Evaluating Noise Emissions of Endourological Lasers: A Comparative Analysis of Ho:YAG, Tm:YAG, and Thulium Fiber Laser Systems

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Endourology and Stones

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OBJECTIVE To evaluate the noise levels of Holmium:YAG (Ho:YAG), Thulium Fiber (TFL), and pulsed Thulium:YAG (p-Tm:YAG) lasers across various settings, focusing on compliance with safety thresholds and potential impact on communication in the operating room (OR).

MATERIALS AND METHODS Noise measurements were taken in an empty OR using sound meters placed 1 m from the laser source. Ambient noise, standby, ready, and lasering modes at three settings (0.2 J-50 Hz, 0.5 J-20 Hz, and 1 J-10 Hz) were measured. Background noise was adjusted logarithmically, and sound emissions were weighted on dBA. Eleven laser models across Ho:YAG, TFL, and p-Tm:YAG systems were analyzed using descriptive and inferential statistics.

RESULTS Noise levels varied significantly by system and setting. All lasers produced < 55 dBA during standby/ready modes. During lasering, the Rocamed MH01 (Ho:YAG), RevoLix (Tm:YAG), and IPG Urolase PRO (TFL) were the quietest. The Quanta Cyber Magneto (Ho:YAG), Dornier Thulio (Tm:YAG), and EMS Laserclast (TFL) reached the highest noise levels, up to 66.06 dBA. All lasers complied with NIOSH (85 dBA) and OSHA (90 dBA) limits, though several exceeded the 55 dBA threshold for high-concentration tasks.

CONCLUSION Endourological lasers produce < 55 dBA in standby/ready modes but may exceed this during lasering, potentially impacting communication and focus in the OR. While occupational noise risks are minimal, attention to noise emissions is crucial for optimizing surgical team performance. Future studies should explore noise impact on surgical outcomes. UROLOGY xx: xxx–xxx, xxxx. © 2025 The Author(s). Published by Elsevier Inc.

Laser lithotripsy plays a crucial role in the treatment of stone disease. With the introduction of alternatives to well-established Holmium-Yttrium-Aluminum-Garnet (Ho:YAG) generators, such as Thulium Fiber lasers (TFL) and pulsed Thulium-Yttrium-Aluminum-Garnet (p-Tm:YAG) lasers, the urological landscape is changing rapidly.[1-3] While most urological research focuses on patient outcomes, less attention is given to the effects of surgery on surgeons and operating room (OR) personnel.

Eye protection has traditionally been prioritized in laser safety protocols; however, the risk of noise-induced hearing loss (NIHL) from laser use remains less understood. Sound pressure is a physical quantity expressed in the unit decibel (dB). NIHL can result from a single, intense impulse sound or prolonged, continuous exposure to elevated noise levels.[4] Impulse noise poses a greater risk due to its potential to cause mechanical damage within the cochlea and to overwhelm the ear's natural protective mechanisms[4] due to mechanical damage in the cochlea and overload of the cellular antioxidant system.[5]

Occupational noise-induced hearing loss (ONIHL) is the most prevalent occupational disease in the world.[6] ONIHL is defined as a partial or complete hearing loss in one or both ears as the result of one's employment; it is a function of continuous or intermittent noise exposure and usually develops slowly over several years.[7]

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To address this, the US National Institute for Occupational Safety and Health (NIOSH) and the Occupational Safety and Health Administration (OSHA) have established recommended exposure limits of 85 and 90 dB on the A-frequency scale (dBA), respectively, based on an 8-hour time-weighted average (TWA).[8-10]

Moreover, the United States and European guidelines recommend 55 dB in dBA threshold for tasks requiring high concentration, such as "decisions under time pressure" or "decisions with severe consequences."[11] Ambient noise exhibits a tendency to affect performance during surgery, causing decreased concentration and mental loading during surgery.[12]

This study aims to evaluate and compare the noise emissions of Ho:YAG, TFL, and p-Tm:YAG lasers across various laser settings, focusing on their compliance with established safety thresholds.

