Low Frequency Noise-Induced Pathology: Contributions Provided by the Portuguese Wind Turbine Case

Nuno A. A. Castelo Branco, M.D.
Senior Surgical Pathologist, R. Prof. Dias Amado, No. 5-1B, 1600-612 Lisbon, Portugal

Mariana Alves-Pereira, Ph.D.
Biomedical Engineer, Lusófona University, Campo Grande 376, 1749-024 Lisbon, Portugal

Augusto Martinho Pimenta, M.D.
Senior Neurologist, Julio de Matos Hospital, Av. do Brasil, 53, 1700-063, Lisbon, Portugal

José Reis Ferreira, M.D.
Senior Pneumologist, Clínica Doentes Pulmonares, Campo Grande, 4, 1700-092, Lisbon, Portugal

Summary
In November 2006, 4 Industrial Wind Turbines (IWT) were installed in the vicinity of a residential dwelling in Portugal. In March 2007, this team was contacted by the family requesting assistance in dealing with their Infrasound & Low Frequency Noise (ILFN) problem that they claimed was being generated by the IWT. The family began legal proceedings for the removal of the IWT, and in September 2007, this team's first report was presented at the 2nd International Meeting on Wind Turbine Noise. In June 2010, a follow-up report of this case was presented at the 14th International Meeting on Low Frequency Noise and Vibration and its Control, wherein ILFN-induced pathology was confirmed through histology in this family's thoroughbred horses. The goal of this report is to provide second follow-up to this case, five years later.

PACS no. 43.40.Ng, 43.50.Qp, 43.80.Gx

1. Introduction

(Please see disclaimer notice provided at the end of this report.) Over the past 35 years, this team of scientists has studied the biological response to Infrasound & Low Frequency Noise (ILFN) exposure in both human populations [1-4] and laboratory animal models [5-7]. Initially prompted by the signs and symptoms observed among a population of aeronautical technicians [3], by the mid-1990's, study populations included commercial airline pilots and flight attendants [8,9]. In 2001, the team began receiving complaints from families regarding ILFN in their homes [10], and subsequently the inquiry was widened to include residential exposures [11]. By 2007, this team had already accumulated a vast body of knowledge regarding the biological effects of ILFN exposure, including a clinical protocol for establishing the extent of ILFN-induced pathology [1,2,12]. It is within this context that private citizens worldwide have requested our assistance with their ILFN-related issues.

2. First Contact in March 2007

In November 2006, 4 2-MW Industrial Wind Turbines (IWT) were installed in the vicinity of the farm of Family R. This rural dwelling also housed the family's business: breeding thoroughbred Lusitanian horses and bulls for bullfighting events. The IWT were installed at a distance of 321-642 m from the residential home. Complaints of sleep disturbances were first reported in December 2006. In mid-March, Mr. and Mrs. R received a letter from their 12-year-old son's schoolteacher, expressing concern for the growing difficulties in an otherwise outstanding student, "*particularly in English, Humanities and Physical Education. He progressed in Mathematics, which is a field that naturally attracts his type of intelligence. However, in the above mentioned coursework, it seems that [the child] has lost interest, makes a lesser effort, as if he were permanently tired. In Physical Education,*

an abnormal amount of tiredness is also observed. Is [the child] leading a healthy life? Does he sleep sufficient hours during the night?" This immediately prompted the parents to begin legal proceedings and seek medical assistance, and thus, this team's first contact with Family R. During the month of April 2007, Family R hired an accredited acoustical firm to conduct continuous acoustical monitoring of ILFN both inside and outside their home, for a period of 2 weeks, and that included real time wind speed data. Legally stipulated annoyance levels were exceeded during the day (7am-8pm), evening (8-11pm) and night (11pm-7am) hours. dBA noise levels were also exceeded for a sensitive zone during night hours, but were within legal limits for a mixed zone. Municipal Authorities where Family R.'s property is located had not yet classified the area as sensitive *or* mixed. Numerical data regarding acoustical and wind speed information, independently collected by the accredited firm, was provided to this team for analysis. Figure 1 provides a visual comparison of ILFN levels inside the master bedroom under different conditions.

