ORIGINAL ARTICLE

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Damaging Noise Levels Are Seen in Arthroscopic Surgery

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Purpose: To determine whether orthopaedic surgeons performing arthroscopic shoulder, hip, and knee surgeries are exposed to damaging noise levels, while also comparing noise levels between these different arthroscopic procedures and further analyzing common arthroscopic knee procedures such as meniscectomy and anterior cruciate ligament reconstruction.
Methods: A retrospective review was conducted using prospectively collected intraoperative audio measurements during arthroscopic procedures from March 2021 to February 2023. Metrics included the maximum decibel (dB) level (MDL), time-weighted average (TWA), dose, and projected dose. The MDL is the greatest level of noise during each case, TWA is the average dB level over an 8-hour period, dose is the percentage of allowable daily noise, and projected dose extrapolates exposure over 8 hours.
Results: Out of 124 recordings (13 baseline, 111 procedural—10 hip, 40 shoulder, and 61 knee), MDL exceeded >85 dB for all procedures, highest for shoulder procedures (117.5 dB, $P < .001$). The TWA remained <85 dB for all procedures, which was higher for hip procedures at 62.5 dB ($P = .329$).
Conclusions: While TWA levels stay below high-risk thresholds, MDL frequently surpasses 85 dB, indicating potential harmful exposure. Hip arthroscopy trended higher noise levels compared with shoulder and knee arthroscopy.
Clinical Relevance: Cumulative exposure to the increased noise during arthroscopic procedures put high volume arthroscopic surgeons at risk for noise-induced hearing loss.

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Orthopaedic surgeons take on inherent risks when operating to deliver optimal patient care. These risks include exposure to infectious organisms, surgical smoke, chemicals such as methyl methacrylate when mixing bone cement, musculoskeletal injury, and hazardous noise.[1-4]

Noise-induced hearing loss (NIHL) affects nearly 5% of the global population. Exposure to hazardous noise is a common occupational risk affecting about 22 million U.S. workers. Occupational NIHL has a significant impact worldwide, being responsible for 16% of disabling hearing loss in adults.[5,6] The estimated annual worker's compensation claims for occupational hearing loss average between $49 and $67 million.[7,8] The National Institute for Occupational Safety and Health established a recommendation limiting noise exposure over 85 A-weighted decibels (dBA) averaged over an 8-hour workday. Those exposed to levels above this are at a significant risk for hearing loss over a lifetime. For every 3 dBA above the recommended 85 dBA, exposure duration should be halved. Even common noise such as traffic from inside a car or the sound at a sporting even can reach these levels.[9] At noise levels that exceed this recommendation, the Occupational Safety and Health Administration mandates employers implement a hearing conservation program to help prevent hearing damage.[10]

Kwan et al.[11] showed that on average maximum dB levels reached 99 dB during orthopaedic surgical procedures across subspecialties. Among the orthopaedic subspecialties, spine and adult reconstruction have been shown to have the highest levels of noise exposure.[11]

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Moreover, the total joint arthroplasty literature has extensively studied hazardous noise showing that levels consistently reached over 100 dB, levels at which hearing protection programs should be considered.[12-14] Noise exposure during total knee arthroplasty has been found to reach levels greater than 75 dB from the instruments alone.[15,16] Spine literature has shown similar findings of routine hazardous noise level of over 85 dBA during surgical treatment.[17] Meade et al.[17] showed that in both cervical and thoracolumbar surgeries, recordings were found to reach a maximum decibel (dB) level (MDL) of over 100 dB.[17] Despite these studies, there are no hearing conservation programs established for orthopaedic surgeons.

Although there is literature on the general noise exposure to sports orthopaedic surgeons, there is paucity of literature to describe the of noise exposure focusing on arthroscopic procedures alone. The purpose of this study was to determine whether orthopaedic surgeons performing arthroscopic shoulder, hip, and knee surgeries are exposed to damaging noise levels, while also comparing noise levels between these different arthroscopic procedures and further analyzing common arthroscopic knee procedures such as meniscectomy and anterior cruciate ligament (ACL) reconstruction. We hypothesized that noise levels would reach levels that could lead to NIHL.