MATERIALS AND METHODS

Noise measurements were conducted in an empty OR using two smartphones equipped with the Decibel X-Pro Sound Meter application (Sky Paw Co Ltd, Hanoi, Vietnam).[13] Two operators recorded measurements simultaneously, with each device positioned 1 m in front of each laser. The laser fiber was positioned within a ureteroscope, which was inserted into a saline-filled container at a fixed distance, to simulate standard OR practice and ensure realistic procedural conditions. Three sound intensity measurements were recorded under multiple conditions: ambient noise, noise during laser standby and ready modes, and lasering noise at three different laser settings (0.2 J-50 Hz, 0.5 J-20 Hz, and 1 J-10 Hz) and different pulse durations. This approach allowed us to analyze how different energy-frequency configurations, while delivering the same total power, could differently impact the acoustic noise generated during laser activation.

According to recently published expert recommendations, a combination of low power (averaging between 5 and 8 W) and low frequency (averaging between 10 and 15 Hz) should be used for laser lithotripsy of ureteral stones, while higher power settings (15-30 W) are recommended for the pulverization of kidney stones.[14-16] Nonetheless, some surgeons worldwide continue to adopt high-frequency settings; therefore, we decided to test a higher frequency setting of 50 Hz to evaluate whether increasing the frequency could have a greater impact on the decibel levels produced.

To accurately compare the noise emissions of different laser systems, background noise was accounted for using the formula: $L_{\_laser} = 10 \times \log_{10} (10^{(L\_total/10)} - 10^{(L\_ambient/10)})$, which isolates the laser-generated sound level ($L_{\_laser}$) by subtracting ambient noise ($L_{\_ambient}$) from the total measured noise ($L_{\_total}$).

Three laser sources and 11 specific laser models were tested, each with designated fiber diameters. The Ho:YAG lasers included the Quanta Cyber Magneto, paired with a 200 μm fiber, the Rocamed MH01, using a 272 μm fiber, and the Dornier Medilas H Solvo35, with a 270 μm fiber. The Tm: YAG tested were the RevoLix, utilizing a 272 μm fiber, and the Dornier Thulio, equipped with a 270 μm fiber. For the TFL, the IPG Urolase PRO, the EMS Laserclast, the Stortz multiLASE and the Woll-Pulvis 60+ were paired with 272 μm fibers, while the Coloplast TFL Drive and the Quanta Fiber Dust used 200 μm fibers.

We analyzed the dB data with descriptive statistic techniques, calculating the minimum, maximum, average, and peak dBA levels for each measurement scenario, with all measurements weighted on dBA to reflect human auditory sensitivity. The measures' mean from the two smartphones was used to improve accuracy. Data are presented as means and standard deviations of the average dBA measured over a 10-s interval, comprehensively comparing noise emissions across the different laser systems and fiber configurations. Laser noise emissions were compared using the Student's *t* test or the Chi-squared/Fisher exact test, as appropriate. A two-sided *P*-value of $< .05$ was considered indicative of statistical significance. All study data were analyzed using IBM SPSS version 30 (IBM, Armonk, NY).

RESULTS

Standby and Ready Modes

The average noise levels produced in standby and ready modes by various laser systems are shown in Supplementary Figure 1. A comparison of noise levels between different laser systems in standby and ready modes is presented in Supplementary Table 1. The following data are presented in standby mode, which is shown first, followed by ready mode.

Lasers producing lower noise levels included the TFL EMS Laserclast (38.79 ± 3.15 dBA and 39.83 ± 3.38 dBA), the TFL Quanta Fiber Dust (40.22 ± 1.94 dBA and 40.09 ± 1.87 dBA), and the TFL Wolf-Pulvis 60+ (43.82 ± 2.28 dBA and 43.51 ± 2.28 dBA).