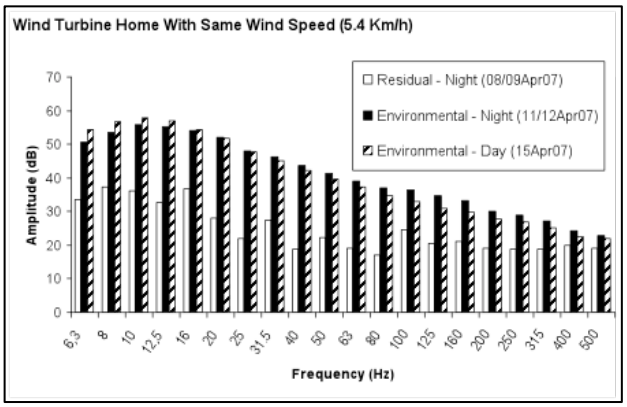

Figure 1. Comparison of ILFN levels in 1/3 octave bands, in dBL, *at the same windspeed*, and recorded inside the master bedroom. Residual (no IWT blade movement); Environmental (with rotating IWT blades) [13].

These ILFN levels were compared to those obtained in other ILFN-rich residences and occupational environments [13], and were deemed to be problematic for the health of this family. In order to obtain relevant clinical data, specific medical examinations were provided. For the rationale justifying the medical examinations reported herein, please see [1-3, 12]. The 12-year-old child received a neurological test assessing cortical nerve conduction times: P300 Event Related Evoked Potentials (ERP). P300 ERP disclosed nerve conduction time to be 352 ms, when expected value should be closer to 300 ms. Brainstem Auditory Evoked Potentials (BAEP) disclosed asymmetries in the right and left nerve conduction times, and the right I-V interval interlatency value was at the threshold of normal (4.44 ms). Mr. and Mrs. R. disclosed slight to moderate pericardial thickening: between 1.7 mm and 2.0 mm (normal for the equipment in use: <1.2mm) [12]. Respiratory drive was below normalized values in both adults (46%-53%, normal: >60%), suggesting the existence of brain lesions in the areas responsible for the neurological control of breathing [14]. Observations made by the family included animal behavioural changes: Horses were seen to lie down and sleep during the day; Dogs were lethargic, and no longer jumped up requesting attention from their owners; Ants simply disappeared. All data was presented at the 2nd International Meeting on Wind Turbine Noise, held in Lyon, France in September 2007, where this team concluded that precautionary measures regarding the placement of IWT near residential dwellings were justified, and that safe distances between IWT rotating blades and inhabited buildings had not yet been determined by the scientific community [13].

3. 2010 Update and Equine Pathology

By 2010, Mrs. R and the children no longer resided in their rural home, having moved to a suburban apartment. For Mr. R, however, this was not an option given the care required by thoroughbred Lusitanian horses and prize bulls that, as his only source of income, he bred and trained for bullfights. After the summer vacation in 2007, spent away from the farm, the 12-year-old child had again received the P300 ERP examination that, this time, disclosed nerve conduction times much closer to normal: 302 ms. In 2010, this child was again an outstanding student, top of his class. Over these 3 years, Mr. R's health and wellbeing had continuously and visibly deteriorated: intolerance to (any) noise had become more severe; situations compatible with an unregulated sympathetic nervous system increased in frequency; and cognitive impairment became more pronounced. As a result of the first phase of the (still ongoing) legal proceedings, IWT were

ordered to be shut down during evening and night hours (8 pm - 7 am), and the IWT closest to the home (322 m) was ordered to be removed. Meanwhile, however, more IWT continued to be installed in the immediate vicinity surrounding the R family home. Legal proceedings underway refer only to the first 4 IWT. The R family was now being confronted with yet another problem that would severely aggravate their already delicate financial situation: a condition was now developing in the horses during the first year of life that was substantially reducing the family's equine income. Between 2000 and 2006, 13 healthy thoroughbred Lusitanian horses were born and raised on Mr. R's property. All horses (N=4) born after 2007 on his farm developed asymmetric flexural limb deformities. Besides the IWT installed in November 2006, no other changes (constructions, industries, etc) were introduced into the area during this time. Detailed results from the tissue study carried out among these equines and their corresponding controls were presented at the 14th International Meeting on Low Frequency Noise and Vibration and its Control, held in Aalborg, Denmark, in June 2010 [15]. One of this team's most consistent findings over the past 30 years of histological and ultrastructural analyses of human and animal ILFN-exposed tissues has been the organized proliferation of collagen and elastin fibers in the absence of an inflammatory process [1,2,5,6]. This same morphological feature appeared in the tissue fragments of the horses that were born, *or raised*, on Mr. R's farm after 2007 [15]. Equine flexural limb deformities developed by Mr. R's horses was the object of a Master's Thesis defended at the School of Veterinary Medicine, Technical University of Lisbon in 2012 [16].

