

Too Loud for Comfort: A Simulated Evaluation of Cast Saw Noise

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Background: Orthopaedic cast saws are an integral component to a pediatric orthopaedic practice but can also be associated with patient anxiety and noise exposure for patient. Although previous studies have deemed the noise generation from orthopaedic cast saws to be within safe occupational exposure levels, no study to date has compared the noise generation from a cast saw used in various exam room settings.

Methods: A simulated fiberglass cast model was used. Noise generation was assessed using calibrated sound level meters with measurements performed at 18 inches, 36 inches, and 6 ft measured from the cast saw. Measurements were performed in 1 of 2 clinical settings: (1) an open bay setting and (2) an enclosed exam room. In the enclosed exam room, the 6-foot measurement was performed behind the closed exam door. An orthopaedic cast saw with built-in vacuum was used to continuously cut the fiberglass model for 1 minute with measurements of peak and mean sound generation, recorded in decibels (dB), a logarithmic scale. Three measurements were recorded at each distance. Between group comparisons were performed with statistical significance set at $P=0.05$.

Results: Baseline sound levels were similar between cohorts with progressive decreases in mean sound with increasing distance from the saw. Mean sound levels were significantly higher in the enclosed room setting at 18 inches (92.8 dB, 95% confidence interval (CI): 91.72-93.88 vs. 90.6 dB, 95% CI: 89.91-91.29; $P=0.043$) and 36 inches (90.3 dB, 95% CI: 89.9-90.7 vs. 86.0 dB, 95% CI: 85.18-86.82; $P=0.017$). At 6-ft distance, however, the enclosed room demonstrated a 13.8-fold sound reduction compared with the open bay (72.0 dB, 95% CI: 71.59-72.4 vs. 83.4 dB, 83.14-83.72; $P<0.001$).

Conclusion: By closing the exam door, a 13-fold reduction in noise exposure can be achieved for adjacent patients and personnel. Consideration should be given for using orthopaedic cast saws in an enclosed exam room to prevent unnecessary noise

exposure with hearing protection of cast saw operators and treated patients.

Clinical Relevance: Orthopaedic cast removal.

Key Words: cast saw, noise, trauma, pediatric

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Orthopaedic cast saws are an integral component to the practicing pediatric orthopaedic surgeon but they do have the potential for unwanted consequences. Cast saws have been identified as a cause of considerable anxiety in children. Katz et al¹ showed that in children undergoing cast removal, heart rate increased an average of 26.9%. The driver of the child's anxiety has been shown to be, at least in part, associated with the noise exposure from the cast saw, with several authors identifying reduction in anxiety levels with the use of hearing protection during cast removal.¹⁻³ However, noise exposure from the cast saw has implications of a different variety for orthopaedic staff. Previous studies have reported high rates of noise-induced hearing loss in orthopaedic staff,⁴ with the cast saw being a source of considerable noise exposure.⁴⁻⁶

The clinical use of cast saws in outpatient pediatric orthopaedic clinics is most commonly performed in 1 of 2 settings: (1) an enclosed exam room⁵ or (2) a large open bay casting room.⁶ Open bay casting rooms offer several theoretical benefits by allowing for multiple patients to be roomed in a centralized location enabling for centralized housing of supplies and staffing to facilitate improved efficiency of care, although these claims have not been previously investigated. However, the use of cast saws in these open bay settings does provide added difficulty for synchronous patient care with the sound generated from the saw overwhelming the capacity to effectively interact with patients simultaneously. In addition, adjacent patients and clinical staff are exposed to increased noise exposure from the cast saw. Although the sound exposure from orthopaedic cast saws has not been shown to exceed levels deemed safe for occupational exposure,^{5,6} research has shown that long-term exposure to low pressure sound, below safe occupational thresholds results in noise-induced hearing loss⁷ indicating the need for risk minimization to at risk staff.

To date, no study has compared the sound generation of an orthopaedic cast saw when utilized in an enclosed clinical exam room, as compared with an open

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bay cast room setting. We sought to investigate this question using a simulated casting model, hypothesizing that the use of a cast saw in an enclosed exam room would result in increased sound generation within the exam room compared with an open bay setting but significant reductions in sound exposure at distances representing adjacent patients and staff.

METHODS

After receiving exempt clearance from the Institutional Review Board, a cast removal simulation was performed. The cast model consisted of 3-inch wide fiberglass casting material (Delta-Lite Plus; BSN Medical Inc., Rutherford College, NC), 5 ply in thickness, set to a length of 12 inches. Cast models were allowed to cure for 8 hours and were placed on an exam table atop cotton cast padding (Specialist 100; BSN Medical Inc.), 2 ply in thickness. Testing was performed in 2 different settings: (1) an enclosed exam room measuring 11.5 ft wide×13 ft in length×9 ft tall with tile flooring, plaster walls, and acoustic tile roof and (2) an open bay casting room consisting of 5 exam bays in a room 27 ft wide×32 in length×9 ft tall with tile flooring, plaster walls, and acoustic tile roof.

