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Noise exposure in TKA surgery; Oscillating Tip Saw systems vs. Oscillating Blade Saw systems

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Abstract

Background. Historically it has been suggested that noise induced hearing loss (NIHL) affects approximately 50% of the orthopaedic surgery personnel. This noise may be partially caused by the use of powered saw systems that are used to make the bone cuts. The first goal was to quantify and compare the noise emission of these different saw systems during TKA surgery. A second goal was to estimate the occupational NIHL risk for the orthopaedic surgery personnel in TKA surgery by quantifying the total daily noise emission spectrum during TKA surgery and to compare this to the Dutch Occupational Health Organization guidelines.

Methods. A conventional Sagittal oscillating blade system with a full oscillating blade and two newer oscillating tip saw systems (handpiece and blade) were compared. Noise level measurements during TKA surgery were performed during cutting and hammering, additionally surgery noise profiles were made.

Results. The noise level was significantly lower for the oscillating tip saw systems compared to the conventional saw system, but all were in a range that can cause NIHL. The conventional system hand piece produced a considerable higher noise level compared to oscillating tip handpiece.

Conclusion. Noise induced hearing loss is an underestimated problem in the orthopaedic surgery. Solutions for decreasing the risk of hearing loss should be considered. The use of oscillating tip saw systems have a reduced noise emission in comparison with the conventional saw system. The use of these newer systems might be a first step in decreasing hearing loss among the orthopaedic surgery personnel.

Key words: TKA surgery; hearing loss; orthopaedic theatre; saw blade; noise induced hearing loss

Introduction

Historically it has been suggested that Noise-induced hearing loss (NIHL) affects approximately 50% of the orthopaedic surgery personnel [1-3]. One study has shown that the operation theatre of the department of Orthopaedic Surgery was subject to the loudest noises in a hospital [4]. This is partly caused by the noise generated from the powered bone saws during bone cutting [5-10]. Another factor is the hammering used to position implants, which is associated with very high impact peak noises [5-10]. A combination of these two different types of noise is a major cause for the high incidence of NIHL among the orthopaedic surgery personnel [3].

Bone saws are available in different design concepts (fig. 1a). The current conventional design features a fully oscillating blade shaft (fig. 1a, upper). A newer design features an oscillating tip powered through an internal mechanism of a stationary, hollow shaft (fig. 1a, middle and lower). Since the bony cuts in total knee arthroplasty (TKA) are often made by guiding the blade shaft through a slot in a metal guiding block, one of the proposed advantages of the latter design is a lower noise emission due to decreased blade-block interaction with less chance for soft tissue damage. However, no quantitative acoustic information from this new saw blade design is available from a clinical setting.

Sydney et al. (2007) have performed noise measurements in a laboratory setting, using both a conventional oscillating blade saw and an oscillating tip saw in simulated TKA surgeries on porcine knees [11]. Although they concluded that the oscillating tip saw featured reduced noise exposure in their experiment, different factors may have influenced their results compared to regular TKA surgeries on human patients. In particular, differences in working place environment and the properties of cadaveric porcine bone may have affected the results.

The first goal of this study therefore was to quantify and compare the noise emission of these different saw systems (blade and hand piece) when used in a standard operating room during TKA surgery. Our hypothesis is that the newer oscillating tip saw systems produce significantly less noise during cutting than the conventional oscillating blade saw system. A second goal was to estimate the occupational NIHL risk for the orthopaedic surgery personnel in TKA surgery by quantifying the total daily noise emission spectrum, also including impact noises due to hammering, during TKA and to compare this to the Dutch Occupational Health

Organization (ARBO) guidelines.

Materials & Methods

1. Bone saw instruments

A conventional Sagittal oscillating blade saw (Dual-Cut, Stryker, Michigan, USA) and two oscillating tip saws (Precision Saw and Falcon Blade, Stryker, Michigan, USA) were selected for comparison in this study (fig. 1a). The Stryker System 5 hand piece with built-in motor unit was used to power the Sagittal oscillating blade saws. The oscillating tip saws were powered by a newer Precision hand piece system 7.
Therefore, 3 different saw systems were examined during cutting: (I) Sagittal oscillating blade saw with System 5 hand piece (SAG), (II) Precision Saw with Precision hand piece system 7 (PRE), and (III.) the Falcon Blade with Precision hand piece system 7 (FAL). In addition, the System 5 and system 7 hand pieces alone were examined on noise emission. Different types of cuts were made during each TKA surgery: the tibia cut, the distal femur cut, and the 4-in-1 chamfer cut. For each cut, the same type of closed-slot metal cutting block (Scorpio, Stryker, Michigan, USA) was used to ensure guidance of the blade when cutting through the bone.

