International Tinnitus Journal, Vol. 12, No. 1, 64–70 (2006)

Characteristics of Tinnitus in a Population of 555 Patients: Specificities of Tinnitus Induced by Noise Trauma

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Abstract: Tinnitus is often associated with hearing loss of a known etiology. In this study, we compared tinnitus that appeared to be induced by noise trauma with that perceived to start in other circumstances in a population of 555 patients attending the specialist tinnitus clinic at the University Hospital in Montpellier, France. Patients had consulted for persistent tinnitus for 7 years from the onset of their symptoms. Among these tinnitus patients, 17% described their tinnitus as starting after excessive noise exposure. The patients who had a history of noise trauma had a symmetrical hearing loss, and no difference was seen in lateralization of tinnitus perception. This subset of patients was mainly male and on average was 10 years younger than other tinnitus patients. In this population, the hearing loss is significantly less than that measured in the other patients, even allowing for their younger age. Statistical analysis showed a significant correlation between a history of exposure to noise trauma and the presence of a high-pitched "whistling" tinnitus. The presence of whistling tinnitus was significantly correlated with high-frequency hearing loss. The intensity of tinnitus, measured using a visual analog scale, appeared to be stronger than the measured hearing loss would suggest.

Key Words: acoustic trauma; human; inner ear; ringing ears

Even today, epidemiological data on tinnitus remain patchy. Despite this, studies to date do underline the high prevalence of tinnitus. Within European studies, three countries have produced plentiful data. In the United Kingdom, 10% of the adult population admit to experiencing tinnitus [1]. Approximately 7% of the adult population judge their tinnitus to be sufficiently severe to warrant consulting a doctor [2]. When questioned, 5% of German adults stated that they had irritating tinnitus, 1% of adults considered themselves handicapped by their tinnitus, and 0.5% were unable to live a normal life [3]. At the time of questioning, 50% of tinnitus patients graded their symptoms as "serious to unbearable." This study also showed that the annual incidence of chronic tinnitus was 0.33% of the population. However, prevalence varied, ranging from 1% to 8% between the various German states. In France, a study involving the population around Nice produced results similar to those of other countries with regard to the prevalence of tinnitus [4]. A further French study focusing on the quality of life of 603 tinnitus sufferers showed clearly that in 26% of patients, tinnitus created difficulties in everyday life [5]. The presence of tinnitus engenders notable modifications of behavior and a clear deterioration in quality of life. Irritability, stress, anxiety, and deterioration in quality of sleep are frequently described both by tinnitus patients themselves and by their families [5]. Tinnitus appears to affect both the professional and the family life of its sufferers. It has a deleterious effect on intrafamily rela-

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tionships, especially because of the difficulty that relatives may have in understanding what the tinnitus sufferer is undergoing [6].

In the vast majority of cases, tinnitus is associated with a hearing loss of known etiology (e.g., presbycusis). Noise trauma is known to be associated with the origin of many cases of tinnitus [7]. Taking account of the sound level in discos and clubs and from personal stereos (especially when listened to through headphones), one can anticipate the advent of an entire new generation of tinnitus sufferers.

The aim of this study was to define more clearly the effect of noise trauma on tinnitus. To do this, we compared tinnitus induced by noise trauma with that induced in other circumstances; we studied a population of 555 patients seen in a specialist tinnitus clinic at University Hospital, Montpellier.

PATIENTS AND METHODS

We undertook this prospective study with 555 patients attending a specialist tinnitus clinic at University Hospital, Montpellier, France, between 1998 and 2003. Each patient was seen by the same clinician.

Semiological Study

The semiological analysis of tinnitus covered several parameters, and each patient completed a questionnaire. The patients were asked their age at first appearance of the tinnitus and its duration. Also, they were asked for a description of the sound; most patients were able to describe their tinnitus as whistling or buzzing. If the description did not fall into either of these categories, it was defined as "other."

