CDC Workplace Safety and Health

Evaluation of Potential Noise Exposures in Hospital Operating Rooms

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Health Hazard Evaluation Report
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Abbreviations

AL	Action level
ANSI	American National Standards Institute
ASA	Acoustical Society of America
CFR	Code of Federal Regulations
dB	Decibels
dBA	Decibels, A-scale
Hz	Hertz
Leq	Equivalent continuous noise level
NAICS	North American Industry Classification System
NCB	Balanced noise criterion
NIHL	Noise induced hearing loss
NIOSH	National Institute for Occupational Safety and Health
OR	Operating room
OSHA	Occupational Safety and Health Administration
PEL	Permissible exposure limit
REL	Recommended exposure limit
SLM	Sound level meter
TWA	Time-weighted average

Highlights of the NIOSH Health Hazard Evaluation

The National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation at West Virginia University Hospital in Morgantown, West Virginia. Hospital management was concerned with noise exposures in operating rooms when loud surgical instruments were used.

What NIOSH Did

- We evaluated the operating rooms for noise on April 22–23, 2009.
- We monitored the surgical staff's exposure to noise.
- We measured sound levels at different frequencies in several operating rooms during surgery.

What NIOSH Found

- The noise levels we measured for employees did not exceed occupational exposure limits.
- Sounds over 90 decibels occurred intermittently and for short periods of time.
- During a craniotomy, which occurred in an operating room with nonsound absorbent walls, ceilings, and floors, noise from powered surgical instruments could cause speech interference.

What Managers Can Do

- Ensure that currently used instruments are operating as quietly as possible. Check them periodically to maintain the lowest possible noise level.
- Research what options are available for surgical instruments that are quieter than those currently used.
- Tell instrument manufacturers that noise reduction is an important consideration when deciding on a purchase.
- Provide optional hearing protection for employee use.

What Employees Can Do

- Tell management if you notice a change in volume while using a surgical instrument. This may indicate that it needs servicing.
- Wear hearing protection when high noise activities are performed.
- Keep the volume low when music is played during surgeries. This will help reduce speech interference.

Summary

On July 11, 2008, NIOSH received a management request from West Virginia University Hospital to assess employee exposures to noise in the ORs, especially during procedures where loud surgical instruments were used. On April 22–23, 2009, NIOSH investigators evaluated employee exposures to noise in the ORs during surgeries.

Nine employees (surgical technicians, registered nurses, and a surgeon) contributed 12 full-shift noise dosimetry measurements over 2 days. None of the measurements exceeded the OSHA or NIOSH noise exposure limits. Certain intermittent activities that usually lasted less than 30 seconds at a time generated sound levels measured at over 90 dBA. Noise-generating activities include drilling, surgery preparation, and clean up.

The employer and employees identified surgeries where loud instruments were used, and sound level measurements were taken during those procedures. Results from the spectral analysis indicated that noise levels in the OR were higher than levels recommended by ANSI and ASA and may cause speech interference for employees.

Reducing noise exposures in an OR can be challenging because some sounds are required during surgery (e.g., vital sign monitors, alarms, and employee communication) whereas other sounds, especially from drilling and sawing instruments, could be reduced. Using quieter powered surgical instruments would be the most effective way to reduce noise exposures in ORs and to minimize speech interference and risk of NIHL.

Personal noise measurements taken during surgeries in ORs did not exceed the OSHA or NIOSH exposure limits for noise. Noise from powered surgical instruments, which occurs in rooms with nonsound absorbent walls, ceilings, and floors, could cause speech interference. Noise exposures should be reduced through preventive maintenance of powered surgical instruments. Noise output should be considered when selecting replacement instruments.

Keywords: NAICS 622110 (General Medical and Surgical Hospitals), intermittent noise, dose, operating rooms, drills, surgery, loud music

Introduction

On July 11, 2008, NIOSH received a management request from West Virginia University Hospital to assess employee exposures to noise in the ORs, especially during procedures using loud surgical instruments. No employees had reported hearing loss to management. On April 22–23, 2009, NIOSH investigators evaluated employee exposures to noise in several ORs during surgeries.