2. Measuring noise levels

Four different kinds of noise measurements were performed in this study: measurements of the saw systems during cutting and of the hand piece alone (2.1), TKA surgery noise profiles (2.2), and impact noise measurements during metal-on-metal hammering (2.3). All these noise measurements were performed with a calibrated sound level meter (2260 Investigator, Brüel & Kjær, Narum, Denmark). When used, the sound level meter was calibrated daily and has a measurement error of <0.1 dB. The three different measurements are explained separately below.

All measurements were carried out during TKA surgeries. All cuts during surgery were performed by two experienced surgeons, both skilled in all saw systems used. Inclusion criteria were patients with primary osteoarthritis requiring total knee replacement surgery. Excluded were patients with diseases that could negatively impact bone quality (osteoporosis, Paget disease, multiple myeloma, malignant bone tumors and rheumatoid arthritis).

2.1 Saw blade cutting measurements

During the tibia cut, distal femur cut and 4-in-1 chamfer cut in TKA surgery, the sound level meter was held over the shoulder of the surgeon, with the microphone tip next to the surgeon's ear while pointing towards the sound source at approximately 40 centimetres distance from the noise source (fig. 1b). This ensured that representative measurements were obtained while maintaining surgical sterility. In addition, measurements of the hand pieces alone were performed at approximately 40 centimetres distance from the noise source. In this way an estimation of the influence of the hand piece on the total noise emission of the saw system during cutting can be made.

During cutting the noise levels were measured on an A-weighted scale. This is a logarithmic measure of the measured sound intensity in comparison to a reference level, which is set to the threshold of human hearing, $I_0 = 10^{-12}$ [W/m^2]. The A-weighted scale (dB(A)) closely reflects the loudness perceived by the human ear.

In order to check whether potential hearing loss in the range of normal speech would be expected, full frequency spectra were measured for a limited number of cases: 9 frequency spectra for PRE, 6 for SAG and 4 for FAL. Analyses were performed in line with Sydney et al. [11].

The selection of used saw type was randomized for each patient.

2.2 TKA surgery profile measurements

The ARBO guidelines state that during an 8-hour working day the averaged noise level ($L_{Aeq, 8hour}$) should be below 85 dB(A) while a noise level below the 80 dB(A) is recommended [12]. The $L_{Aeq, 8hour}$ is a good measure of a subject's daily occupational noise exposure [12]. Therefore entire TKA surgery profiles were made to calculate the $L_{Aeq, 8hour}$ which includes all noises generated in TKA surgeries.

Four noise profiles of TKA surgeries were measured at 1.4 meter distance of the saw system (fig. 1b). This was the closest distance where the sterility could be maintained, while keeping the noise level meter at a constant distance. Noise measurements of 10 seconds on an A-weighted scale were made, creating an entire TKA surgery noise profile with discrete steps of 10 seconds. The measurements were started at incision and stopped when the wound in the knee was closed. It was ensured that no one was standing between the sound source and the sound level meter. Given the length of the measurement, TKA surgery profiles were only performed for SAG and FAL, which were found to be the noisiest and most quiet saw systems respectively. For both cases the measurements were performed twice after which the values were averaged.

2.3 Impact noise measurements

The ARBO guidelines also state that peak noises with a C-weighting ($L_{C, peak}$) should be below the 140 dB(C) and they recommend the $L_{C, peak}$ to be below the 135 dB(C) [12]. It is also known that the pain threshold is already at 120 dB(C) [11]. Therefore the impact (peak) noises of the metal-on-metal hammering are measured separately on a C-weighted scale. This was performed during hammering of the 4-in-1 chamfer block, femur box and tibial tray component onto the bone. These measurements were measured at ear distance (0.4 meter) from the noise source (fig. 1b).