For spatial localization, patients were asked to describe their symptoms as being either left- or right-sided or as nonlateralized. In regard to variability over time, certain patients described their tinnitus either as stable over time or as fluctuating (usually louder at bedtime and on awakening). Descriptions outside of these categories were defined as "other."

Intensity was measured on a visual analog scale graded from 0 to 100, where 0 corresponded to an absence of tinnitus and 100 indicated the loudest tinnitus imaginable.

Clinical Study

Each patient underwent a thorough audiovestibular clinical examination. After otoscopy, audiometry was undertaken for each ear (air conduction, bone conduction, and speech audiometry). Complementary investigations, such as otoacoustic emissions, evoked auditory potentials, videonystagmography, computed tomography, and magnetic resonance imaging scans, were undertaken as necessary to help to diagnose any hearing loss.

Statistical Study

We considered the length of history, age at presentation, intensity of the tinnitus, and any associated hearing loss as continuous variables. We analyzed the description of the sound of the tinnitus, its spatial localization, and the variability of the intensity as noncontinuous variables. The comparison between noise trauma–induced tinnitus and that induced by other factors was performed using various statistical tests (SAS software version 8.2; SAS Institute Inc., Cary, NC). Depending on the variables under analysis, a Student's *t*-test or chi-squared testing was undertaken. We used chi-squared testing to study any associations between two variables in a class, ANOVA testing to study variables in the same class and continuous variables, and Pearson correlation coefficients to compare two continuous variables. All the data, whether in a table or in text, are expressed as the mean plus or minus the standard deviation. For more clarity, data plotted in the graphs are expressed as the mean plus or minus the standard error of the mean.

RESULTS

Overall Population

Table 1 details the population that was seen within a specialist tinnitus clinic (N = 555). This cohort contained broadly similar numbers of male and female patients (55.7% and 44.3%, respectively). There was a broad age range of patients, from 11 to 91 years, with the average age at presentation in the clinic being 54 ± 15 years. Tinnitus had first been noticed by the patients

Table 1. Description of the Population Seen in the Specialist Tinnitus Clinic

	Total Population (N = 555)	NT Population (n = 90)	Other (n = 465)
Patients (%)	100	16.2	83.8
Male (%)	55.7	75.6	50.9
Female (%)	44.3	24.4	49.1
Age (yr)	54.0 ± 15.0	45.8 ± 15.9	55.9 ± 14.5
Age at onset (yr)	47.2 ± 15.2	39.7 ± 14.9	49 ± 15
Duration (yr)	7.2 ± 9.0	6.3 ± 10.6	7.2 ± 8.5

NT = noise trauma.
Note: Age is expressed as the mean ± standard deviation. Duration of tinnitus is calculated as the age at onset of tinnitus to the age when seen in the clinic.

Table 2. Patients' Descriptions of Circumstances of First Tinnitus Appearance

Circumstance	No. of Patients (n = 522)	Percentage
Spontaneous	191	36.6
Ear pathology	182	34.8
Psychological problems	83	15.9
Nonotological pathology	52	10.0
Other	14	2.7

at an average age of 47 years (47.2 ± 15.2 years) Therefore, patients had been suffering from tinnitus for an average of 7.2 ± 9.0 years prior to being assessed at the tinnitus clinic.

Generally, patients were able to describe the circumstances in which they noticed the appearance of their tinnitus (Table 2). In 36.6% of cases, the tinnitus appeared spontaneously (i.e., without any clearly identifiable cause). Tinnitus was often attributed to ear pathology (34.8%) or, in fewer cases, to another illness (10%). In 15.9% of cases, the tinnitus appeared in association with psychological problems, such as emotional trauma, depression, or episodes of stress or anxiety. Finally, 2.7% of patients described "other" as the context.

