermatological	Skin growths and rashes, Infections, Psoriasis, Urticaria, Asthma, Allergenic Rhinitis	Skin itching, Skin burning
Respiratory	Pharyngitis, Pneumonia, Bronchitis, Cold and sore throat	Coughing, Congestion in head and chest, Shortness of breath, Hoarseness
Glandular	Hyperthyroidism Hypothyroidism, Diabetes, Prostatitis	Overweight, Underweight
Urological	Kidney stones, Nephritis, Renal colitis, Cystitis	Irregular urination, Pain in bladder area, Blood in urine
Muscular and skeletal	Fibrositis, Arthritis, Hernia, Bursitis, Rheumatism, Tendonitis, Myositis	Backaches and neckaches, Soreness in muscles, Cramps

Table V *: Categorization and Examples of Diagnostic Disorders and Symptomatic Complaints*

(Reprinted from the Journal of Safety Research, 8, A. Cohen, The influence of a company hearing conservation program on extra-auditory problems in workers, p 150, Copyright 1976, with kind permission from Elsevier Science Ltd, The Boulevard, Langford Lane, Kidlington 0X5 1GB, UK)

There are other studies that attest to the extra-aural effects of noise. Mohr et. al. in 1965 submitted five human subjects to high intensity (up to 154 dB) and low-frequency (1-100 Hz) noise. Subjective reports given by the exposed individuals included complaints of chest wall vibration, gagging sensation, coughing, and choking respiration. One subject continued to cough for 20 minutes after exposure (27).

In 1969, Ponomar'kov et al. exposed dogs to wide band noise of 130-135 dB. The dogs, sacrificed after 1.5-2.0 hours of exposure, had pulmonary hemorrhages up to 3 mm in diameter (35). More recently, Nekhoroshev et al. exposed guinea pigs to 8 and 16 Hz at 120-140 dB, 3 hours daily for 1, 5, 10, 15, 25 and 40 days. After studying the morphofunctional changes in the myocardium, they reported problems of blood flow leading to widening of capillaries, fragmentation of myofibrils in the region of z-line, and pieces of fragmented chromatin around the edges of the nuclei (28).

In an outstanding study performed by Cohen in 1976 on 400 workers employed by a boiler plant, the implementation of a hearing protection program was shown to decrease absenteeism and diagnosed disorders (11). However, the number of symptomatic complaints did not decrease and, in fact, were increased. The goal of this study was not to show that an extra-aural clinical entity exists in occupational noise environments. However, it does just that, as can be seen in Table V, reproduced from his work. In other words, the use of hearing protection neutralized the alarm organ (the ear) and allowed the workers to remain in the noisy environment for longer periods of time without any awareness of the consequences of acoustic pressure exposure. All the symptomatic complaints and diagnosed disorders listed for these workers are very close to those which characterize the Vibroacoustic Disease.

Thus, Cohen found a multitude of symptoms, affecting many different organs and systems, and which have been very difficult to attribute to noise exposure alone. Although the purpose of his paper was somewhat different than ours, his findings appear to validate our observations.

Other Comments

One of the most frequent clinical situations observed in these patients, even in Stage I, are infections. This higher incidence of infections has been reproduced in animal models (29). In fact, individuals exposed to low frequency noise have important immunologcal changes (10) which have also been reproduced in animal models (1). The respiratory infections observed in our patients, right from the beginning of their exposure time, are intimately associated with the morphological changes and damage caused by the low frequency noise on the epithelial cells of the entire respiratory tract (9, 21,29). Lastly, the effect that this type of noise has on the respiratory tract may justify Mohr's observations on his voluntary human subjects (27) as mentioned in the previous section.

Since the VAD is insidious and with a vast number of nonspecific signs and symptoms, most patients are accused of malingering. Also, in many instances, there is no diagnostic technique that can confirm the organic nature of the patients' complaints. Thus the VAD goes largely undetected and unchecked, and the workers are even penalized for their repeated absences and lack of productivity. In some cases this has led to alcohol abuse.