Process Description

Eighteen ORs are used for a wide variety of surgeries, but employers and employees identified higher noise exposures during neurosurgeries and orthopedic surgeries. Some examples include craniotomies, spine disectomies, hip surgeries, and repairing fractured bones. Orthopedic surgeries last 2–4 hours and were reported to create more impact noise. Neurosurgeries last from 4–8 hours and use drilling instruments intermittently for several minutes at a time.

Operating rooms include a sterile zone and a nonsterile zone during surgical procedures. The sterile zone (work area of highest noise exposure) is the area around the surgical patient where sterile clothing, sterile instruments, and disinfectants are used to prevent the risk of infection by reducing or eliminating the presence of bacteria and other microorganisms. It initially is the site where the disinfectant is placed on the patient, but extends outward to the surgeons and other OR personnel after they put on their sterile surgical gowns. The surgeons are assisted by scrub nurses (surgical technicians, registered nurses), circulating nurses, anesthesiologists, residents, and medical students. Surgeons, scrub nurses, and residents are usually located in the sterile zone. The nonsterile zone includes the areas of the OR outside of the sterile zone and is staffed by the rest of the surgical team.

The ORs have vinyl floors, drywall walls, observation windows, and drywall ceilings. The ceilings include a combination of recessed lighting and fluorescent lights covered by plastic panels. The ORs are equipped with metal shelves, metal tables, light structures, and surgery monitoring equipment. None of the ORs contain materials designed specifically to absorb sound or reduce reverberation. The loudest instruments used during surgery include pneumatic high speed drills used for bone dissection and accessing neural structures within the cranial vault, and

Introduction (continued)

powered surgical instruments with sawing, drilling, and cutting attachments used in orthopedic surgery. Vital sign monitors and other instruments (e.g., electrocautery) can contribute constant and intermittent sounds during the surgery. Additionally, during surgery preparation and postsurgery clean up, noise is generated by metal-to-metal contact between the metal instruments and metal trays and tables or when OR staff accidentally drop instruments on the floor. Some surgical staff also reported that loud music, ringing phones, and beepers contribute to noise exposures in ORs.

Assessment

Nine employees (four surgical technicians, four registered nurses, and one surgeon) contributed 12 full-shift personal noise measures over 2 days. Spark® 706RC noise dosimeters (Larson Davis, Provo, Utah) were worn by the employees while they performed their daily activities. The noise dosimeters were attached to the wearer's belt, and a small remote microphone was fastened to the wearer's scrubs at a point midway between the ear and the outside of the shoulder. A windscreen provided by the dosimeter manufacturer was placed over the microphone during measurements to reduce or eliminate artifact noise, which can occur if objects bump against an unprotected microphone. The dosimeters averaged noise levels every second. At the end of the sampling period, the dosimeter was removed and paused to stop data collection. The noise measurement information stored in the dosimeters was downloaded to a personal computer for interpretation with Larson Davis Blaze® computer software. The dosimeters were calibrated before and after the measurement periods according to the manufacturer's instructions.

The dosimeters collect data by using different settings so that one can directly compare the noise measurement results with the three different noise exposure limits referenced in this survey, including the OSHA PEL, the OSHA AL, and the NIOSH REL. OSHA uses a 90-dBA criterion and a 5-dB exchange rate. The difference between the OSHA PEL and AL is the threshold level used for each. The PEL has a 90 dBA threshold, and the AL has an 80 dBA threshold. During noise dosimetry measurements, noise levels below the threshold level are not integrated by the dosimeter for accumulation of dose and calculation of TWA noise level. The NIOSH REL for noise differs from the OSHA PEL in that the NIOSH criterion level is 85 dBA, the NIOSH threshold level is 80 dBA, and NIOSH uses a 3-dB exchange rate. These dosimeters also allow a user-defined fourth setting. For this evaluation the fourth setting, designed to be a true Leq, was identical to the NIOSH setting with the exception that the threshold level was set to OFF. This allowed for the integration of all sound levels, including those below 80 dB. Table 1 summarizes the dosimeter settings used in this evaluation.