Lasers with medium noise levels were the Tm:YAG RevoLix (45.93 ± 3.50 dBA and 46.69 ± 2.44 dBA), the TFL IPG Urolase PRO (45.98 ± 3.64 dBA and 51.26 ± 2.59 dBA), the Ho:YAG Rocamed MH01 (46.40 ± 3.44 dBA and 46.28 ± 3.31 dBA), the TFL Storz multiLASE (46.98 ± 1.97 dBA and 46.82 ± 1.98 dBA), and the Ho:YAG Dornier Medilas H Solvo (48.80 ± 1.75 dBA and 49.42 ± 1.81 dBA).

Higher noise levels were recorded for the Coloplast TFL (49.90 ± 1.40 dBA and 49.88 ± 1.42 dBA), the Ho:YAG Quanta Cyber Magneto (51.50 ± 1.30 dBA and 51.21 ± 1.33 dBA), and the Tm:YAG Dornier Thulio (58.51 ± 4.18 dBA and 58.51 ± 3.35).

Lasering Modes

Laser Settings: 0.2 J-50 Hz. The average noise levels produced by various laser systems at the setting of 0.2 J-

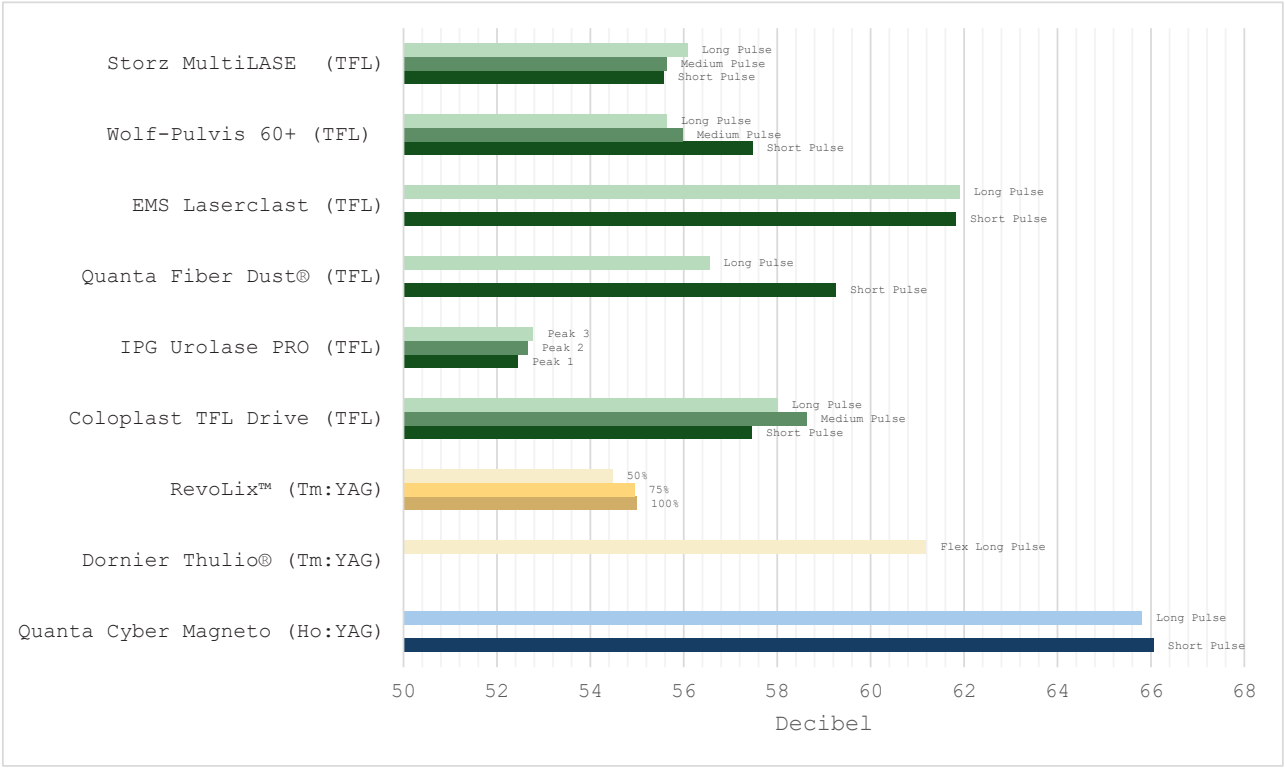

Figure 1. Comparison of decibel levels for various endourological laser systems at a setting of 0.2 J-50 Hz. Ho:YAG, Holmium: Yttrium Aluminum Garnet; TFL, Thulium Fiber Laser; Tm:YAG, Thulium: Yttrium Aluminum Garnet.

