Published in final edited form as:

J Occup Environ Med. 2003 December ; 45(12): . doi:10.1097/01.jom.0000100040.45929.42.

Impact of OSHA Final Rule—Recording Hearing Loss: An Analysis of an Industrial Audiometric Dataset

Dr. Peter M. Rabinowitz, MD, MPH, Mr Martin Slade, MPH, Ms. Christine Dixon-Ernst, MS Hyg, CIH, MA, CCC-A, Ms. Kanta Sircar, MPH, and Dr. Mark Cullen, MD

Yale University School of Medicine, New Haven, Connecticut (Dr Rabinowitz, Mr Slade, Ms Sircar, Dr Cullen); and Alcoa Inc., Alcoa Corporate Center, Pittsburgh PA (Ms Dixon-Ernst)

Abstract

The 2003 Occupational Safety and Health Administration (OSHA) Occupational Injury and Illness Recording and Reporting Final Rule changed the definition of recordable work-related hearing loss. We performed a study of the Alcoa Inc. audiometric database to evaluate the impact of this new rule. The 2003 rule increased the rate of potentially recordable hearing loss events from 0.2% to 1.6% per year. A total of 68.6% of potentially recordable cases had American Academy of Audiology/American Medical Association (AAO/AMA) hearing impairment at the time of recordability. On average, recordable loss occurred after onset of impairment, whereas the non-age-corrected 10-dB standard threshold shift (STS) usually preceded impairment. The OSHA Final Rule will significantly increase recordable cases of occupational hearing loss. The new case definition is usually accompanied by AAO/AMA hearing impairment. Other, more sensitive metrics should therefore be used for early detection and prevention of hearing loss.

Noise-induced hearing loss is one of the most prevalent occupational conditions.¹ Since the 1983 Occupational Safety and Health Administration (OSHA) Hearing Conservation Amendment, annual audiometric surveillance of individuals exposed to noise at levels of 85 dBA or greater has been a central part of industrial hearing-conservation programs. The 1983 OSHA rule defines a 10-dB “shift” or worsening in hearing at an average of 2000-, 3000-, and 4000-Hz frequencies as a Standard Threshold Shifts (STS). The 1983 standard allows age-correction of an STS for presbycusis using standardized tables, but makes it clear that such age correction is optional. If the professional supervisor of the hearing-conservation program (a physician or audiologist) determines an STS to be work-related, the OSHA standard mandates action including retesting, written notification, and counseling regarding hearing protection.

The 1983 OSHA standard, however, does not specify which hearing loss cases need to be recorded on a company’s OSHA log. Later guidance documents required the recording of hearing loss cases if there had been an average shift in hearing from a baseline of 25 dB or more at the frequencies of 2000, 3000, and 4000 Hz, again allowing age correction.

In January 2001, OSHA released a draft of a new recordkeeping standard. This standard originally proposed the recording of all work-related 10-dB STSs (age correction allowed) on the OSHA 300 log. This draft received support from a number of professional groups, including the American College of Occupational and Environmental Medicine, the American Academy of Audiology (AAO), the Council on Accreditation of Occupational

Hearing Conservation, and National Hearing Conservation Association. At the same time, OSHA received comments that recording of 10-dB STSs would result in many “false-positive recordings” either because of “audiometric testing errors, because the hearing loss was temporary and not persistent, or because the case was insufficiently work-related.” Commenters taking this position challenged the medical significance of a 10-dB STS, stating that the OSHA recordability provisions are intended to “collect data on serious injuries and illnesses, not potential precursors.”²

In 2002, OSHA released a revised recordkeeping rule, requiring the recording of work-related 10-dB STS on the OSHA 300 log only if the absolute average at 2000, 3000, and 4000 Hz was equal to or greater than 25 dB. This rule took effect on January 1, 2003. In the decision to add the requirement that cases of 10-dB STS should also exhibit at least 25 dB of hearing loss in the average of 2000, 3000, and 4000 Hz, OSHA stated that the 10-dB STS at higher levels (above 25 dB) are “more significant,” and that the new rule provides a reasonable “middle ground” solution to “reconcile the differences between a highly sensitive measure (all 10-dB shifts) and increasingly insensitive measures (15-, 20-, or 25-dB shifts).”

