Medical Informatics Europe 2002
G Surján et al. (eds)
IOS Press 2002

On Prediction of Hearing Recovery After Acute Acoustic Trauma Caused by Impulse Noise

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Abstract. The present study investigates the prediction of how successfully hearing returns to normal after an acute acoustic trauma caused by a firearm shot, an explosion or other impulse noise. Study material consisted of 113 conscripts who had suffered an acute acoustic trauma during their military service. A logistic regression model was formed to predict hearing recovery. From several possible variables at least five were found to be important among our dataset, which is still rather limited. However, more data will be acquired later in order to elaborate the research more widely by using other methods also.

1. Introduction

We studied the prediction of hearing recovery after an acute acoustic trauma caused by exposure to impulse noise. The dataset of the subjects suffering such a problem included data of mainly conscripts who were exposed to heavy noise caused by firearms during their compulsory military service. We were interested in investigating reasons that had influence on the hearing recovery. We predicted the hearing recovery by means of logistic regression. The dataset was too small in order to apply more sophisticated methods, e.g. neural networks, but in the future we are going to take advantage of them after having collected more cases.

The recovery of hearing is naturally very important after an acute acoustic trauma in military service, working life or leisure time. Military service is also an interesting surroundings for medical data mining [1-3], since the dataset collected is very homogeneous. Medically investigated study subjects were healthy (excluding the acoustic trauma) men of almost same age. Although hearing protection is of utmost importance in prevention of acute acoustic trauma and associated hearing impairment in military environment [1-3], it may also be possible to improve the recovery process by carefully assessing and understanding factors that affect it.

The aim of the present study was to explain relations between variables in the data, particularly those concerning tinnitus (ringing noise inside ear) and hearing recovery. Another objective was to classify or predict, which of the subjects would or would not have recovered. Recovery was defined as a reduction of the initial hearing impairment caused by acute acoustic trauma to a level at which the maximum dB value of the last audiometry measurement was at 20 decibels or less.

2. Hearing impairment data

The retrospective dataset was comprised of 113 men of ages between 15 – 34 years. The majority of 90 % was 18 – 21 years old (median 20 years), one was exceptionally younger and a few older. Mostly they were Finnish conscripts, whose military service lasted either 8 or 11 months, but some (those around 30 years) were regular officers. Age as an explanatory variable (univariate model) was statistically significant for the hearing recovery. Hearing of a subject was investigated also before the military service. At that time13 subjects of 113 had a hearing impairment in either one or both ears. This, however, does not significantly affect recovery.

Hearing is deemed to be normal if at all measured frequencies of 0.5, 1, 2, 3, 4, 6, and 8 kHz a patient is able to hear a stimulation noise of 20 dB. Originally the current response variable was known only for 61 patients, but in cases where a patient had recovered till the second audiometry recording the missing third values were substituted by the values of the second recordings. Thus there were finally 93 cases available to the study.

Delay between an acoustic trauma and the beginning of medical treatment was the third variable (in addition to age and hearing before the military service). The time unit of 6 hours or 0.25 day was used. Its range was 0.25 – 8.0 days and median 1 day. Patients who did not recover had an average of 1.42 days, but those who did recover had only 0.86 day. According to the t-test ($p = 0.015$) this was a significant difference, but the distribution was skewed. Instead, the nonparametric Mann-Whitney U test did not give a statistically significant difference ($p = 0.084$). The fourth variable was a site where an acoustic trauma happened (indoors, terrain, shooting range or gallery). This was divided into two groups: assault rifles and other weapons or other noise source (binary value). It was not significant for hearing recovery. The type of a weapon or noise source that caused a hearing damage was mostly assault rifle (70 % of cases) or heavy weapon like cannon or other reason like explosion, but this variable was not significant. Neither was a number of shots to which a conscript was exposed. On average it was 3.0 shots for the recovered patients and 4.9 for the others. The distance of shooting was 0.72 m and 0.68 m for the former groups, but it was not significant. Audiometry maximum values were significant (t-test, $p = 0.001$). For the first audiometry recording its mean was 46.0 dB for the recovered cases and 53.1 dB for the others, for the second recording the means were 16.4 dB and 36.3 dB, and for the third recording the means were 24.0 dB and 30.0 dB, respectively. For the first and second one the difference was significant, but not for the third recording since most of the recovered patients recovered up to the second recording.