A commercially available cast saw (Delta-Saw; BSN Medical Inc.) with attached vacuum function was used on high setting to saw each sample continuously for a duration of 1 minute. Testing performed on 4 samples in each of the 2 exam settings for a total of 8 samples tested. Sound generation was measured using a commercially available sound level meter (Model r8080; REED Instruments, Wilmington, NC). Sound was recorded using the unit decibels (dB), a nonlinear unit that represents a logarithmic ratio described in reference to known reference levels.⁵

Sound generation was assessed at 3 distances: 18 inches, 36 inches, and 6 ft, measured from the saw blade (Fig. 1). The testing was arranged such that the 6-foot measurement was recorded behind the closed exam room door in the enclosed exam room setting. Measurements were recorded to include baseline noise levels, peak noise generation, and average noise generation, measured in dB, over the 1-minute testing period for each sample. Baseline noise levels were measured as the ambient noise in an empty room for the corresponding clinical setting (exam room or open fracture bay). Noise levels were compared with acceptable occupational noise exposure limits as detailed by the National Institute for Occupational Safety and Health (NIOSH) and Occupational Safety and Health Administration (OSHA) (Table 1).⁸

Statistical Analysis

Data analysis was performed using SPSS statistical package version 24 (SPSS Inc., Chicago, IL). Significance was set at $P < 0.05$. Descriptive statistics were generated. Peak and average noise levels were compared between the 2 treatment groups, open bay versus closed room setting, using univariate analysis of variance.



FIGURE 1. Depiction of sound level meters position at 18 and 36 inches relative to testing sample in the closed exam room setting. The sound level meter utilized for the 6-ft measurement is not depicted.

RESULTS

The baseline sound levels were statistically similar between the open bay and the closed exam room (open: 57.67 ± 1.65 dB vs. closed: 56.77 ± 1.11 dB; $P = 0.194$). When assessing mean sound generation at a function of distance from the cast saw, a progressive decrease with increasing distance was evident (Fig. 2). Mean sound levels were significantly higher in the closed exam room setting at 18 inches (92.8 dB, 95% CI: 91.72-93.88 vs. 90.6 dB, 95% CI: 89.91-91.29; $P = 0.043$) and 36 inches (90.3 dB, 95% CI: 89.9-90.7 vs. 86.0 dB, 95% CI: 85.18-86.82; $P = 0.017$). At 6 ft distance, however, the closed exam room demonstrated a 13.6% mean sound reduction in comparison to the open bay (72.0 dB, 95% CI: 71.59-72.4 vs. 83.4 dB, 83.14-83.72; $P < 0.001$).

Assessment of mean peak sound levels is summarized in Table 2. There was no significant difference in mean peak sound level between testing settings at a distance of 18 inches from the cast saw (closed: 97.17 dB vs. open: 95.2 dB; $P = 0.228$). Sound measurement at 36 inches, however, demonstrated that the peak sound level in the closed exam room setting was significantly higher than the open bay (closed: 91.8 dB vs. open: 87.17 dB;

TABLE 1. Summary of OSHA Continuous Noise Levels and Permissible Occupational Exposure Duration⁸

OSHA Continuous Decibel (dBA) Level	Permissible Exposure Duration
85	16 hours
90	8 hours
95	4 hours
100	2 hours
105	1 hours
110	30 minutes
115	15 minutes

OSHA indicates Occupational Safety and Health Administration.