Table 1. Dosimeter settings

Parameters	OSHA AL	OSHA PEL	NIOSH REL	Leq
Response	Slow	Slow	Slow	Slow
Exchange rate	5	5	3	3
Criterion level	90	90	85	85
Threshold	80	90	80	off
Upper limit	115	115	115	115

Area noise levels and octave band frequency spectrum analysis (measurement of noise in different frequencies) were measured with System 824 SLM and real-time frequency analyzers (Larson Davis, Provo, Utah). The SLMs were equipped with 0.5-inch random incidence Type 1 electret microphones, and the instruments measured noise levels between 16 and 157 dBA. The SLMs were calibrated before and after the measurement periods according to the manufacturer's instructions. SLMs were mounted on a tripod at a height of approximately 5 feet. Because of space limitations and the desire to keep the SLM outside the sterile zone, the instruments were located approximately 3 meters from the OR table.

More information on occupational exposure limits and health effects for noise can be found in the Appendix.

RESULTS AND DISCUSSION

Table 2 shows the personal noise dosimetry results. None of the employees' TWA results exceeded the OSHA or NIOSH exposure limits for noise during our visit. Two registered nurses and one surgical technician had TWA noise exposures at or above 80 dBA, based on NIOSH noise measurement settings. Time-weighted average noise exposures of surgeons during total knee replacement and total hip replacement surgeries have been previously reported to range from 74.8–82.1 dBA [Love 2003]. Although the noise exposures we measured were below occupational exposure limits, noise exposures could be higher depending on the type of surgeries performed and surgical instruments used. For daily noise exposures of 80 dBA to 85 dBA, NIOSH considers the risk of material hearing impairment to be 1% to 8% over a 40-year working lifetime. NIOSH defines material hearing impairment as an average hearing threshold level that exceeds 25 dB at 1000, 2000, 3000, and 4000 Hz [NIOSH 1998]. Observations of noise induced hearing loss were reported in 11 of 22 OR personnel studied [Willet 1991]. Personnel with hearing loss had 22 years of exposure, on average. However, hearing loss observed in the Willet study did not meet the NIOSH definition for hearing impairment.

Table 2. Full shift personal noise exposure levels measured on April 22 and 23, 2009

Job Title	Sterile Zone	Duration (h:mm)	OSHA PEL TWA (dBA)	OSHA PEL Dose* (%)	OSHA AL TWA (dBA)	OSHA AL Dose* (%)	NIOSH REL TWA (dBA)	NIOSH REL Dose* (%)
Registered nurse	Yes	8:43	72	7.7	76	15	83	60
Registered nurse	Yes	8:17	68	4.6	72	8.5	81	44
Registered nurse	No	7:05	43	0.1	63	2.2	71	4.4
Registered nurse	No	7:50	46	0.2	60	1.6	70	3.4
Surgical technician	Yes	7:35	64	2.8	74	11	80	29
Surgical technician	Yes	7:44	55	0.8	70	6.3	77	16
Surgical technician	Yes	6:56	48	0.3	65	3.0	73	6.2
Surgical technician	Yes	7:49	38	0.1	58	1.1	68	2.2
Surgical technician	Yes	9:07	Dosimeter Malfunction - Microphone Fault					
Circulating nurse	Yes	7:54	55	0.8	69	5.1	76	11
Surgeon	Yes	1:02	Dosimeter Malfunction - Logged data only 1 hour					
Exposure Limits			90	100	85	100	85	100

*The various dose percentages are the amounts of noise accumulated during a work day, with 100% representing the maximum allowable daily dose.

Employees working outside the sterile zone, further from noise generating surgical instruments, had lower noise exposures. When employees entered the sterile zone, an additional sterile gown was placed over their scrubs and removed when they left the zone. At times, this gown covered the dosimeter microphone and could have slightly reduced the sound levels recorded by the dosimeter. A dosimeter worn by the surgeon malfunctioned and took measurements for about an hour instead of the surgeon's full shift. Over that hour, the instrument measured the OSHA PEL TWA at 56 dBA, the OSHA AL TWA at 65 dBA, and the NIOSH REL TWA at 74 dBA. Because the surgeon was working in the sterile zone, and the entire duration of the surgery was not measured, the actual noise exposure may have been higher. However, the surgeon was also wearing a loose-fitting hood that may have acted as a noise barrier.