In an analysis of the impact of the new rule, OSHA reviewed a National Institute for Occupational Safety and Health (NIOSH) database of audiograms to determine the proportion of audiograms meeting the recording criteria. This database was assembled in 1987 and includes audiometric data on noise-exposed employees from representative companies in the United States and Canada. A total of 3.09% of audiograms met the final rule’s criteria for recording hearing loss, whereas 0.83% met the previous recording criteria of a 25-dB shift. Based on national projections of 4,680,500 workers enrolled in hearing-conservation programs, OSHA calculated the new rule would lead to an additional 105,000 cases of occupational hearing loss being recorded annually.

We performed an analysis of a large industrial audiometric database to provide an independent review of the significance and impact of the changes in the OSHA hearing loss recordkeeping rule.

Methods

The Alcoa Audiometric Database

Alcoa Inc. maintains a database of audiometric testing done for hearing-conservation purposes in compliance with OSHA standards. Under Alcoa health and safety protocols, individuals exposed to 85 dBA or greater sound levels on an 8-hour time-weighted average are required to have yearly audiograms. Individuals exposed to between 82 and 84 dBA are required to have surveillance audiometry performed every 3 years. The database at the time of analysis contained 336,653 audiograms on over 25,426 individuals working at 12 aluminum production facilities in North America and who had had at least 3 audiograms during the study period of 1982 to 2002, and who had at least 3 years between the first and last tests. Types of exposure included mining, refining, aluminum smelting, and secondary aluminum production. Pure-tone audiograms were performed using sound booth environments that met OSHA standards for audiometric testing. For the past 20 years, the centralized database has been developed under the direction of the chief hearing conservationist for the corporation, who is both an audiologist and an industrial hygienist. There have been ongoing efforts to ensure quality of the testing and data entry through periodic site visits and ongoing review of centralized data. A separate industrial hygiene database includes results of noise level testing.

All research took place on an anonymous set of audiometric data that had personal identifiers removed or scrambled. These data have been imported into SAS version 8.02

(SAS Institute, Inc., Cary, NC)⁵ for the purpose of data analysis, for statistical analysis, and original code written to perform assessments of hearing loss. We were therefore able to follow individuals longitudinally during their work career. The Human Investigation Committee of Yale University School of Medicine as well as Alcoa's Occupational Health Advisory Committee approved the research protocols.

Determination of Baseline and Calculation of Hearing Shifts

Because regular audiometric testing in Alcoa facilities began to increase significantly in 1982 (near the time of adoption of the original OSHA hearing-conservation standard), an individual's audiometric baseline was considered to be the first test occurring after 1981. The baseline was used as comparison to calculate the shift measures. An individual was considered to have a confirmed 10-dB STS if the average hearing level worsened from baseline by 10 dB or more in average at 2000, 3000, and 4000 Hz, and this degree of worsening persisted on the subsequent test. The 10-dB STS was calculated both with and without age correction using the tables in Appendix D of the OSHA Hearing Conservation Standard.³ If the absolute hearing threshold level average at 2000, 3000, and 4000 Hz was also greater or equal to 25 dB, the individual was judged to have had hearing loss potentially recordable under the new OSHA criteria. If an STS was identified and confirmed, that audiometric test became the baseline for subsequent calculations for those particular shift criteria. Therefore, it was possible for an individual to have several subsequent 10-dB shifts after having an initial shift. For the new OSHA criteria calculations, baseline was reset after each age-corrected 10-dB shift, whether or not the 2000-, 3000-, and 4000-Hz average was equal or greater to 25 dB.

For comparison purposes, we also calculated the occurrences of 25-dB age-corrected shifts that would have been reportable under the previous OSHA guidelines.

To determine whether the age of the worker affected the occurrence of the hearing loss event, we performed these analyses on the overall subject population, as well as the subset of individuals who were age 25 or less at the time of first hearing test.