4. 2015 Update

In terms of legal proceedings, in May 2013 the Supreme Court of Justice of Portugal decided that the remaining 3 IWT had to be removed from the vicinity of Mr. R's property [17]. The developer is reportedly appealing to the European Courts. Given the installation of other IWT in the immediate vicinity, the R Family property will still potentially be impacted by ILFN, although new studies to that effect would be required. Mr. R continues to live away from Mrs. R and the children, and his health has further deteriorated. The respiratory drive value that in 2007 was 46% (normal: >60%) is now at 28%. The development of balance disturbances associated with loss of consciousness has apparently caused several falls, requiring medical treatment for facial and rib fractures. This situation is still under clinical study, as late-onset epilepsy is one of the most severe outcomes of excessive ILFN exposure. However, diagnosis of this neurological disorder requires time to be properly established within a clinical context. While disconcerting, this is unsurprising given the already documented cases of balance disturbances and late-onset epilepsy among ILFN-exposed persons [18-20]. To date, the only remarkable element in the severe degradation of Mr. R's health is its rapidity, when compared to the evolution of this pathology seen in workers exposed to occupational ILFN. Ultimately, though, this observation is unsurprising, given the distinct time-exposure patterns of residential vs. occupational exposures.

5. The Scientific Approach

This IWT case is but one of many residential ILFN cases with which this team has been confronted, i.e., IWT are but one in a long list of ILFN-generating industries capable of disturbing citizens' right to a healthy physical environment in their homes. The approach applied to this IWT case is consistent with this team's long-standing methodology: confirmation of the presence of the agent of disease (ILFN), and clinical assessment of the parameters deemed relevant by 30 years of past research. Other agencies and institutions have studied health impacts caused by the proximity of IWT to residential dwellings [21,22 for example]. Apparently, however, all have chosen subjective and clinically unreliable measures to characterize "health impacts," unsurprisingly leading to many inconclusive results. Hypersensitivity to noise or intolerance toward sounds, commonly called *annoyance*, is frequently considered a measure of health. Usually there are large variations in the levels of annoyance assessed among family members living in the same ILFN-rich home, and among families and neighbours living in clusters of homes under the same ILFN exposure conditions. Since no prior noise exposure histories are generally included in these "health impact" studies, the fact that annoyance levels are directly related to prior and overall noise exposure

histories remains, therefore, unaccounted for. The same lack of information occurs for concurrent occupational or recreational exposures – no information of this type is generally collected among these populations. But even if annoyance levels were correctly assessed, their relationship to a proper "health impact" remains a mystery, with the exception of the relatively vague notion of "quality of life". Medical scholars trained in the scientific method know that the measure of annoyance *is not* a clinically objective parameter. Hence, any statement regarding "health impacts" merely based on (incomplete) assessments of annoyance levels is, at best, perplexing. Medical scholars trained in epidemiology will also recognize that transverse studies are quite insufficient to establish causality (or lack thereof) between an agent of disease and a specific pathology. This is particularly true when prior exposures to that same agent of disease under study are not taken in account. Having put forth why annoyance is an improper measure, both in terms of its extraordinary subjectivity and of its clinical uselessness, it is now pertinent to share this team's (long) experience with the medical concept of annoyance, which was termed in 1984 as hypersensitivity to noise or intolerance to sound [23]. Normal Wistar rats, independent of age, react to the sound of a blown kiss by becoming tense and discretely irritated. In rats exposed for extended periods of time to ILFN, the sound of a blown kiss produces a dramatic startle response, some of them losing balance, and falling backwards [24]. Fusion of actin-based, cochlear stereocilia, both amongst themselves as well as with the upper tectorial membrane, was observed in ILFN-exposed rat cochlea. These results were presented at the 8th International Meeting of the Commission on the Biological Effects of Noise, held in Rotterdam, The Netherlands, in 2003, and wherein it was postulated that the fusion of these actin-based structures could be an organic basis for the hypersensitivity to noise and intolerance to sound observed in ILFN-exposed populations, i.e., an organic-based hypothesis for annoyance [24,25]. If so, it would follow that annoyance is the product of cumulative exposures to ILFN, and not necessarily a hereditary trait related to an oversensitive auditory function. If this were indeed the case, however, *the needs of the many outweigh the needs of the few* would justify the exclusion of this "sensitive" segment of the population from the decision-making process.