Results and Discussion (continued)

NIOSH investigators observed and recorded times when noise-producing activities (drill use, music use, and during postsurgery clean up) were performed in several of the ORs. After correlating the observation times with the results from the employees' dosimeters, the sound level ranges for specific activities were found to range from 76–95 dBA during drill use, 67–94 dBA during playing of music, and 69–90 dBA during postsurgery clean-up activities. For all activities observed, sound levels over 90 dBA were observed for 1 to 20 seconds and occurred intermittently. Intermittent and short duration exposure of surgical staff to higher noise levels generated by surgical instruments may be less damaging to hearing than constant or long duration exposures [Ullah et al. 2004].

A separate study found noise levels similar to ours during use of drills for orthopedic surgeries, ranging from 71–95 dBA across 10 different surgeries [Nott and West 2003]. These researchers also noted that noise levels during set up of surgical instruments ranged from 94–104 dBA as instruments were placed in surgical trays. Several other noise researchers have found noise levels during use of surgical instruments (drills and saws) exceeding 90 dBA [Dodenhoff 1995; Mullett et al. 1999; Siverdeen et al. 2008].

Sound level and octave band frequency spectrum measurements were collected every second during two craniotomies. Spectral measurements during pneumatic drilling (loudest activity) were graphed to illustrate octave band noise levels (Figure 1). Octave band measurements provide information about the frequency distribution of noise. Because the energy from noise is usually widely distributed over many frequencies, the frequency range is broken into a smaller range of frequencies (called bandwidths), the most common being the octave band (defined as a frequency band where the upper band frequency is twice the lower band-edge frequency). Octave band analysis allows for determination of the dominant noise frequencies in a work area and can be useful for identifying potential engineering controls. For example, if low frequency noise is dominant (i.e., the highest octave-band sound levels occur in frequencies of 500 Hz or less), noise is likely generated by vibration, and noise controls that reduce or isolate the vibration from tools or equipment might decrease noise levels. If high frequency noise is dominant (i.e., the highest octave-band sound levels occur in frequencies of 2000 Hz or greater), installation of noise enclosures, barriers, or sound absorption systems is typically the most effective approach for noise reduction

[Driscoll and Royster 2003]. The highest sound pressure levels occurred primarily in the lower frequencies (less than 1000 Hz) at 31.5 Hz, 500 Hz, and 630 Hz. Because the SLMs were placed about 3 meters from the operating table, measurements underestimate sound levels closer to the source.