Because frequency of testing varied between individuals, we calculated an annualized rate of shifts by dividing the total number of each hearing shift criteria during an individual's follow up by the time between first and last audiometric test.

Calculation of Hearing Impairment

Hearing impairment was defined by American Medical Association (AMA)/AAO criteria as an average hearing threshold in either ear for the frequencies of 500, 1000, 2000, and 3000 Hz that exceeded 25 dB.⁴ For each individual, we calculated whether the impairment was present at baseline or occurred during the follow-up period. For individuals who were not impaired at the time of first test but who developed hearing impairment later, we determined whether a hearing shift had also taken place during the individual's audiometric testing history, and the time relationship between development of hearing impairment and the occurrence of a hearing "shift."

Survival Analysis for Hearing Loss Events

Kaplan-Meier survival curves were constructed to determine the probability of developing a hearing shift over time. These curves were constructed using each employee's first post-1981 audiometric test as their baseline test. For each type of hearing loss being evaluated, only the first occurrence of a shift or impairment was modeled. If a given type of hearing loss event was never experienced by a given employee, the time from their baseline

audiometric test until their last audiometric test was recorded, and at that time, the subject was considered censored.

Log-rank tests were used to determine whether survival curves significantly differed from each other. For this, and all other analyses, a significance level of 0.05 was used.

Results

Demographics and Baseline Hearing Status

Table 1A shows the distribution of categorical demographic variables for the study population. The population was predominantly male and white, with the next largest racial/ethnic group being black.

Table 1B presents categorical variables, including age and hearing status at time of first test. The average age at baseline was 37.7 ± 9.6 years. Baseline hearing in the left ear was slightly worse than the right, both at the high frequencies of 2000, 3000, and 4000 Hz as well as the frequencies used to calculate AMA/AAO impairment (500, 1000, 2000, and 3000 Hz), although the mean values of both these frequency ranges were within normal limits for both ears.

Noise Exposure

Over the time period of this study, the average of all noise level measurements recorded by company industrial hygienists and safety officers in the facilities studied was 84.4 dB with a standard deviation of 5.9 dB and a range from 60.1 to 115.5 dB. Recorded noise levels across facilities remained relatively constant during the study period. However, it was not possible to assign cumulative occupational noise exposures to each individual.

Frequency of Hearing Loss Outcomes

Table 2 shows the relative frequency of the different outcome measures, expressed as a rate of shifts per study year. The shift measure that occurred with the greatest frequency was the nonage-corrected 10-dB STS. The rate of age-corrected 10-dB STS was quite similar to the rate of the new OSHA recordable hearing loss criteria (1.9 vs. 1.6%, an absolute difference of 0.3%). The previous OSHA recordable 25-dB shift criteria, however, occurred much less frequently than either of these measures.

As Table 2A demonstrates, it was possible for an individual to have more than 1 hearing shift during the study period, because if a confirmed shift occurred, the baseline was reset for that ear. The more frequently a hearing shift measure occurred overall, the more likely it was to recur in an individual over the course of the study.

Unlike hearing shift metrics, hearing impairment could only occur once in an individual. Impairment was detected in at least 1 ear in a total of 8379 individuals (33.0%). Of these, 4072 individuals were impaired on their first audiometric test, whereas an additional 4307 individuals became impaired during the course of follow up.

Time to Hearing Loss Event

Figure 1 shows the percent of persons developing each of the hearing shift outcomes or hearing impairment during the follow-up period. The steepest decline in event-free survival was for nonage-corrected 10-dB STS, indicating that this metric occurs sooner and with greater frequency than the others. More than 40% of the subjects followed for 20 years had at least 1 nonage-corrected STS. For the entire study population, there was little difference in the curves for developing either the 10-dB age-corrected STS or the new OSHA hearing

loss criteria, although the difference between all 4 curves achieved statistical significance with $P < 0.01$. The slowest metric to develop was the 25-dB age-corrected shift, which remained a rare event even after 20 years of work.

Younger Workers

Figure 2 shows survival curves for workers who were less than 25 years old at the time of the first test. The relative slopes of the curves resemble the overall population, although all metrics occur later and with lesser frequency than the older population. There is a greater difference between the curves for 10-dB age-corrected STS and the new OSHA criteria, although this difference remains small.