METHODS

Following Institutional Review Board waiver, a retrospective review of prospectively collected data cohort study per the methodology of Kwan et al.[11] was conducted measuring noise exposure levels in the operationg room (OR) for orthopaedic arthroscopic shoulder, knee, and hip procedures. Procedural recordings were completed between March 2021 and February 2023. The National Institute for Occupational Safety and Health has developed an iOS (Apple, Cupertino, CA)-based sound level meter application for health professionals to collect noise exposure data that can be used in conjunction with an external microphone. In this case, an iMM-6 calibrated external microphone (Dayton Audio, Springboro, OH) was attached to the iOS device. The iMM-6 microphone was worn by the resident staff in the front pocket of scrubs or lead vest to most closely replicate the surgeon's hearing zone defined as a 2 foot wide sphere around the head.[18]

Baseline data collections were obtained in the OR before surgery without OR personnel or music playing in the background. The duration of the surgical case was recorded in minutes and defined as the time from scrubbing into the case to breaking scrub. Other OR data recorded included the operative surgeon, presence of background music, and procedure performed. The noise characteristics recorded included (Table 1) MDL, time-weighted average (TWA), dose, and projected dose. MDL is defined as the highest recorded dB level using an A-weighted dB scale. TWA is defined as the TWA projected over an 8-hour period on an A-weighted scale. Dose and projected dose are both expressed as percentages, where dose is defined as the percentage of noise over 24 hours that should not exceed 100%. Projected dose is the measured noise dose projected forward over 8 hours.

Recordings were taken in the OR with 2 fellowship trained orthopaedic surgeons, who are senior authors of this study (1 sports fellowship trained, J.S.; 1 shoulder and elbow fellowship trained, L.A.) at 2 different facilities. Arthroscopic procedures included shoulder arthroscopy, knee arthroscopy, and hip arthroscopy. Arthroscopic knee procedures were subdivided into meniscectomy and ACL reconstruction procedures and analyzed. Based on a power analysis, we attempted to collect recordings for 40 procedures per each subspecialty. This was calculated under the assumption of an effect size of 0.25 using 6 groups with a power of 0.80, meaning 80% chance of detecting a real difference and an alpha of 0.05.

Baseline and operative recordings were compared. Continuous data are presented as median (first quartile; third quartile) and categorical data are presented as percentage (%). Normality for continuous data was assessed via Shapiro-Wilks and Kolmogorov-Smirnov testing. Mann-Whitney *U* tests were used to compare continuous data for groups of 2 and Kruskal-Wallis tests for groups of 3. P values $< .05$ were deemed significant when applicable. All statistical analyses were performed using R studio (version 4.1.2, Vienna, Austria).

TABLE 1 Description of Noise Metrics and Recommended Limits

Noise Metric, Unit	Description	Recommended Limit
Maximum decibel level, dB	Highest recorded decibel level	85 dB
Time-weighted average, dB	Projected noise level over an 8-hour period	85 dB
Dose, %	Percentage of maximum allowable noise over 24 hours	100%
Projected dose, %	Estimated total dosage if individual was exposed to same noise level for 8 hours	100%

dB, decibel.

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RESULTS

A total of 124 recordings were recorded and analyzed (Table 2). This included 13 preoperative baseline recordings and 111 operative recordings in various arthroscopic orthopaedic surgical procedures. Of the operative recordings, 10 (9%) were hip procedures, 40 (36%) were shoulder procedures, and 61 (55%) were knee procedures, which were further subdivided between 45 (74%) ACL reconstructions and 16 (26%) meniscectomies (Table 3).