Since hearing impairment can affect either only one or both ears, we segmented audiometry recordings to the speech frequency band of 0.5 – 2 kHz, where values of both left and right ear were summed up, and to the frequency band above the former, where values of the left and right ear were separately computed to two different sums. Thus three variables were formed from these recordings.

3. Results

We used the logistic regression [4] method (SPSS program) in order to classify the cases of the dataset. We accomplished tests with random samples of sizes of 65, 70, and 75 % of 93 cases as a training set to build a model. When their results were rather similar, only those of the set 75 % are presented in the following. First statistical significance of univariate influence was explored one by one by comparing a logistic regression model that contains only a constant to a model that contains a constant and one independent variable. Six variables were subsumed into the computation. Although they were not all significant in univariate tests (like those which were omitted), they all were useful for the multivariate consideration. They were the audiometric value of the speech frequency band, corresponding values of the right ear and left ear of the upper frequency band, age, delay between an acoustic trauma and beginning of treatment, and noise source. Computed test values are presented in Table 1.

Table 1: Univariate test results of logistic regression for audiometric value of the speech frequency band, corresponding values of the right ear and left ear of the upper frequency band, age, delay between an acoustic trauma and beginning of treatment, and noise source.

Variable	Estimated slope coefficient	Standard error	Odds ratio	-2 log likelihood	likelihood ratio test statistic	p
constant	-0.044	0.247		92.4		
speech	-0.004	0.006	1.00	91.7	0.66	0.417
right ear	0.002	0.003	1.00	92.1	0.31	0.576
left ear	0.008	0.003	1.01	85.3	7.11	0.008
age	0.259	0.152	1.30	88.3	4.09	0.043
delay	0.375	0.213	1.46	88.4	3.94	0.047
noise source	0.940	0.530	2.56	89.2	3.19	0.074

For the univariate tests we used $p < 0.05$ as a bound of significance. For multivariate tests we selected all six variables, because the first three of them are known to affect jointly and the last three variables had $p < 0.25$ in Table 1. For all the variables the odds ratio is calculated for an increase of one unit.

By using logistic regression we obtained results that according to Wald test the slope of the noise source variable was not significant. Furthermore, removal of this variable did not weaken likelihood ratio either. Therefore, the variable was eliminated from the model and we ran further tests with the five remaining variables which were all significant in the multivariate model.

Table 2: Classification of the cases of the training set with a cut-off value of 0.5.

		Predicted		
		Final hearing status		Correct
Observed		normal	impaired	%
Final hearing status	normal	38	4	91
	impaired	6	21	78

Table 3: Classification of the cases of the test set with a cut-off value of 0.5.

		Predicted		
		Final hearing status		Total
Observed		normal	impaired	
Final hearing status	normal	13	2	15
	impaired	3	6	9
Total		16	8	24

By first using the training set we tested the model. These results are given in Table 2, where 86 % were correctly predicted (total accuracy). By using the test set of 25 % from the dataset we obtained results presented in Table 3, where 79 % were correctly predicted. The model predicted 87 % of the normal hearing cases and 67 % of the impaired hearing cases.

Relation between duration of tinnitus and unsuccessful hearing recovery was observed. Evidently tinnitus remains longer with patients, whose hearing did not recover to normal. Their tinnitus lasted for 38.5 days on an average, whereas that of the recovered cases was 13.8 days. This was statistically significant ($p = 0.003$). Duration of tinnitus cannot, nevertheless, be utilized in the prediction of the hearing recovery, since tinnitus may continue even after the hearing has recovered and all the patients in the data suffered from tinnitus.

4. Conclusion and discussion

By using multivariate logistic regression we found that at least five variables were important for the prediction of the hearing recovery after an acute acoustic trauma caused by impulse-type noise of firearm shots, explosions or other phenomena alike. In the future we shall continue our study by dealing with considerably more cases in order to make sure that the results are not merely due to chance and to explore usefulness of other variables that were insignificant in the current small dataset. Moreover, we shall take advantage of more sophisticated means, such as neural networks in order to study more versatile classifications and predictions. Regarding the present dataset neural network methods could not yet be used because of too small number of cases. Neural networks are useful, because they allow nonlinear mappings [4] in the multivariate pattern space of cases and might therefore reveal new interesting features of this type of data. Such models may be useful in order to predict hearing impairment and to support design of treatment for these patients.

References

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