6. Looking Ahead

Mr. R is not alone when it comes to life disruption due to the installation of IWT in the proximity of a residential home. This problem has become a societal issue compelling an intelligent approach, rather than a crystallized view based on antiquated notions and concepts. It is clear that the great motivation for marshalling energy and effort toward industrial wind farms is legitimately based on a worldwide shortage of electrical energy. It would seem, however, that under the guise of *the needs of the many outweigh the needs of the few*, humans are collectively forgetting their own history that has unequivocally shown the benefits of dealing with adverse health effects outright, rather than later. The dichotomy stipulating that either one accepts the development of adverse health effects among certain segments of the population, *or*, one does not have sufficient electrical energy for all the modern gadgets (including cars), is archaic and fictitious. An effort toward developing and implementing appropriate construction techniques that would minimize the deleterious effects of in-home ILFN could be, perhaps, an excellent beginning. The hindrance to this apparently viable beginning is the *sine qua non* prior recognition that ILFN is, *de facto*, a physical agent of disease.

Acknowledgement

The authors deeply appreciate the participation of Family R. in the development of this study.

References

[1] M. Alves-Pereira, N.A.A. Castelo Branco: Vibroacoustic disease: Biological effects of infrasound and low frequency noise explained by mechanotransduction cellular signaling. Progress Biophysics & Molecular Biology 93 (2007) 256-279. www.academia.edu/10671962/Vibroacoustic_disease_Biological_effects_of_infrasound_and_low-frequency_noise_explained_by_mechanotransduction_cellular_signalling.

[2] N.A.A. Castelo Branco, M. Alves-Pereira: Vibroacoustic disease. Noise & Health 6 (2004) 3-20.

[3] N.A.A Castelo Branco: The clinical stages of vibroacoustic disease. Aviation, Space & Environmental Medicine 70 (1999) A32-9.

[4] N.A.A Castelo Branco: Vibroacoustic disease – An emerging pathology. Aviation, Space & Environmental Medicine 70 (1999) A1-6.

[5] N.A.A. Castelo Branco, J. Reis Ferreira, M. Alves-Pereira: Respiratory pathology in vibroacoustic disease-25 years of research. Revista Portuguesa de

Pneumologia XIII (2007) 129-135.
www.scielo.oces.mctes.pt/pdf/pne/v13n1/v13n1a08

[6] N.A.A. Castelo Branco, E. Monteiro, A. Costa e Silva, J. Reis Ferreira, M. Alves-Pereira. Respiratory epithelia in Wistar rats born in low frequency noise plus varying amounts if additional exposure. Revista Portuguesa de Pneumlogia IX (2003) 481-492.

[7] M.J.R. Oliveira, A. Sousa Pereira, A.P. Águas, E. Monteiro, N.R. Grande, N.A.A. Castelo Branco. Effects of low frequency noise upon the reaction of pleural milky spots to mycobacterial infection. Aviation, Space & Environmental Medicine 70 (1999) A137-40.

[8] A. Araujo, F. Pais, J.M.C. Lopo Tuna, M. Alves-Pereira, N.A.A. Castelo Branco: Echocardiography in noise-exposed flight crew. Proc. Internoise 2001, 1007-10 (ISBN: 9080655422).

[9] M. Alves-Pereira, M.S.N. Castelo Branco, J. Motylewski, E. Kotlicka, A. Pedrosa, N.A.A Castelo Branco: Airflow-induced infrasound in commercial aircraft. Proc. Internoise 2001, 1011-14 (ISBN: 9080655422).

[10] R. Torres, G. Tirado, A. Roman, R. Ramirez, H. Colon, A. Araujo, F. Pais, J.M.C. Lopo Tuna, M.S.N. Castelo Branco, M. Alves-Pereira, N.A.A Castelo Branco: Vibroacoustic disease induced by long-term exposure to sonic booms. Proc. Internoise 2001, 1095-98 (ISBN: 9080655422).

[11] A. Araujo, M. Alves-Pereira, J. Joanaz de Melo, N.A.A. Castelo Branco: Vibroacoustic disease in a ten-year-old male. Proc. Internoise 2004, No. 634 (7 pages) (ISBN: 8001030555).

[12] N.A.A. Castelo Branco, M. Alves-Pereira, A.J.F. Martinho Pimenta, J. Reis Ferreira: Clinical protocol for evaluating pathology induced by low frequency noise exposure. Euronoise 2015, paper no. 601.