The median MDL reached above 85 dB for both operative (99.9 dB) and baseline recordings (86.7 dB); however, it was significantly higher during operative recordings ($P < .001$). The TWA does not reach levels above 85 dB; however, it showed a similar trend on average for the operative recordings of 57.5 dB being significantly higher ($P < .001$) than average TWA for average baseline measurements (33.9 dB). Dose and projected dose were both significantly higher for operative recordings than baseline measurements ($P < .001$).

The sound measurements during each type of surgical arthroscopic procedure, divided in shoulder, hip, and knee procedures, were then compared (Table 3). The median MDL was all above 85 dB and ranged from 97.2 dB for knee procedures to 117.5 dB for shoulder procedures. Shoulder arthroscopic procedures had the highest median MDL, which was statistically significantly higher compared with hip and knee procedures ($P < .001$). However, this trend is not consistent while comparing average TWA and dose. TWA was found to be highest on average for hip procedures at 62.5 dB and lowest for knee procedures at 57.5 dB ($P = .329$). Projected dose was similar for hip, shoulder, and knee procedures with a higher projected dose of 3.3% for hip procedures compared with the same average projected dose between shoulder and knee procedures at 1.5% and 1.2%, respectively ($P = .448$).

The knee arthroscopic procedures were then subdivided into ACL reconstruction and meniscectomy procedures (Table 4). ACL reconstruction cases on average are over 2 times as long as meniscectomy cases, with both procedures producing MDL above 85 dB. The median MDL for ACL reconstruction cases was lower at 97.2 dB compared with meniscectomies at 99.1 dB; however, this was not found to be statistically significant ($P = .909$). TWA, however, was statistically significantly higher for ACL reconstruction cases at 59.6 dB versus 55.0 dB for meniscectomies ($P = .014$) (Table 3).

DISCUSSION

This study found that arthroscopic procedures expose surgeons to noise that reaches maximum noise levels above 85 dB. The average noise over an 8-hour period, TWA, trended higher among hip arthroscopic procedures; however, these levels do not average >85 dB. In addition, when looking at common arthroscopic knee

TABLE 2 Sound Measurements at Baseline Versus Sound Measurements of Arthroscopic Surgical Procedures

	Baseline	Operative	
	N = 13	N = 111	*P* Value
Measurement time, minutes	0.45 [0.45;1.45]	76.5 [61.5;93.5xs]	<.001
Procedure			
Hip	N/A	10 (9%)	
Shoulder	N/A	40 (36%)	
Knee	N/A	61 (55%)	
Knee procedures			
ACL	N/A	45 (74%)	
Meniscectomy	N/A	16 (26%)	
MDL, dB	86.7 [69.7;90.3]	99.9 [96.4;115.7]	<.001
TWA, dB	33.9 [28.2;35.3]	58.7 [55.2;62.2]	<.001
Dose, %	0.0 [0.0;0.0]	0.2 [0.1;0.5]	<.001
Projected dose, %	0.4 [0.2;0.7]	1.5 [0.7;2.9]	.001

Note: Values are given as the count with the percentage in parentheses or as the median.
ACL, anterior cruciate ligament; MDL, max decibel level; TWA, time-weighted average.

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TABLE 3 Average Sound Measurements Based on Arthroscopic Procedure Type

	Hip	Shoulder	Knee	
	N = 10	N = 40	N = 61	*P* Value
Measurement time, minutes	74.0 [69.5;96.2]	75.5 [61.0;93.0]	83.5 [53.5;93.5]	.923
MDL, dB	97.9 [95.6;99.0]	117.5 [111.2;120.3]	97.2 [95.2;101.1]	<.001
TWA, dB	62.5 [56.8;63.1]	58.8 [55.7;60.7]	57.5 [54.0;62.6]	.329
Dose, %	0.5 [0.2;0.6]	0.2 [0.1;0.4]	0.2 [0.1;0.6]	.325
Projected dose, %	3.3 [1.2;3.8]	1.5 [0.9;2.8]	1.2 [0.6;2.8]	.448

Note: Values are given as the median with 95% confidence interval in brackets.
MDL, max decibel level; TWA, time-weighted average.