One of the main reasons for the continuing controversy about this pathology is the insistence of many scientists on the study of pure models. In the case of occupational noise environments, this is virtually impossible. Even if an environment is classified as "vibrational", there is no escaping the noise that is inherent to this environment. Similarly, an environment classified as "noisy" always has some component of vibration. It is important to note that vibration at or above 16 Hz produces noise, and low-frequency noise induces vibration through the phenomena of resonance. In spite of successive world-wide and independent publications indicating the existence of an extra-aural effect in occupational noise environments, there are equally successive papers neutralizing and/or invalidating this clinical evidence. Using arguments such as, "noise is a confounder of vibration", and so forth, the idea of an extra-aural pathology is successfully undermined and is never taken seriously enough (16). This is one of the reasons why the study population used in this paper consists only of workers who perform aircraft run-up procedures. Had we included workers of other professions, equally exposed to high sound pressure levels and low-frequency noise, and diagnosed with the VAD, extraordinary pathologies never previously described could have been discussed, such as 2 cases of reflex epilepsy, where a Jacksonian partial crisis is triggered by contact with a vibration tool (32).

Meanwhile thousands of individuals are suffering because:

1) occupational physicians are not aware of this pathology, since this topic is not taught in medical schools;
2) the patients are frequently accused of malingering;
3) the eventual disabilities are not recognized as a professional hazard, risk or disease and lead to extreme social and family dysfunction;
4) the patients are not eligible for any type of anticipated retirement nor compensation; and
5) the patients die at an early age, with no recognition of the real occupational cause of death, and with all the consequences this brings to their families.

Beyond the ethical and human aspects, serious economic factors must be considered. Among these are the on-the-job accidents, low productivity, high absenteeism, destruction of equipment due decreased performance, and the obvious associated loss of profit given all these factors. The medical costs of these individuals affect the entire society.

This is why this subject is so touchy. If the Vibroacoustic Disease is recognized as the occupational disease that it is, the number of compensations owed to thousands of workers throughout the world is vast. This brings an apparent cost to insurance companies, employers and governments. But to continue denying its existence causes an even higher cost to these entities. It is urgent to tackle this problem immediately.

Unfortunately, it is not only in the occupational setting that one is exposed to low-frequency noise. Traffic and public transportation are an important source of low-frequency noise, as are dance clubs, high-powered car and home stereos, lawn mowers and leaf blowers, and leisure vehicles (jet skis, motorcycles, etc.), among others. The common citizen is daily exposed to these environments, voluntarily or not. In fact, the younger generation is almost continuously exposed to music where the low-frequency bands are very significant, and are boosted by increased bass levels. In teenagers and young adults, these situations induce changes in the normal development of the endocrine and immune systems. When this generation enters the work force, where they are apt to be *occupationally* exposed to this type of noise, they already have the stigma of these previous exposures. The extent to which they already present signs and symptoms may indicate the individual susceptibility to this stressor. Thus there is an urgent need to have rigorous and well defined physical examinations for potential employees who will be working in these types of environments to avoid disabilities at a young age, on-the-job accidents, and an overall economic loss. It should be noted that, at least in Portugal, any pre-existing pathology that is aggravated by occupational activity is of the responsibility of the employer. So if selection of employees is not taken seriously, the costs for the employer are not only substantial, but are also unfair, because the employer cannot be liable for the employee's previous activities. Low-frequency noise is omnipresent in modern society and thus should be considered an issue of public health.

The exploration of Space is another field where low-frequency noise is pervasive. This is due to two major sources: the life support systems and the more modern and flexible composite materials used to build the spacecraft structure. Since spacecraft are in vacuum, the acoustic energy is absorbed only by living organisms. This is aggravated by the fact that in space crews, exposure occurs 24 hrs a day because there is no sanctuary for recovery. Interplanetary flights will involve years of continuous exposure. Mood and behavioral disturbances are the first signs of the VAD, and this may seriously jeopardize any long-term mission. Studies should be focused towards selection of the less susceptible individuals, and all possible measures of protection including pharmacological, chemical, physical and psychological must be investigated in order to avoid undue morbidity that could adversely affect mission completion.