Prevalence of Hearing Impairment at the Time of Threshold Shift

As Table 3 demonstrates, hearing impairment, defined as an average hearing threshold greater than 25 dB at the frequencies 500, 1000, 2000, and 3000 Hz, was frequently present at the time an individual experienced a hearing shift. The prevalence of impairment varied by type of shift. At the time of a first 10-dB nonage-corrected STS, only 31.6% of subjects also had hearing impairment. By the time they had had a 10-dB age-corrected STS with or without 25 dB average at 2000, 3000, and 4000 Hz, however, the prevalence was greater than 59%. Virtually all subjects who had a 25-dB age-corrected shift were hearing-impaired at the time of the shift.

For employees aged 25 or less at the time of the first hearing test, the prevalence of hearing impairment was significantly lower at the time of the shift event. Even in this population, however, more than half of individuals with a hearing shift potentially recordable under the new OSHA rule had hearing impairment at the time of the shift.

Time from Hearing Shift to Impairment

Table 4 shows, for the individuals who were not impaired at baseline but who developed impairment during the follow-up period, the time between development of various shift events and the development of impairment.

The various shift measures occurred with different frequencies in individuals who developed impairment. In the overall study population, 75% of impaired individuals had had a confirmed 10-dB nonage-corrected shift, but only 43% had an age-corrected 10-dB shift, and less than 9% had a 25-dB shift during the study period.

Of the different measures, the metric preceding impairment by the greatest time interval was the nonage-corrected 10-dB shift, which occurred on average 0.41 years before impairment developed. This time interval represents a potential “window of opportunity” to take preventive action to avoid development of hearing impairment. The age-corrected 10-dB STS occurred closer to the time of impairment. Shifts recordable under the new OSHA rule as well as those recordable under the previous guidelines actually occurred on average after the onset of AAO/AMA hearing impairment.

In the younger-worker subgroup, the shift measures were more likely to precede impairment and by a greater interval of time. The nonage-corrected STS occurred more than 2 years on average before the development of impairment.

Discussion

These data indicate that the new OSHA record keeping rules could result in an 8-fold increase in cases of recordable hearing loss for an industrial hearing-conservation program compared with the previous recordability criteria.

OSHA requires that the professional supervisor of the hearing-conservation program, who is either a physician or an audiologist, review all audiograms demonstrating an STS to determine work-relatedness and appropriate follow up for the affected individual. These evaluations will take on a new aspect, because our data suggest that most age-corrected STSs will also be potentially recordable on the OSHA log.

The results of this analysis support OSHA's assertion that cases meeting the new criteria for recording hearing loss are "medically significant." In fact, such cases seem to appear late in an employee's work career, by which time hearing impairment has usually developed. Cases fitting the new OSHA criteria and cases of age-corrected 10-dB shifts are not sensitive measures or "early flags" of noise-induced hearing loss. In fact, more than 59% of individuals with either type of shift were already hearing impaired by AAO/AMA criteria at the time of hearing shift. On average, individuals who developed impairment did so before having a threshold shift recordable under the new OSHA guidelines.

The fact that hearing loss impairment is so frequent at the time that a 10-dB age-corrected shift occurs also means that one must search elsewhere to find "early warning" of hearing loss that gives a "window of opportunity" for preventive action before the development of hearing impairment. In this study, not all the workers developing impairment were found to have a confirmed threshold shift at all. Although more than 40% of such individuals had a nonage-corrected 10-dB shift during the study period, only approximately 20% had either a 10-dB age-corrected 10-dB shift or hearing loss by the new OSHA recordability criteria. This could have been because they were already close to impairment at date of entry into the study, and only a slight degree of worsening was necessary to achieve impairment. Another reason was that a shift needed to be confirmed on a subsequent test to be counted in this study, and if no subsequent audiograms were performed, the shift would not have been counted. Perhaps the most important factor, however, was the effect of age correction in allowing a certain amount of hearing loss to occur over time without a shift being achieved. As a result, age-corrected 10-dB threshold shifts, or STSs, are not useful as early indicators of hearing loss.