TABLE 4 Sound Measurements of Common Arthroscopic Knee Procedures

	ACL Reconstruction	Meniscectomy	
	N = 45	N = 16	*P* Value
Measurement time, minutes	89.5 [7654;95.4]	38.0 [37.5;45.0]	<.001
MDL, dB	97.2 [95.2;101.3]	99.1 [95.7;99.5]	.909
TWA, dB	59.6 [56.0;63.6]	55.0 [52.4;58.1]	.014
Dose, %	0.3 [0.1;0.7]	0.1 [0.1;0.2]	.042
Projected dose, %	1.2 [0.7;2.9]	1.3 [0.6;2.4]	.362

Note: Values are given as the median with 95% confidence interval in brackets.
ACL, anterior cruciate ligament; MDL, max decibel level; TWA, time-weighted average.

procedures, both meniscectomies and ACL reconstructions can cause noise levels above 85 dB.

Understanding where these noise levels may come from is important. Previous studies reporting hazardous noise exposure in the operating room have examined instrumentation alone. Routinely used surgical instruments can generate noise levels over 130 dB, including common orthopaedic instruments such as surgical saws, reamers, mallets, and suction.[19-22] The current study focuses on the noise exposure among arthroscopic orthopaedic operations which requires specialized instrumentation than previously studied orthopaedic subspecialities that may contribute to noise levels differently. This includes but is not limited to arthroscopic towers and pumps, suction, shavers, ablation devices, and burrs. In addition, during procedures such as ACL reconstructions requiring autograft, use of small saws can also be used that can contribute to increased noise levels that may reach levels over 85 dB.[23,24] Reported studies have shown NIHL in over 50% of orthopaedic surgery staff members and over 20% of operations exceeding acceptable levels of noise exposure.[20,22,25] NIHL can be caused by a 1-time exposure to hazardous levels or cumulative exposure to high noise levels; therefore, effects of repetitive exposure of high levels of noise from orthopaedic procedures can contribute to NIHL over time.[26]

Our study supports previous established findings of intraoperative noise among sports medicine procedures reaching levels over 85 dB.[11] However, these previous findings do not determine the risk during specific arthroscopic procedures of the hip, knee, and shoulder and include procedures performed by sports medicine surgeons that are not limited to arthroscopy alone.[11] While averaging all arthroscopic procedures from the present study, MDL reached over 99 dB. In addition, all hip, shoulder, and knee arthroscopic procedures had an average MDL above the recommended 85 dB. Moreover, the greatest MDL was for shoulder arthroscopic procedures with a median of 117.5 dB. However, the median TWA among arthroscopic procedures averaged 58.7 dB, being higher among hip procedures of 62.5 dB compared with shoulder and knee procedures. The difference in MDL for shoulder arthroscopic procedures may be attributed to differences in patient and instrumentation positioning. Arthroscopic shoulder procedures performed in the beach chair position may bring noise generating instruments closer to the surgeon's hearing zone. This can put surgeons doing a high volume of arthroscopic shoulder procedures in the beach chair

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position at higher risk compared with those who position patients in the lateral decubitus more often.

TWA levels, dose percentage, and projected dose are below the high-risk levels reported by the National Institute for Occupational Safety and Health and represent lower risk procedures for noise exposure over an 8-hour period compared with other orthopaedic subspecialities previously mentioned. Despite the TWA being lower than 85 dB on average, surgeons are still being exposed to levels above the recommended dose when focusing on the MDL averages across all arthroscopic procedures. With the median time of these procedures around 76.5 minutes, a greater number of procedures can be completed within an operative day. Although not described in literature thus far, it becomes a concern that the effects of these high noise levels may be additive. Further studies on this topic in the future are crucial to determine the additive and long-term effects of high-noise level exposure during arthroscopic orthopaedic surgery.