In the military field, performance impairment may be acute or insidious. It is acute when the individual is subjected to long-term extreme environments such as actual combat conditions or extended live training operations. It is insidious when exposure to extreme environments occurs irregularly over long periods of time. In the military, low-frequency noise is one of the most important but also the most neglected stressor, occuring in locations such as armored cars, submarines, helicopters, among others. The consequence of decreased performance may be revealed by weapon systems malfunction, waste of ammunition or even destruction of the entire equipment. We cannot forget that today any soldier is a technician; the learning process is expensive and long. Long-term exposure to this type of noise, even during training, may shorten the person's lifetime, and may impair or disable the individual. The costs are first supported by the military, and later by the entire community.

We urge the scientific community to direct efforts towards

a) studying a means for some protection;
b) identifying groups at risk;
c) establishing selection criteria for workers for these types of environments;
d) defining occupational standards that would avoid later disabilities; and
e) allocating funds for studies to explore the VAD as an analog for other pathologies; e.g., immunodepression, extra-cellular matrix biology, epilepsy, and movement disorders.

CONCLUSION

The Vibroacoustic Disease is a nosologic entity induced by occupational exposure to high sound pressure level and low-frequency noise. There have been numerous descriptions of the signs and symptoms, some of them published over 20 years ago, that validate this present work. In the real world there are no pure environments. Acoustic frequency spectra are continuous; but certain frequency bands can predominate. In the Vibroacoustic Disease, signs and symptoms are related to the predominance of low-frequency bands. Thus, the main clinical picture has a systemic character, involving the whole body, with special emphasis upon neurological, respiratory and cardiovascular pathology.

In the beginning, the clinical complaints do not have a gross morphological or clinical basis, but with time, as the lesions establish themselves, there is a chronological stratification of the findings.

The clinical evaluation of our medical files led to the establishment of the three clinical stages. In Stage I, slight mood swings are evident, as well as non-specific gastrointestinal and respiratory complaints. In Stage II the symptoms and signs become more intense; numerous infectious and inflammatory processes occur, associated with an immunological component. In Stage III the clinical picture becomes severe, with psychiatric disturbances, neurological, respiratory, osteo-articular, cardiovascular and gastrointestinal pathological conditions.

Underlying this pathology are important immunological, endocrine, hemostasis and coagulation changes, and extra-cellular matrix proliferation. All these mechanisms are interwoven, even though the exact relationship is not yet well defined. However, the activation of myofibroblasts to produce extra-cellular matrix, the existence of immunodepression, and the activity of the endocrine system are undoubtedly interrelated, and are at least partially responsible for pathology we observe in our population. This pathology is not pure, just as the environments are not pure. There are also contaminating pathologies caused by exposure to the higher frequency bands, and given enough time, they will also be apparent.

One last point must be made: many aeronautic, aerospace and military professions have specific characteristics that are normally not taken in account in occupational medicine for forensic purposes, such as large variations in daily exposure time. Sometimes personnel are exposed to an extreme environment for 24 hrs, and then may go a week with no exposure. Strict guidelines for an 8-hour daily exposure are inadequate where noise is concerned. The consequences of working 1, 2, 6 or 10 hours are completely different. If exposure time is too long, lesions become definitive. Experts who define standards must be aware of these peculiarities, and must work on the basis of exposure times not of days, but of years. The number of exposure hours responsible for the no-return in terms of irreversible occupational lesions are not evenly distributed throughout a 24 hr period. Nevertheless, professional diseases are generally established on the basis of daily exposure.

This pathology is insidious, so it is mandatory that the first signs be adequately recognized. This will identify the susceptible individual and will allow for the necessary measures to avoid permanent disability. Thus, it is fundamental that the physician have a high degree of suspicion and that the occupational environment of the patient is properly evaluated and defined.

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