Table 3. Diagnoses of Hearing Loss

Hearing Loss	No. of Patients (N = 555)	Percentage
Endocochlear		
Presbycusis	232	41.8
Noise trauma	119	21.4
Ménière's-like syndrome	35	6.3
Sudden-onset hearing loss	22	4.0
Ototoxicity	21	3.8
Ménière's disease	19	3.4
Familial deafness	17	3.0
Petrous bone fracture	7	1.3
Other	6	1.1
Total	469	86.1
Conductive		
Chronic otitis media	9	1.6
Serous otitis media	1	0.2
Total	10	1.8
Retrocochlear		
Vascular malformation	8	1.4
Acoustic neuroma	2	0.4
Total	10	1.8
Other		
Shingles	2	0.4
Unknown	23	4.1
Total	26	4.7
No hearing loss	31	5.6

Note: The differential diagnoses of presbycusis and noise trauma are based on the shape of the audiogram and the age of the patient. The diagnosis of Ménière's disease is based on the American classification that includes tinnitus, vertigo, and deafness. Other variations of these symptoms that do not fit into the classic diagnosis of Ménière's disease are categorized as Ménière's-like syndrome (endolymphatic hydrops).

Table 4. Semiology of Tinnitus

	Total Population (N = 555)	NT Population (n = 90)
Lateralization (%)		
Right side	30.1	34.8
Left side	36.4	34.8
Nonlateralized	33.5	30.3
Frequency characteristics (%)		
Whistling	77.9	98.8
Buzzing	11.6	0
Other	10.4	1.2
Temporal characteristics (%)		
Stable	73	79.5
Fluctuant	14	13.2
Other	12.9	7.2

NT = noise trauma.

With regard to a clinical diagnosis, 86.1% of tinnitus patients had a sensory (cochlear) hearing loss, 1.8% a retrocochlear hearing loss, and 1.8% a conductive hearing loss (Table 3). Only 5.6% of patients had a normal pure-tone audiogram (hearing loss of < 10 dB between 250 and 8,000 Hz). The details of the pathological findings associated with tinnitus are shown in Table 3.

Analysis of the audiograms of the tinnitus patients showed a predominantly left-sided hearing loss, particularly in the higher frequencies (data not shown). We asked the patients to classify their tinnitus with regard to spatial localization and frequency, intensity, variability with time, and duration (Table 4). We found that most patients described their tinnitus as whistling (77.9%), stable (73%), and more noticeable either within the left ear or on the left side (36.4% left ear, 30.1% right ear), the left ear being the ear in which hearing loss on audiometry was more obvious. However, this spatial localization was not statistically significant.

Noise Trauma Population

In this study, we focused on those patients who said that the onset of their tinnitus began after noise trauma. These patients constitute 16.21% of the total (n = 90; see Table 1). This subset was mainly composed of men (75.6%) as compared to women (24.4%). These patients were also younger than was the overall population (45.8 ± 15.9 years versus 55.9 ± 14.5 years) but still were consulting for tinnitus symptoms that were of long duration (6.3 years on average).

Table 5. Origin of Noise Trauma in 90 Patients

Origin	Percentage of Population
Amplified music	39.6
Firearms	16.2
Alarms	14.0
Motorized tools (engines)	11.6
Medical treatment	9.3
Explosions	9.3

ORIGIN OF NOISE TRAUMA

The origins of the noise trauma are shown in Table 5. The main source described was amplified music (39.6%). Within this category were concerts (53%), discotheques (35%), and prolonged use of personal stereos, especially when listened to through headphones (12%). Next most prevalent was firearm use (16.2%), the majority related to hunting or shooting as a leisure activity. More surprising is the not insignificant number of patients who described their tinnitus as being precipitated by alarm sirens (14%) or as occurring after medical intervention (9.3%); some causes listed were dental care or such otological investigations as stapedial reflexes or auditory evoked potentials. Tinnitus precipitated by use of machinery accounted for 11.6% (mainly such do-it-yourself tools as drills and grinders. Finally, 9.3% of patients said that their tinnitus followed blast exposure.