Many professional supervisors of hearing-conservation programs might not be aware that age correction of the audiogram is an optional procedure under the OSHA Hearing Conservation Standard. As stated previously, the results of this study indicate that age correction removes any early warning benefit of the STS. The nonage-corrected STS, by contrast, occurred in over 75% of the individuals in this study who developed impairment and occurred on average 0.4 years before the development of impairment. This "window of opportunity" was greater in the younger age cohort. Other more sensitive metrics such as the NIOSH 15-dB shift criteria⁶ could give even greater time windows.

From a public health point of view, the difference in the record-keeping metrics between a younger and an older worker population are significant. Younger workers took more time to develop an OSHA recordable hearing loss, and there were greater time intervals preceding impairment for the implementation of preventive efforts. Even so, more than one third of individuals in this group had hearing impairment by the time they met the new OSHA recordable criteria. Therefore, even in younger workers, there is a need for better early indicators of hearing loss, which can lead to early intervention to prevent more significant loss.

The rate of hearing loss event for the new OSHA criteria was smaller in this study than the percentage of audiograms meeting the new OSHA criteria reported by OSHA in their analysis of the NIOSH database. It is possible that slightly different study entry, baseline determination, and follow-up criteria could explain this difference, because some of the Alcoa employees were exposed to levels lower than 85 dBA. In addition, the NIOSH database includes audiograms from an earlier time period, and subsequent hearing-conservation efforts to reduce noise exposures and provide hearing protection could have resulted in lower rates of hearing loss in recent decades.

Several limitations of this study are worth noting. The study population was drawn from a single, albeit diverse, type of industry. Hearing-conservation programs in other industrial settings with other types of noise exposure could differ in their hearing loss experiences. The period of follow up was truncated for individuals who began work before 1982 (when regular testing began) or who were still working at the end of the study interval. Not all individuals in the study had audiograms performed yearly, which could have decreased the sensitivity of some of the hearing loss measures. Furthermore, because this was an analysis of anonymous data, there was no attempt to perform individual case review and determine the “work-relatedness” of each case. It is possible that some of these cases of hearing loss, on individual review, would be judged not to be work-related. In general, however, the population was under surveillance because of noise exposures close to or above the OSHA action level for an industrial hearing-conservation program. Therefore, despite these limitations, this study appears to provide relevant insight into the “real world” impact of the new OSHA standard.

Conclusion

The results of this study show that the 2002 OSHA Occupational Injury and Illness Recording and Reporting Final Rule will dramatically increase the number of potentially recordable cases of occupational hearing loss. This new performance metric appears likely to increase the awareness of employers and physicians serving as professional supervisors of hearing-conservation programs regarding hearing loss and its prevention. The results of this study also show that both the new OSHA case definition for recordable hearing loss as well as the age-corrected STS represent significant medical events that are usually associated with hearing impairment by AAO/AMA criteria. For early detection and prevention of this prevalent occupational condition, hearing-conservation programs will need to use other more sensitive measures of hearing loss.

Acknowledgments

The authors thank Alcoa Inc. for assistance with this study. Partial support for this research was received from the National Institute for Occupational Safety and Health (NIOSH) award 1 K01 0800173-01.

References

1. Rabinowitz PM. Noise-induced hearing loss. *Am Fam Physician*. 2000; 61:2749–2756. 2759–2760. [PubMed: 10821155]
2. Occupational Safety and Health Administration. Occupational Injury and Illness Recording and Reporting Requirements—Final Rule. *Federal Register*. 2002;44037–44048. [PubMed: 12120663]
3. Occupational Safety and Health Administration. 1910.95 CFR Occupational Noise Exposure: Hearing Conservation Amendment (Final Rule). *Federal Register*. 1983;9738–9785.
4. Cocchiarella, L.; Andersson, GBJ., editors. *Guides to the Evaluation of Permanent Impairment*. 5. Chicago: American Medical Association Press; 2001. p. 613
5. SAS, version 8.2. Cary, NC: SAS Institute, Inc; 2002.