3. <u>Noise quantification</u>

3.1 Averaging of noise levels

The average noise levels and their standard deviation (SD) per saw system were calculated. This was done by first calculating the sound intensities I [W/m^2] from the measured A-weighted noise levels L_A [dB(A)] using:

$$I = I_0 * 10^{(L_A/10)} \qquad (1)$$

After averaging these intensities, an average A-weighted decibel scale was determined using the inverse relationship:

$$L_A = 10 * {}^{10}\log(I / I_0) \qquad (2)$$

3.2 TKA surgery profile measurements

During the four entire TKA surgery measurements, noise measurements of 10 seconds were made at a constant distance of 1.4 meter of the patient's knee (fig 1b). A distance correction was performed for the measurements during hammering or cutting of the surgeon, to ensure the measurements are representative to the surgeon's ear. This was done by again first calculating the sound intensity using equation 1. The sound intensities during hammering or cutting then were corrected for the longer distance using

$$I_{corrected} = (r_{requested}/r_{actual})^2 * I \qquad (3)$$

with $r_{requested}$ = 0.4 [m] the required distance and r_{actual} =1.4 [m] the actual measurement distance. From these corrected and non-corrected intensities the average sound intensity was calculated and converted back again using equation 2.

The equivalent noise level over 8 hours, $L_{Aeq, 8hour}$ is calculated for the entire TKA surgery profiles according to [12]:

$$L_{Aeq,\ 8\ hour} = L_{Aeq,\ corrected} + 10 * {}^{10}\log (T_h / 8) \qquad (4)$$

With T_h the actual time [h] a subject is subjected to the noise. The $L_{Aeq, 8hour}$ is parameter reflects a subject's daily occupational noise exposure [12]. It was further assumed that 3 to maximum 5 operations per day are performed and that the average operation time would be 90 minutes, leading to a total operation time T_h of 4.5 to 7.5 hours.

3.2 Impact noise measurements

The average impact noise (L_{Ceq}) was calculated in the same as described in the previous paragraph for L_{Aeq}.

4. Data analysis

Statistical analysis was performed with SPSS software (19.0; SPSS inc., Chicago, Illinois) and Microsoft Excel 2007. P-values were obtained by non-parametric tests, Mann-Whitney for 2 sample comparisons and Kruskall-Wallis for multiple sample comparisons, due to the logarithmic decibel scale. Statistical significance was reached when $p<0.05$. As described in the previous section, the averages and standard deviations were computed by first calculating the sound intensities on a linear scale. From this linear scale the average and standard deviation were taken and again calculated to the dB scale.

Results

A total of 108 patients were included, 44 in the SAG group, 33 in the PRE group and 31 in the FAL group.

Saw blade cutting measurements

The cutting blocks used for each cut had little influence on the noise level (Kruskal-Wallis, $p=0.550$). Therefore, it was chosen not to differentiate between the different cuts for further analysis. In figure 2a the different saw systems and their noise levels are shown. Shown is that there are significant differences between the SAG vs. PRE and SAG vs. FAL (both Mann-Whitney, $p<0.001$). Also a significant difference between PRE and FAL was found (Mann-Whitney, $p<0.001$). It should be noted that the noise level for all saw systems and all cuts exceeds 75 dB(A), which is regarded as potentially hazardous for some individuals in case of regular exposure [13]. Figure 2b shows a significant difference between the noise levels of the two hand pieces System 5 and System 7 (Mann-Whitney, $p=0.008$).

Figure 3 shows the frequency spectra that were made of the different saw systems during the surgery cuts. The frequency interval of human speech spans approximately the region of 400-5000 Hz. One can see that for all saw systems the main contribution to the total noise is in this region.

TKA surgery noise profiles

The average noise levels during four entire surgeries was measured for FAL (n=2) and SAG (n=2). The calculated noises of a surgery with the use of SAG exceeded the noise with the use of FAL, respectively 83.7 dB(A) and 80.0 dB(A). The daily exposure level ($L_{Aeq,\ 8hour}$) for 3 TKA surgeries, taking 90min as an estimated average surgery time, is then 81.2 dB(A) and 77.5 dB(A) for respectively SAG and FAL. The SAG is then above the ARBO recommendation of $L_{Aeq,\ 8hour}$ <80.0 dB(A).