Hearing Loss

Whereas in the overall population patients showed a mainly left-sided high-frequency hearing loss (≥4,000 Hz), patients in the noise trauma population had similar hearing loss in each ear (Fig. 1). However, the degree of hearing loss was significantly lower than that in patients suffering from other ear pathology (Fig. 2A). This difference may be explained by the age difference between the two groups, as the patients exposed to noise trauma were, on average, 10 years younger. To determine the influence of age on the hearing loss, we performed a stratified study on two groups of patients with demonstrable hearing loss, whether or not they had a history of noise trauma: those 40 years old and older and those younger than 40 years. Among those younger than 40, hearing loss at 250, 500, 1,000, and 8,000 Hz was significantly less in the patients with a history of noise trauma. However, we observed no significant difference in hearing loss at 2,000, 4,000, and 6,000 Hz (see Fig. 2B). This difference cannot be explained by an age difference between the two subsets, because the average age of these traumatized and non-

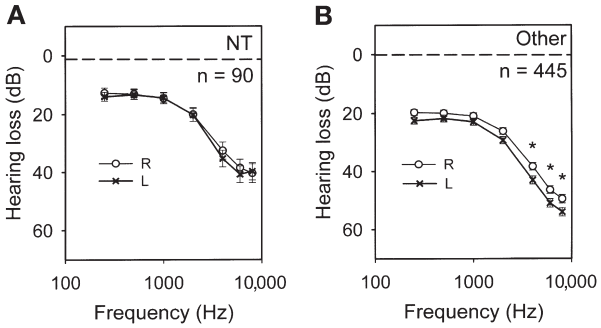

Figure 1. Pure-tone audiograms in subjects with a history of noise trauma (*NT*) and those with other ear pathology. Graphs show the average hearing loss in dB (± standard error of the mean) measured in the right ear (*R*, *circles*) and the left ear (*L*, *crosses*). (A) In patients with a history of noise trauma, the hearing loss is symmetrical and less severe than in those with other ear pathology (B). In addition, in patients with no history of noise exposure, the hearing loss is significantly greater in the left ear than in the right, at frequencies greater than 4,000 Hz (*asterisk*).

traumatized patients younger 40 was 30.0 ± 7.5 years and 29.0 ± 7.4 years, respectively. Among those who were 40 years old or older, hearing loss between 250 and 1,000 Hz was significantly greater in the patients who did not experience noise trauma, although we observed no significant difference at 2,000, 4,000, 6,000, and 8,000 Hz. These results show that whatever a pa-

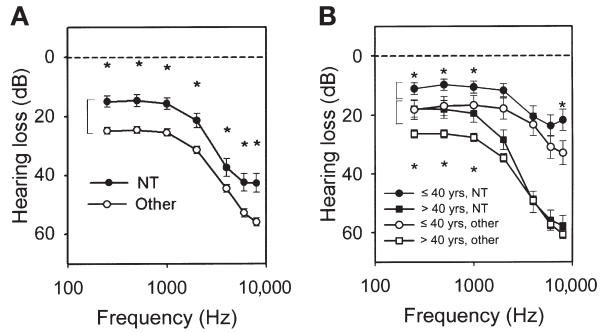

Figure 2. Hearing loss as a function of age. (A) Hearing loss in those patients with a history of noise trauma (*NT*, *closed circles*) is significantly less than that in patients with other ear pathologies, at every frequency measured. (B) Audiograms in patients aged 40 or younger (*circles*) and in those older than 40 (*squares*). In whichever age group, hearing loss is less obvious in those patients with a history of noise trauma (*white symbols*) than in those without (*black symbols*). Among those aged 40 years or younger, the difference is significant at 250, 500, 1,000, and 8,000 Hz, whereas in those older than 40, the difference is significant only in the lower frequencies (250, 500, and 1,000 Hz). Note the characteristic notch in the audiogram at 6,000 Hz in those younger patients with a history of noise trauma. Asterisks indicate a significant difference ($p \leq .05$). All data points on the graphs represent the mean ± standard error of the mean.