6. National Institute of Occupational Safety and Health. Criteria for a Recommended Standard: Occupational Noise Exposure Revised Criteria 1998. Cincinnati: Department of Health and Human Services; 1998. p. 105

Fig. 1.
Comparison of Hearing Loss Metrics in Hearing Conservation Program.

Fig. 2. Comparison of Hearing Loss Metrics in Hearing Conservation Program. Employees Under Age 25 at First Audiometric Test

TABLE 1A

Descriptive Characteristics of the Sample—Categorical Variables

Characteristic	Level	Frequency	Percentage
Gender	Male	22,529	88.61
	Female	2678	10.53
	Undetermined	219	0.86
Race/ethnicity	Asian American	139	0.55
	Black	1883	7.41
	White	22,328	87.82
	Hispanic or Latino	690	2.71
	Native American	164	0.65
	Undetermined	222	0.87

TABLE 1B

Descriptive Characteristics of the Sample—Continuous Variables

Characteristic	Level	Mean	Standard Deviation	1st Quartile	2nd Quartile (median)	3rd Quartile	Interquartile Range
Age at first test (years)		37.7	9.6	30.0	37.0	44.4	14.3
Initial hearing level (not age-corrected): average of 2 k, 3 k, and 4 kHz (dB)	Right ear	18.12	15.89	6.67	13.33	25.00	18.33
	Left ear	20.46	16.93	6.67	15.00	30.00	23.33
Initial hearing level (not age-corrected) average of 0.5 k, 1 k, 2 k, and 3 k (dB)	Right ear	12.23	9.90	5.00	10.00	16.25	11.25
	Left ear	13.18	10.46	6.25	10.00	17.50	11.25
No. of audiograms		12.75	7.37	7	11	17	10
Years of follow up		11.85	5.14	7.15	11.95	16.98	9.83

TABLE 2A

Frequency of Hearing Loss Outcomes Using Different Criteria

	10 dB STS Not Age-Corrected	10 dB STS Age-Corrected	10 dB Age-Corrected STS, 25 dB Average 2, 3, 4 kHz	25 dB Shift Age-Corrected
No. of shifts	15,361	6,011	4,967	711
Shift rate per year of follow up	4.6%	1.9%	1.6%	0.2%

TABLE 2B

Number of Individuals With Given Number of Shifts

No. of Shifts	10 dB (not age-corrected)	10-dB Age-Corrected	10 dB Age-Corrected With 25 dB Average	25 dB Age-Corrected
0	15,593	20,938	21,684	24,794
1	5,829	3,337	2,813	561
2	5,862	885	713	64
3	852	190	158	6
4	226	56	42	1
5	43	14	13	0
6+	21	6	3	0
Total	28,426	25,426	25,426	25,426

STS, standard threshold shift

TABLE 3

Prevalence of Hearing Impairment at the Time of Hearing Shift *

Type of Hearing Shift	Percent Impaired at the Time of Hearing Shift			
	All Employees		Employees Under the Age of 25 at First Audiometric Test	
	No.	Percent	No.	Percent
10-dB shift, not age-corrected	9148	31.64	697	18.08
10-dB age-corrected shift	5957	59.85	464	30.60
10-dB age-corrected shift + 25 dB average	5294	68.64	290	51.72
25-dB age-corrected shift	4364	97.55	207	89.86

* Excluding employees with hearing impairment at the time of first test.

TABLE 4

Time Between Hearing Shift and Onset of Impairment

Shift Measure	Employees Not Impaired on Their First Audiometric Test, But Who Later Developed Hearing Impairment (<i>n</i> = 4307)	
	No. of Impaired Who Also Had Shift	Mean Time (years) From Shift to Impairment
10-dB STS, not age-corrected	3,236 (75.13%)	0.49
10-dB age-corrected STS	1,997 (46.37%)	0.08
10-dB age-corrected STS + 25 dB average 2, 3, 4 KHz	1,931 (44.83%)	-0.21
25-dB age-corrected shift	459 (10.66%)	-2.10