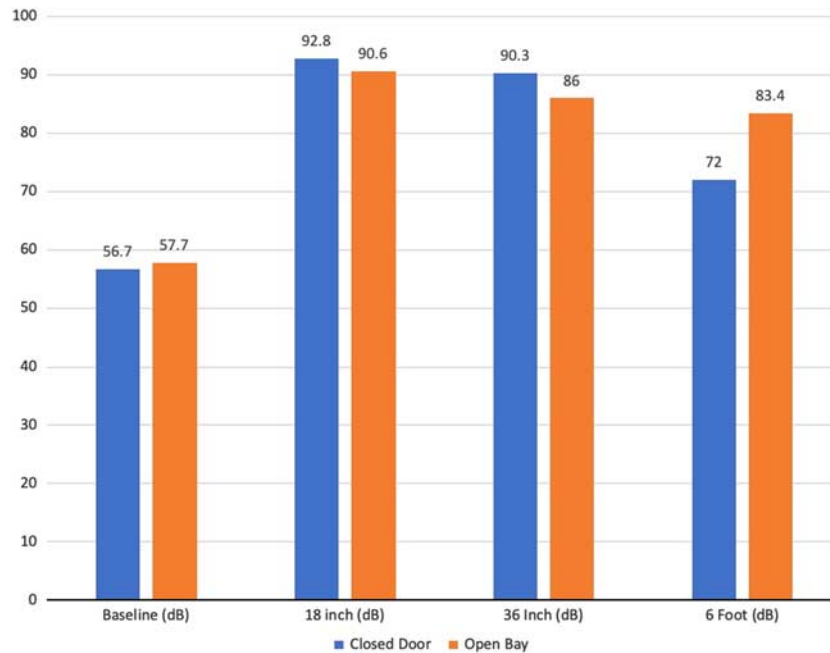


FIGURE 2. Mean sound level generated by an orthopaedic cast saw at various distances according to testing group.

$P=0.023$). This finding reversed at the 6 ft measurement with the closed exam room demonstrating significantly lower mean peak sound levels (closed: 73.8 dB vs. open: 84.7 dB; $P=0.0018$). Despite these differences, all levels did not surpass previously defined safe occupational sound exposure levels.

Clinical Implications

Sound generation as recorded in decibels (dB), is a nonlinear logarithmic scale, calculated using the equation: $dB = 10\text{Log}_{10}(I/I_0)$ in which I indicates the sound intensity and is assessed in reference to I_0 , the standard threshold of hearing.⁹ Using the inverse square law, the predicted mean sound generation level at distance can be calculated using the dB level for the 18-inch distance measurement. Using this calculation, a mean sound generation of 92.8 dB in the closed exam room at 18 inches would predict a mean sound generation of 80.7 dB at 6 ft. Using sound intensity, the pressure amplitude experienced at the tympanic eardrum can be calculated using the equation: $I = (P^2)/2\rho_0c$ where P indicated the pressure amplitude, ρ_0 indicates the

air density (1.29 kg/m^3), and c indicates the speed of the sound (estimated at 343 m/s).⁹

Combining these calculations, a comparison in sound of 0 and 20 dB is shown to result in a 100-fold increase in the sound intensity and an associated 10-fold increase in tympanic membrane pressure. When applied to the current results, the closed exam room resulted in a 7.4-fold reduction in the predicted sound intensity (measured: $1.58 \times 10^{-5} \text{ W/m}^2$ vs. predicted: $1.2 \times 10^{-4} \text{ W/m}^2$) and a 2.7-fold reduction in the tympanic membrane pressure amplitude. In comparison to the measured values in the open bay, the enclosed exam room resulted in a 13.8-fold reduction in sound intensity and a 3.7-fold reduction in tympanic membrane pressure at a distance of 6 ft, representing the exposure for adjacent staff and patients.

DISCUSSION

The orthopaedic cast saw is a vital instrument to the practicing pediatric orthopaedic surgeon. Although previous studies had demonstrated that the occupational sound exposure does not lie outside defined safety levels, the influence of the setting of saw use, has yet to be assessed as it would affect the surgeon, treated patient, and adjacent patients/personnel. This study compared the mean and peak sound generation using 2 different clinical exam settings using a simulated model. Although mean sound generation was significantly higher at distances of 18 and 36 inches from the cast saw when tested in a closed exam room, both mean sound (72 vs. 83.4 dB) and peak sound levels (73.83 vs. 84.7 dB) were significantly lower at a distance of 6 ft from the cast saw.

Open bay clinic settings have the potential to increase the efficiency of orthopaedic care, especially in the

TABLE 2. Summary of Mean Peak Sound Generation During 1 Minute of Continuous Cast Saw Use in Different Testing Setting and Various Distances

Testing Setting	Distance	Mean Peak Sound Level (dB)	95% Confidence Intervals (dB)
Closed exam room	18 inches	97.17	95.9-98.4
	36 inches	91.8	91.17-92.43
	6 ft	73.83	72.6-75.09
Open bay	18 inches	95.2	94.12-96.3
	36 inches	87.17	86.3-88.02
	6 ft	84.7	84.2-85.2

execution of a dedicated fracture clinic, by allowing providers to see multiple patients in a setting with centrally located ancillary staff, including cast technicians, supplies, and equipment. This allows for multiple cast technicians to be applying and removing cast as the provider is seeing patients in adjacent beds. In practice, this allows for the possibility of simultaneous use of multiple cast saws, oftentimes while the provider is attempting to interview patients which frustrates the patient care while also exposing multiple patients and providers to the cast saw noise. This study demonstrated that in comparison to an enclosed exam room setting, use of an cast saw in an open bay clinic results in a 13.8-fold greater noise exposure for individuals, representing potential patients, providers, and adjacent staff.