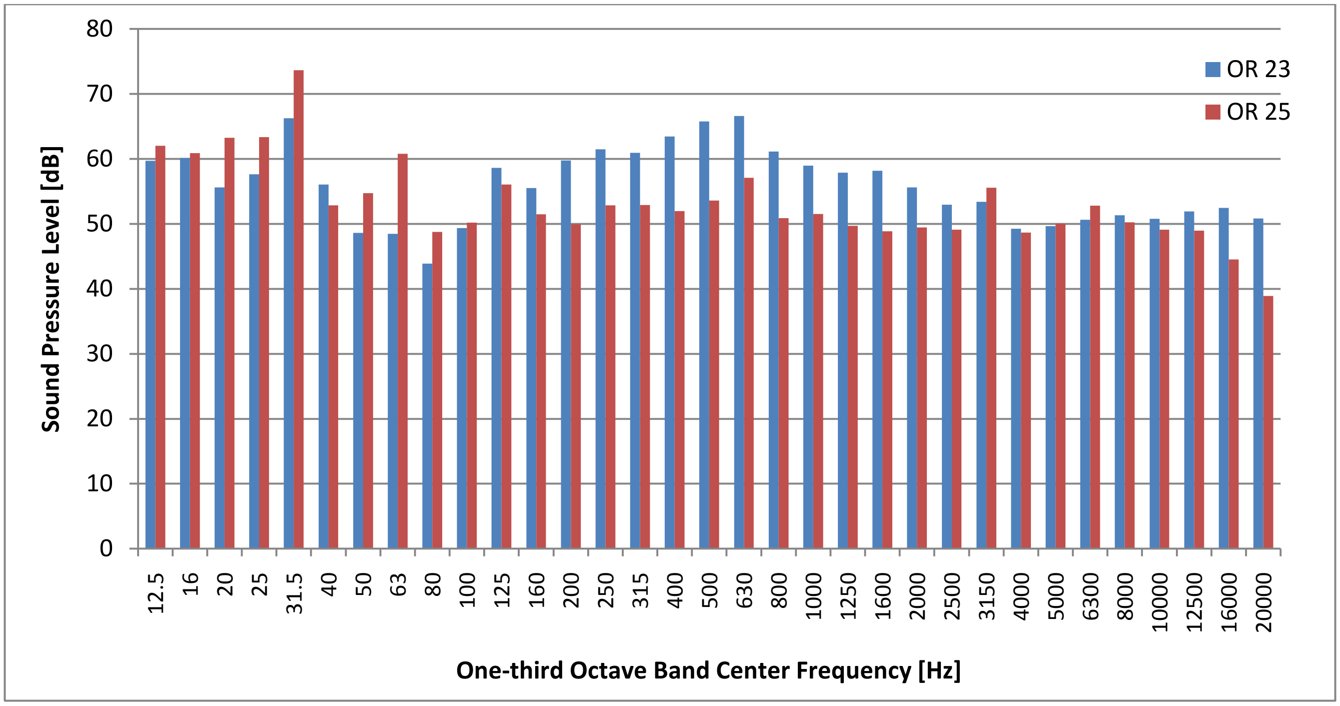

Figure 1. Spectral data in operating rooms during pneumatic drill use.

The third octave band data were combined into octave bands to simplify their analysis and to compare the room noise values to the NCB criterion [ANSI/ASA 1995]. NCBs are used to specify acceptable noise levels in occupied areas. The room noise conditions at this location are characterized as hospital and clinics-operating rooms and are recommended not to exceed NCB 25–30 [ANSI/ASA 1995]. The octave band data for the OR during a craniotomy in the morning and afternoon are shown in Figure 2. The NCB 63 curve was representative of the room noise in the afternoon, and room noise exceeded the NCB 65 curve in the morning. The NCB 65 curve represents acoustical noise criteria limits necessary for occupied indoor work spaces where communication and speech are not required [ANSI/ASA 1995]. During the craniotomy, noise generated by surgical instruments in a room with nonsound-absorbent walls, ceilings, or floors resulted in room noise conditions in which communication between surgical staff may be adversely affected. More information on NCB curves is provided in the Appendix.

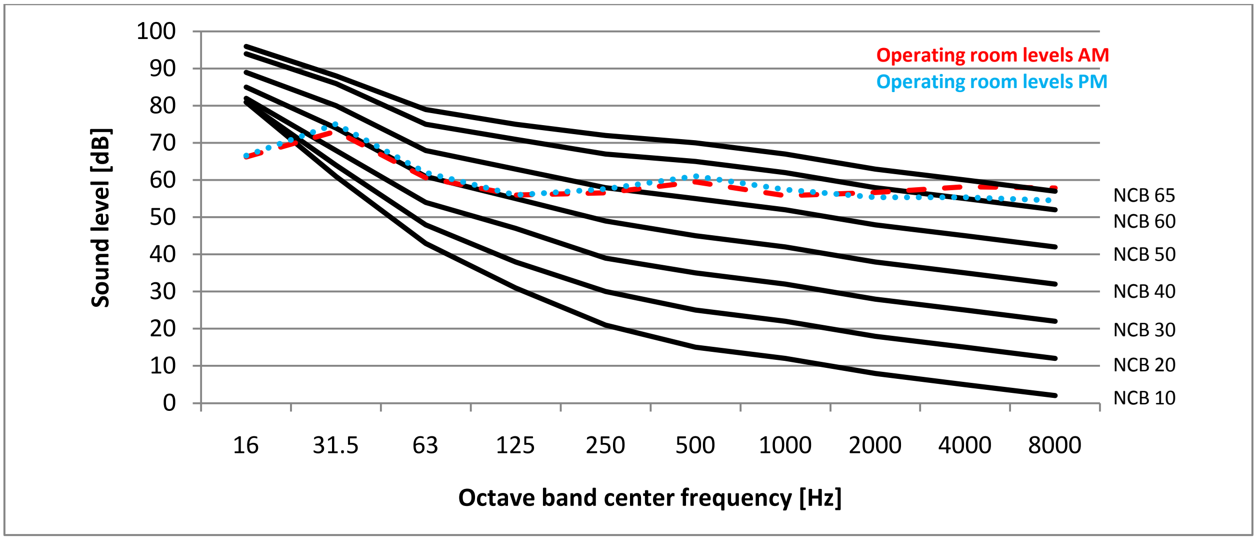

Figure 2. Spectral data from operating room and comparison with NCB curves.