Based on a survey conducted through the Arthroscopy Association of North America, arthroscopists in the United States perform over 300 procedures in a year.[27] Nearly 30% of the surgeons who completed the surveys were above age 55, which is the age group most at risk for NIHL.[27,28] Given the high volume of arthroscopic procedures performed by surgeons with noise levels exceeding recommendations, the cumulative dB exposure, as represented by the present MDL levels recorded in this study, can be detrimental to these surgeons on a long-term basis. Further studies are needed to determine if arthroscopists should wear hearing protection while operating, just as surgeons wear lead to protect from radiographic radiation. This can be further extrapolated to the axillary OR staff including surgical techs, nurses, surgical device representatives, and the anesthesiology team. In addition, patients are also at risk during the duration of the procedure, which should also influence considerations based on the present data.

In contrast, a trend of sports medicine orthopaedic surgical practice that may be considered in favor of noise exposure for these arthroscopic surgeons is the trend of graft choices. Within this study, the MDL reaches a median of 97.2 dB for ACL reconstructions. Bone-patellar-bone autograft is known to be the gold standard graft choice for primary ACL reconstruction; however, since 2014 quadricep tendon autograft has become increasingly popular.[29] Compared with the surgical technique for bone-patellar-bone autograft harvesting, the technique for quadricep tendon autograft harvesting uses of a blade versus a saw.[30] Due to the decreased use of surgical saws when performing quadricep tendon grafting and its increased popularity, this may contribute to a decreased noise exposure risk for surgeons using this technique over time compared with those who use the bone-patellar-bone autograft more frequently.

Limitations

Limitations exist throughout the present study. First, of the 111 procedures, only 10 were hip arthroscopic procedures yielding a relatively small amount compared with shoulder and knee procedures and were therefore under powered. Due to the underpowered number of hip arthroscopy cases included in this study, this may result in a type I error. In addition, due to the smaller sample sizes of the shoulder and hip groups, no subgroup analysis was performed. Given dB levels recorded during these procedures, a more robust sample would determine more definitive, useful data for comparison. Due to the study being retrospective in nature, it can also cause selection bias. In addition, there were only 2 participating surgeons and lack variability among our surgeon population as a result. This includes lack of information or generalizability to different sex surgeons as well. Although their fellowship training was different, this limits our ability to apply to the general population of orthopaedic surgeons as there exists many different preferences, tools, and training among surgeons performing arthroscopic procedures. During the study, the microphone was not placed at ear level as they were positioned under the sterile scrubs. As the noise levels being detected by the microphone are not at ear level, it cannot be determined if the location of the microphone overestimates or underestimates noise levels that can be detrimental to the surgeon. Finally, background noise, such as music and staff, was not controlled throughout the recordings; therefore, this could have an additive effect on the recording noise levels. Of note, it was explained the possible differences of graft choice for ACL reconstruction on noise exposure. This was included not to influence arthroscopists to change graft choice based on noise exposure but noted as an inference based on the information gathered throughout this study and previous studies. We are explaining that cumulative effects can lead to hearing loss due to high volume of arthroscopic surgeons; however, our study alone cannot make this conclusion to determine need for protective wear.

CONCLUSIONS

While TWA levels stay below high-risk thresholds, MDL frequently surpasses 85 dB, indicating potential harmful exposure. Hip arthroscopy trended higher noise levels compared with shoulder and knee arthroscopy.

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DISCLOSURES

The authors (B.F., L.A., J.S.) declare the following financial interests/personal relationships which may be considered as potential competing interests: B.F. reports were provided by Jefferson Health - New Jersey. L.A. reports a relationship with Rothman Orthopaedic Institute that includes board membership and employment; reports a relationship with DePuy, a Johnson & Johnson company that includes consulting or advisory and paid expert testimony and equity or stocks; reports a relationship with Ignite Orthopaedics that includes equity or stocks and paid expert testimony. J.S. reports a relationship with Stryker Endoscopy that includes consulting or advisory. The other authors (H.R.P., W.B., S.K., M.S.) declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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