[13] M. Alves-Pereira, N.A.A. Castelo Branco: In-home wind turbine noise is conducive to vibroacoustic disease. Proc. 2nd Intl Meet Wind Turbine Noise, 2007, Paper No. 3 (11 pages).

[14] J. Reis Ferreira, J. Albuquerque e Sousa, P. Foreid, M. Antunes, S. Cardoso, M. Alves-Pereira, N.A.A. Castelo Branco: Abnormal respiratory drive in vibroacoustic disease. Revista Portuguesa de Pneumologia XII (2006) 369-74.
www.scielo.oces.mctes.pt/pdf/pne/v12n4/v12n4a03

[15] N.A.A. Castelo Branco, T. Costa e Curto, L. Mendes Jorge, J. Cavaco Faísca, L. Amaral Dias, P. Oliveira, J. Martins dos Santos, M. Alves-Pereira: Family with wind turbines in close proximity to home: follow-up of case presented in 2007. Proc. 14th Intl Meet Low Frequency Noise, Vibration and its Control 2010, 31-40.

[16] T. Costa e Curto: [Acquired flexural deformity of the distal interphalangic joint in foals]. Masters Thesis. School of Veterinary Medicine, Technical University of Lisbon (2012) (In Portuguese).
www.repository.utl.pt/bitstream/10400.5/4847/1/Deformaçao%20flexural%20adquirida%20da%20articulaçao%20interfalangica%20distal%20em%20poldros.pdf

[17] Supreme Court of Justice of Portugal. Decision No. 2209/08.oTBTVD.L1.S1, 30 May 2013 (In Portuguese).
www.dgsi.pt/jstj.nsf/954f0ce6ad9dd8b980256b5f003fa814/4559d6d733d1589780257b7b004d464b?OpenDocument

[18] A.J.F. Martinho Pimenta, M.S.N. Castelo Branco, N.A.A. Castelo Branco: Balance disturbances in individuals with vibroacoustic disease. Aviation, Space & Environmental Medicine 70 (1999) A100-6.

[19] A.J.F. Martinho Pimenta, N.A.A. Castelo Branco: Epilepsy in vibroacoustic disease. Aviation, Space & Environmental Medicine 70 (1999) A119-21.

[20] GIMOGMA*: [Epilepsy of vascular etiology, a clinical picture of vibration disease? Revista Portuguesa de Medicina Militar 32 (1984) 5-9.

[21] Executive Office of Energy and Environmental Affairs of the State of Massachusetts, USA: Wind turbine health impact study: Report of an independent expert panel. January 2012.
www.mass.gov/eea/docs/dep/energy/wind/turbine-impact-study.pdf

[22] Health Canada: Wind turbine noise and health study – Summary of results. Department of the Government of Canada. 2014. www.hc-sc.gc.ca/ewh-semt/noise-bruit/turbine-eoliennes/summary-resume-eng.php

[23] GIMOGMA*: [Noise and vibration at the origin of hypo- and hyper acoustic sensitivities in an industrial population]. Revista Portuguesa de Medicina Militar 32 (1984) 17-20 (In Portuguese).

[24] N. Lousã, E. Monteiro, M. Alves-Pereira, N.A.A. Castelo Branco: Rat cochlea exposed to low frequency noise. Proc. 8th ICBEN, 2003, 43-5 (ISBN: 9080799017).

[25] M. Alves-Pereira, J. Joanaz de Melo, N.A.A. Castelo Branco: Actin- and tubulin-based structures under low frequency noise stress. In: A. Méndez-Vilas (ed.). Recent Advances in Multidisciplinary Applied Physics. Elesevier, London, 2005, pp. 955-79 (ISBN: 9780080446486).

*Grupo de Investigação Médica das Oficinas Gerias de Mateiral Aeronautico.

Disclaimer

The authors and the research team they represent would like to clarify that:

No member of this team is party to anti-technology sentiments;

Alternative forms of renewable energy, such as industrial wind turbines, are considered welcome additions to our modern technological society, by all members of this team;

The data reported herein have been scrutinized under one, and only one, agenda - that of pure scientific inquiry;

In no way can or should this report be construed as a document arguing for or against the implementation of industrial wind turbines;

No member of this research team is employed by the firm that conducted the acoustical measurements reported in this article, nor are there any commercial, financial or professional agreements (contractual or otherwise) between the aforementioned accredited firm and any member of this team;

The consulting activities provided by these authors to Family R are of a purely academic and scientific nature and hence are *pro bono*.