Impact noise measurements

The impact noise measurements are shown in table 1. All peak noises comply with the ARBO recommendation of a maximum value of 135 dB(C). However, it is known that the pain threshold of hearing is about 120 dB(C), all average peak noises exceeded this threshold [11].

Discussion

The first goal of this study was to quantify and compare the noise emission of a conventional oscillating blade saw systems (SAG) and two oscillating tip saw systems (PRE and FAL) in a realistic clinical environment.

As expected, the conventional oscillating blade saw system produced significantly more noise compared to the newer oscillating tip saw systems with an absolute difference around 10 dB(A). This difference can be explained by two aspects. First, the new design of oscillating tip blades reduces the noise by a decreased interaction of the moving blade with the saw block. Second, the newer system 7 hand piece is more quiet than the system 5 hand piece as shown in this study.

The average measured noise levels during cutting always exceeded the 75 dB(A) threshold for all saw systems. This is a level that for some individuals might cause hearing loss when being regularly exposed [13]. Since the conventional oscillating blade saw systems exceeded this level by a wider margin than the oscillating tip saw systems, it is inferred that the use of conventional oscillating blade saw systems is more likely to generate NIHL for the orthopaedic surgery personnel.

Our findings are in line with the study of Sydney et al. [11]. Although the measured noise levels in their study were lower than in our study, they also concluded that the newer oscillating tip saw systems produce significantly less noise than the conventional oscillating blade saw systems. The reason for the lower noise emission in the study of Sydney et al. could relate to the use of porcine tibias and femurs, but it could also relate to the acoustic properties of the room in which the measurements were performed.

A second goal of our study was to estimate the occupational NIHL risk for the orthopaedic surgery personnel in TKA surgery by quantifying the total daily noise emission spectrum and to compare this to the ARBO guidelines. The TKA surgery noise profiles revealed that the average noise produced during TKA surgery is higher when using the SAG saw system than using the FAL saw system. In addition to the noise generated by the saw, the metal-on-metal hammering causes peak noises in the range of the pain threshold [11]. For a total of 3 TKA surgeries during one day the noise levels are still below the ARBO limit of $L_{Aeq,\,8hour} < 85$ dB(A), but the SAG may exceed the ARBO recommendation of $L_{Aeq,\,8hour} < 80$ dB(A).

However, the tensor tympani muscle reflex is not fast enough to protect the ear from peak impact noises [14]. Therefore, impact noises may cause instant hearing damaging. Our TKA surgery profile analyses do not take this extra burden into account and therefore our results may still be an underestimation of the actual burden to hearing. Our findings are in line of those found by Love et al. [5], who found comparable values for the average noise produced during TKA surgery. Both are in the range of the pain threshold of hearing. The metal-on-metal peak noise level found in their study (145.5 dB(C)), however was higher than found in our study (131.0 dB(C)) and would also exceed the ARBO limit of 140 dB(C).

Surgeons should be aware that NIHL is a major problem in the orthopaedic theatre and that they should especially protect the orthopaedic surgery personnel from the loud noises produced during TKA surgery [1-3]. We therefore recommend the use of the newer oscillating tip saw systems, preferably FAL, which may reduce the NIHL risk in the operating theatre. This is especially recommended if more than 3 surgeries are performed during one day.

Several articles recommend hearing protection for orthopaedic surgeons [1-3]. However, in practice, surgeons have many objections against hearing protection. Most importantly, it impedes verbal communication with his colleagues in the operation theatre. However from a NIHL protection standpoint they should be advocated.

A limitation of the study is that the TKA surgery profiles were only measured twice with the SAG and FAL. No surgery profiles were made with PRE. However, since the SAG and the FAL system form the upper and lower limit on the noise production, it is to be expected that the results for the other systems are in between these values.

Conclusion

Noise induced hearing loss is an underestimated problem in the orthopaedic surgery. Solutions for decreasing the risk of hearing loss should be considered. The use of oscillating tip saw systems have a reduced noise emission in comparison with the conventional saw systems. The use of these newer saw systems might be a first step in decreasing hearing loss among the orthopaedic surgery personnel.

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