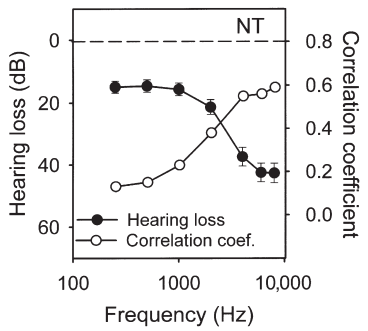

Figure 3. Correlation between the intensity of tinnitus and the hearing loss in those with a history of noise trauma (*NT*). The correlation between tinnitus intensity, as measured on a visual analog scale (*white circles*), and the hearing loss (*black circles*) gives a coefficient that becomes greater as the hearing loss becomes greater. Note that the greatest correlation coefficients occur in the highest frequencies of hearing loss. All data points on the graphs represent the mean ± standard error of the mean.

tient's age, those with a history of noise trauma has less hearing loss than did those with other etiologies of hearing loss.

Semiological Study of Tinnitus

In concordance with our audiometric findings, we noted no predominance in the side of perception of tinnitus in those patients with a history of noise trauma (right ear, 34.8%; left ear, 34.8%; no clear lateralization, 30.3%). Almost all (98.8%) of these patients said that their tinnitus was of a whistling type (see Table 4). Statistical analysis demonstrated a significant correlation between tinnitus precipitated by noise trauma and the perception of it as a whistling type. The intensity of tinnitus perception was significantly correlated with the degree of hearing loss measured between 2,000 and 8,000 Hz. The greater the hearing loss, the stronger the correlation became.

Correlation coefficients were 0.38, 0.55, 0.56, and 0.59 at 2,000, 4,000, 6,000, and 8,000 Hz, respectively (Fig. 3). In 79.5% of cases, patients described their whistling tinnitus as stable over time (see Table 4). We observed no significant difference in the average age of patients depending on whether they described their tinnitus as stable (47.5 ± 15.3 years) or fluctuating (48.8 ± 16 years), but those with stable tinnitus had had it for a longer period (7.9 ± 11.9 years) as compared to those who described fluctuating tinnitus (2.2 ± 2 years).

DISCUSSION

Our study, undertaken in the context of a specialist tinnitus clinic at the University Hospital, Montpellier, shows that tinnitus affects both genders equally. In general, the patients seen tended to have a high-pitched hearing loss that is more marked on the left. From a descriptive point of view, the tinnitus described by the patients in this study was mainly whistling, was stable with time, and was perceived on the left side. Although not statistically significant, this latter finding is in accordance with other studies showing that hearing loss and tinnitus are generally more noticeable on the left side [8]. Among the 555 patients, 17% said that their tinnitus had followed noise trauma. Leisure noise appeared to be the principal cause, especially amplified music, whether from a concert or a disco. This would explain an average age of this group of tinnitus sufferers 10 years younger than that of the other tinnitus patients. Other sources of noise trauma were firearm use and do-it-yourself power tools, which would explain the overwhelming male majority in this noise exposure subgroup. Finally, whatever the pathology responsible for the appearance of tinnitus, patients had suffered for an average of 7 years before being seen in the tinnitus clinic. This may be related to the fact that this study was undertaken in a hospital setting, which tends to be a secondary or tertiary referral clinic for patients with tinnitus.

Lateralization of Tinnitus

In contrast to other tinnitus patients, those with a history of noise trauma demonstrated similar hearing losses in each ear and showed no difference in side of lateralization or nonlateralization of their tinnitus. The majority of tinnitus cases were linked to sound trauma after a concert, an evening at a nightclub, listening to a personal stereo, or using do-it-yourself power tools, in which one would expect both ears to have similar noise exposure. In contrast, studies by Pilgramm et al. [3] and Job et al. [9] show predominantly left-sided tinnitus in young army personnel who are exposed to weapons fire. In our study, the small number of patients who had been exposed to firearm noise did not permit significant study.