Because pneumatic surgical instruments generated the highest noise levels in the OR, noise reduction efforts should focus on using surgical instruments that generate less noise. In a comparison of two different types of saw blades for knee arthroplasty, researchers found that a modified saw blade produced significantly less noise than a standard design [Sydney et al. 2007]. The modified saw blade used an oscillating tip that allowed the shaft of the blade to remain stationary, whereas the design of the standard blade required the entire blade to oscillate. Noise levels in the OR could also be reduced by playing radios at a lower volume. As a general rule, surgical staff should be able to speak to each other without needing to raise their voices when the radio is in use.

Surgical personnel could also wear hearing protection to reduce their noise exposure. However, hearing protection should be chosen carefully, because hearing protectors that excessively attenuate noise may substantially interfere with communication or the ability of surgical staff to hear patient monitoring equipment. Flat response hearing protectors that have a low noise reduction rating and attenuate noise evenly across all frequencies might be an appropriate type of insert-type hearing protector for the OR staff.

Conclusions

Inherent challenges exist in reducing noise exposures in OR settings because some sounds are required during surgery (e.g., vital sign monitors, alarms, and employee communication), whereas other sounds could be reduced (e.g., drilling, sawing, radio volume). Personal noise measurements taken during our visit did not exceed the OSHA or NIOSH exposure limits for noise. Because of loud surgical instrument use and room design conditions, noise levels measured during some surgeries were at levels that may interfere with communication between surgical personnel.

Recommendations

On the basis of our findings, we recommend the actions listed below to create a more healthful workplace.

1. Ensure that existing instruments are operating as quietly as possible, and check them periodically to maintain the lowest possible noise level. A change in volume of an instrument may indicate that the instrument needs servicing or replacement.

2. Contact instrument manufacturers and inquire about surgical instruments that may be quieter than models currently used. Indicate that noise reduction is an important consideration for purchase. Try several different models to see if some are quieter.

3. Although noise levels were below noise exposure limits, hearing protection could be worn when loud activities are being performed. If worn, hearing protection should have a flat frequency response to reduce the effect on speech communication.

4. Keep the volume low when music is played during surgeries. This can also help reduce speech interference for employees.

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The primary sources of evaluation criteria for noise in the workplace are (1) the NIOSH REL [NIOSH 1992], and (2) the U.S. Department of Labor, OSHA PEL [29 CFR 1910.95]. Employers are encouraged to follow the more protective NIOSH REL, although they are required to adhere to the OSHA PEL for compliance purposes.

NIHL is an irreversible, sensorineural condition that progresses with exposure. Although hearing ability declines with age (presbycusis) in all populations, exposure to noise produces hearing loss greater than that resulting from the natural aging process. This noise-induced loss is caused by damage to nerve cells of the inner ear (cochlea) and, unlike some conductive hearing disorders, cannot be treated medically [Ward et al. 2000]. While loss of hearing may result from a single exposure to a very brief impulse noise or explosion, such traumatic losses are rare. In most cases, NIHL is insidious. Typically, it begins to develop at 4000 or 6000 Hz (the hearing range is 20 Hz to 20000 Hz) and spreads to lower and higher frequencies. Often, material impairment has occurred before the condition is clearly recognized. Such impairment is usually severe enough to permanently affect a person's ability to hear and understand speech under everyday conditions. Although the primary frequencies of human speech range from 200 Hz to 2000 Hz, research has shown that the consonant sounds, which enable people to distinguish words such as "fish" from "fist," have still higher frequency components [Suter 1978].