Previous studies have investigated various aspects of sound generation with regard to the orthopaedic cast saw use. Willett⁴ assessed the noise generation of various instruments used in orthopaedic practice. Electric powered cast saws resulted in 95 to 100 dB at the operators ear, decreasing to 80 to 84 dB at a distance of 3 m. Post et al⁵ investigated the effect of cast saw type and distance from saw on noise generation using a simulated fiberglass cast model comparable to this study. Standard cast saws produced noise levels of 96 to 88 dB at a distance of 6 inches, decreasing to 88 to 90 dB at 36 inches. Using a commercially available quiet saw, these noise levels decreased significantly to 64.5 dB at a distance of 6 inches. The reported mean sound values in the current study are comparable, ranging from 89.9 to 93.88 dB in both clinical settings at a distance of 18 inches, with expected decreases in sound levels with increasing distance from the cast saw. This study found that a further 13.8-fold noise reduction could be achieved at a distance of 6 ft by performing the cast removal in an enclosed room as compared with an open bay setting.

Although the mean sound levels measured in this study did not exceed threshold levels deemed safe for occupational exposure, the long-term implications of sound exposure does warrant further attention. Feng et al⁷ demonstrated that long-term exposure, defined as 8-hour daily exposure for a 3-month duration, to low pressure noise at 70 dB in an mouse model resulted in hearing loss through disruption of cochlear ribbon synapses, the structure that connects the inner hair cell to the spiral ganglion neuron. Marsh et al⁶ reported the use of orthopaedic cast saws in open bay adult and pediatric fracture clinics, indicating mean equivalent noise levels over an 8-hour work shift were 77 dB in adult clinics and 76.5 dB in pediatric clinics with peak noise levels of 140.0 and 140.7 dB, respectively. Although the reported peak levels are for excessive noise exposure, the mean exposure levels as indicate the potential risk for noise-induced hearing loss in clinical staff from long-term exposure.

According to the National Institute for Aging, it is estimated that 1 in 3 individuals between 65 and 74 years of age will experience hearing loss, increasing to nearly half of individuals above 75 years. Although there are no studies to date that compare hearing loss between

orthopaedic and nonorthopaedic matched controls, previous studies have demonstrated that instruments commonly utilized in the orthopaedic clinic and operating room demonstrate noise levels that exceed safe thresholds.^{4,10,11} Willett⁴ investigated the prevalence of noise-induced hearing loss in 22 senior orthopaedic staff members, including of 12 consultants with mean age of 47 years. Noise-induced hearing loss was identified in 50% of all tested staff members, as assessed by audiometry, increasing to 66.7% in the consultant subgroup which is particularly concerning given the mean age of 47 years in the consultant group.

Although these noise levels are concerning, other studies have suggested that the intermittent nature of noise exposure in common orthopaedic practice settings may be protective against hearing loss. Ullah et al¹² investigated the hearing of 18 orthopaedic staff members before and following workplace noise exposure. Temporary hearing threshold shifts, defined as a temporary decrease in hearing threshold frequencies that eventually returns to baseline values,¹³ were present but only minimal in magnitude and there were no reports of change in speech discrimination or tinnitus. This information is particularly pertinent to this study given the increased noise levels experienced at close distances in the enclosed exam room setting, representing the noise exposure of the cast saw operator and the patient. Given the long-term exposure for cast saw operators, this data supports the use of hearing protection, even as noise levels below defined threshold levels.

This study cannot be considered without recognition of its limitations. A simulated fiberglass casting model was utilized for reproducibility of the methodology. As this was not a cylindrical model, the peak and mean sound levels may not directly extrapolate to clinical usage, despite the correspondence of noise levels to previously published studies.⁴⁻⁶ In addition, a standard model of fiberglass, 5 ply in thickness was tested using a previously established methodology.⁵ Casting material and thickness may influence the sound levels generated and are not accounted for in this study. Although previous studies have identified significant differences in sound levels generated by various cast saw types,⁵ a single orthopaedic cast saw with an incorporated vacuum function was tested for standardization. The current results may over-estimate of sound level generation for different subtypes of orthopaedic cast saws.

In conclusion, this study demonstrated that by using an orthopaedic cast saw in an enclosed exam room results in significant increases in mean sound generation at distances of 18 and 36 inches from the source while achieving a 13-fold sound intensity reduction at a distance of 6 ft. Consideration for the use of orthopaedic cast saws in enclosed clinic rooms over open bay settings is warranted to reduce noise exposure to adjacent patients and personnel. Although the mean levels of sound generation measured in this study existed below defined threshold levels for occupational noise exposure, consideration for hearing protection should be given for the patient and cast

saw operator to minimize noise exposure, especially in light of the risk of long-term exposure for cast saw operators and its potential for inducing noise-induced hearing loss, even at low pressure levels.

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