Frequency Characteristics

In this study, almost all the patients who had a history of noise exposure said that their tinnitus was of a high-pitched whistling frequency. Statistical analysis showed a significant correlation between noise trauma and whistling tinnitus. The whistling sound was significantly linked to a high-frequency hearing loss. This link correlates with an earlier study on a smaller population showing that a whistling type of tinnitus was correlated with a high-frequency hearing loss and that a buzzing type of tinnitus was correlated with a low-frequency hearing

loss [7]. Other studies have shown similar results. Cahani et al. [10] showed a correlation between high-frequency hearing loss (corresponding to noise trauma) and the frequency of tinnitus as measured by pitch-matching. Eggermont and Roberts [11] demonstrated that the frequency of tinnitus is closely correlated to audiometric hearing loss. In other words, the frequency spectrum of tinnitus is inversely proportional to auditory threshold. If this were the case, one would expect that the whistling tinnitus noticeable after noise trauma would have a spectrum predominating in high frequencies. A more in-depth study would allow verification of this hypothesis.

Intensity Evaluation

In this study, we evaluated the intensity of tinnitus after noise trauma by using a visual analog scale. With this instrument, we significantly correlated the intensity of the tinnitus with the degree of hearing loss between 2,000 and 8,000 Hz. This correlation became stronger with the higher frequencies of hearing loss. These results agreed with our previous study of 58 patients [7], which showed that the intensity of stable whistling tinnitus is perceived as increasingly strong as the high-frequency loss is more marked. It is not easy to compare our results using a visual analog scale with those studies wherein patients are asked to evaluate the frequency and intensity of their tinnitus with an external sound, usually a pure tone generated by an audiometer [12,13]. In these cases, patients were able to perceive the external sound only if it were presented 5–15 dB above their auditory threshold, which poses a problem with interpretation. For example, should tinnitus that has been measured at 10 dB above the auditory threshold be considered as low intensity (only 10 dB) or stronger than the hearing loss would suggest? With tinnitus measurable in this way at 5–15 dB above the threshold, would one have to say that the intensity of tinnitus depends on hearing threshold and that a proportional relationship exists between tinnitus and hearing threshold? Only a study comparing the two types of tinnitus intensity evaluation (audiometric-based pitch matching and visual analog scale) will allow clear answers to those questions. However, the correlation between hearing loss and intensity of tinnitus that we measured in this study suggests that a visual analog scale is the tool of choice to help us to understand the incapacitating character of tinnitus associated with noise trauma.

Stability Over Time

The vast majority of patients with noise trauma described their tinnitus as high-pitched and stable over time. We noted, however, that the few patients who described their tinnitus as fluctuating over time had generally had their tinnitus for a shorter period (2 ± 2 years versus 7.9 ± 11.9 years for stable tinnitus). This being the case, we propose two hypotheses: (1) Fluctuating tinnitus tends to stabilize after a certain length of time or (2) fluctuating tinnitus may disappear, whereas long-standing tinnitus is stable. Only a longitudinal study of tinnitus patients will allow us to clarify these hypotheses further.

CONCLUSION

This study shows that noise trauma appears to provoke a high-pitched whistling tinnitus that is stable over time, occurs in either ear, and usually appears in men who are, on average, younger than the general tinnitus population. If the age and gender are accounted for by the source of the noise trauma (concerts, discos, hunting, do-it-yourself tools), the descriptive aspects of tinnitus are strongly correlated with hearing loss as demonstrated by pure-tone audiometry. Clearly, as many forms of tinnitus exist as there are patients. However, this attempt at categorizing patients' tinnitus as a function of both the etiology and the semiology allows us to evaluate better the medical and psychological treatment of these tinnitus patients. In addition, such a step allows us to better define those populations that are similar to the experimental models of tinnitus and on which therapeutic strategies are being developed [14–20].

ACKNOWLEDGMENTS

The authors thank the Fond d'Aide à la Qualité des Soins de Ville Languedoc-Roussillon for his support in statistical analysis of the data. The authors are grateful to J. Mallet for help and advice regarding administrative considerations and to Dr. G. Charachon for helpful criticisms of the manuscript.

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