The dBA is the preferred unit for measuring sound levels to assess employee noise exposures. The dBA scale is weighted to approximate the sensory response of the human ear to sound frequencies near the threshold of hearing. The decibel unit is dimensionless, and represents the logarithmic relationship of the measured sound pressure level to an arbitrary reference sound pressure (20 micropascals, the normal threshold of human hearing at a frequency of 1000 Hz). Decibel units are used because of the very large range of sound pressure levels which are audible to the human ear. Because the dBA scale is logarithmic, increases of 3 dBA, 10 dBA, and 20 dBA represent a doubling, tenfold increase, and hundred-fold increase of sound energy, respectively. It should be noted that noise exposures expressed in decibels cannot be averaged by taking the simple arithmetic mean.

The OSHA standard for occupational exposure to noise specifies a maximum PEL of 90 dBA for of 8 hours per day [29 CFR 1910.95]. The regulation, in calculating the PEL, uses a 5-dB time/intensity trading relationship, or exchange rate. This means that a person may be exposed to noise levels of 95 dBA for no more than 4 hours, to 100 dBA for 2 hours, etc. Conversely, up to 16 hours exposure to 85 dBA is allowed by this exchange rate. The duration and sound level intensities can be combined in order to calculate an employee's daily noise dose according to the formula:

$$\text{Dose} = 100 \times (C_1/T_1 + C_2/T_2 + \ldots + C_n/T_n)$$

where C_n indicates the total time of exposure at a specific noise level and T_n indicates the reference duration for that level as given in Table G-16a of the OSHA noise regulation. During any 24-hour period, an employee is allowed up to 100% of his daily noise dose. Doses greater than 100% exceed the OSHA PEL.

The OSHA regulation has an additional AL of 85 dBA; an employer shall administer a continuing, effective hearing conservation program when the 8-hour TWA value exceeds the AL. The program must include monitoring, employee notification, observation, audiometric testing, hearing protection devices, training, and record keeping. All of these requirements are included in 29 CFR 1910.95, paragraphs (c) through (o). Finally, the OSHA noise standard states that when employees are exposed to noise levels in excess of the OSHA PEL of 90 dBA, feasible engineering or administrative controls shall be implemented to reduce the employees' exposure levels. NIOSH, in its Criteria for a Recommended Standard, proposes an exposure criterion of 85 dBA as a TWA for 8 hours, 5 dB less than the OSHA standard [NIOSH 1998]. The criterion also uses a more conservative 3-dB exchange rate in calculating exposure limits. Thus, an employee can be exposed to 85 dBA for 8 hours, but to no more than 88 dBA for 4 hours or 91 dBA for 2 hours. The NIOSH REL for a 12 hour exposure is 83 dBA or less.

Because of the different 8-hour criteria and exchange rates, the dose equations used to calculate the equivalent TWA values are different for the NIOSH and OSHA criteria. The OSHA dose equation is

$$TWA = 16.61 \times \log_{10} [Dose/100] + 90,$$

and the NIOSH equation is

$$TWA = 10.00 \times \log_{10} [Dose/100] + 85.$$

The occupational noise regulation promulgated by OSHA and the NIOSH criterion are designed to prevent hearing losses from exposures to intense noise levels. However, noise of intensities lower than that which may cause a loss of hearing can be disruptive in the workplace.

Interference with speech is a possible result of unwanted noise. The noise can interfere with the efficiency and productivity of the staff and can be detrimental to the occupants' comfort, health, and sense of well being. One set of noise criteria for occupied interior spaces, the NCB curves, has been devised to limit noise to levels where satisfactory speech intelligibility is achieved [Beranek 1988, 1989; ANSI/ASA 1995]. The noise criteria were devised through the use of extensive interviews with personnel in offices, factories, and public places along with simultaneously measured octave band sound levels. The interviews consistently showed that people rate noise as troublesome when its speech interference level is high enough to make communications difficult. The recommended space classifications and suggested noise criteria range for steady background noise heard in various indoor hospital occupied activity areas are shown in Table A1.

Table A1. Example NCB specifications for occupied activity areas in hospitals and clinics*

Areas	NCB Curve
Private rooms	25–30
Wards	30–35
Operating rooms	25–30
Laboratories	33–43
Corridors	33–43
Public areas	38–43

*ANSI S12.2-1995 Criteria for Evaluating Room Noise

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Acknowledgments and Availability of Report

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