50 Hz are shown in Figure 1. The following data relate to the noisier pulse lengths.

Lasers producing lower noise levels included the TFL IPG Urolase PRO (52.4 ± 2.4 dBA), the Ho:YAG Rocamed MH01 (54.26 ± 1.63 dBA), and the Tm:YAG RevoLix (54.48 ± 1.44 dBA).

Lasers with medium noise levels included the TFL Storz multiLASE (56.5 ± 1.7 dBA), the TFL Coloplast (57.5 ± 3.5 dBA), the TFL Quanta Fiber Dust (58.2 ± 1.6 dBA), and the TFL Wolf-Pulvis 60+ (58.9 ± 1.7 dBA).

Lasers producing higher noise levels included the Tm:YAG Dornier Thulio (61.19 ± 2.93 dBA), the TFL EMS Laserclast (61.8 ± 2.6 dBA), and the Ho:YAG Quanta Cyber Magneto (66.01 ± 1.92 dBA). Noise levels for the Dornier Medilas H Solvo 35 Ho:YAG laser were not available for this setting.

Laser Settings: 0.5 J-20 Hz. The average noise levels produced by various laser systems at the setting of 0.5 J-20 Hz are shown in Figure 2. The following data relate to the noisier pulse lengths.

Lasers producing lower noise levels included the TFL IPG Urolase PRO (52.54 ± 2.20 dBA), the Ho:YAG Rocamed MH01 (54.26 ± 1.63 dBA), and the Tm:YAG RevoLix (54.26 ± 1.63 dBA).

Lasers with medium noise levels included the TFL Storz multiLASE (55.78 ± 1.76 dBA), the TFL WOLF-Pulvis 60+ (55.98 ± 1.76 dBA), the TFL Quanta Fiber Dust (57.02 ± 0.84 dBA), and the TFL Coloplast (57.53 ± 1.39 dBA).

Lasers producing higher noise levels included the TFL EMS Laserclast (59.90 ± 1.37 dBA) and the Ho:YAG Quanta Cyber Magneto (65.99 ± 2.44 dBA). Noise levels for the Ho:YAG Dornier Medilas H Solvo 35 and the Tm:YAG Dornier Thulio lasers were not available for this setting.

Laser Settings: 1 J-10 Hz. The average noise levels produced by various laser systems at the setting of 1 J-10 Hz are shown in Figure 3. The following data correspond to the noisier pulse lengths.

Lasers producing lower noise levels included the Ho:YAG Rocamed MH01 (51.27 ± 2.50 dBA), the Tm:YAG RevoLix (51.27 ± 2.50 dBA), and the TFL IPG Urolase PRO (53.30 ± 2.92 dBA).

Lasers with medium noise levels included the TFL Quanta Fiber Dust (53.56 ± 1.18 dBA), the TFL Storz multiLASE (53.31 ± 1.79 dBA), the TFL Wolf-Pulvis 60+ (53.48 ± 1.78 dBA), and the TFL Coloplast (56.02 ± 1.64 dBA).

Lasers producing higher noise levels included the TFL EMS Laserclast (57.22 ± 1.92 dBA), the Ho:YAG Dornier Medilas H Solvo 35 (58.17 ± 2.17 dBA), the Tm:YAG Dornier Thulio (60.73 ± 3.39 dBA), and the Ho:YAG Quanta Cyber Magneto (63.57 ± 2.19 dBA).

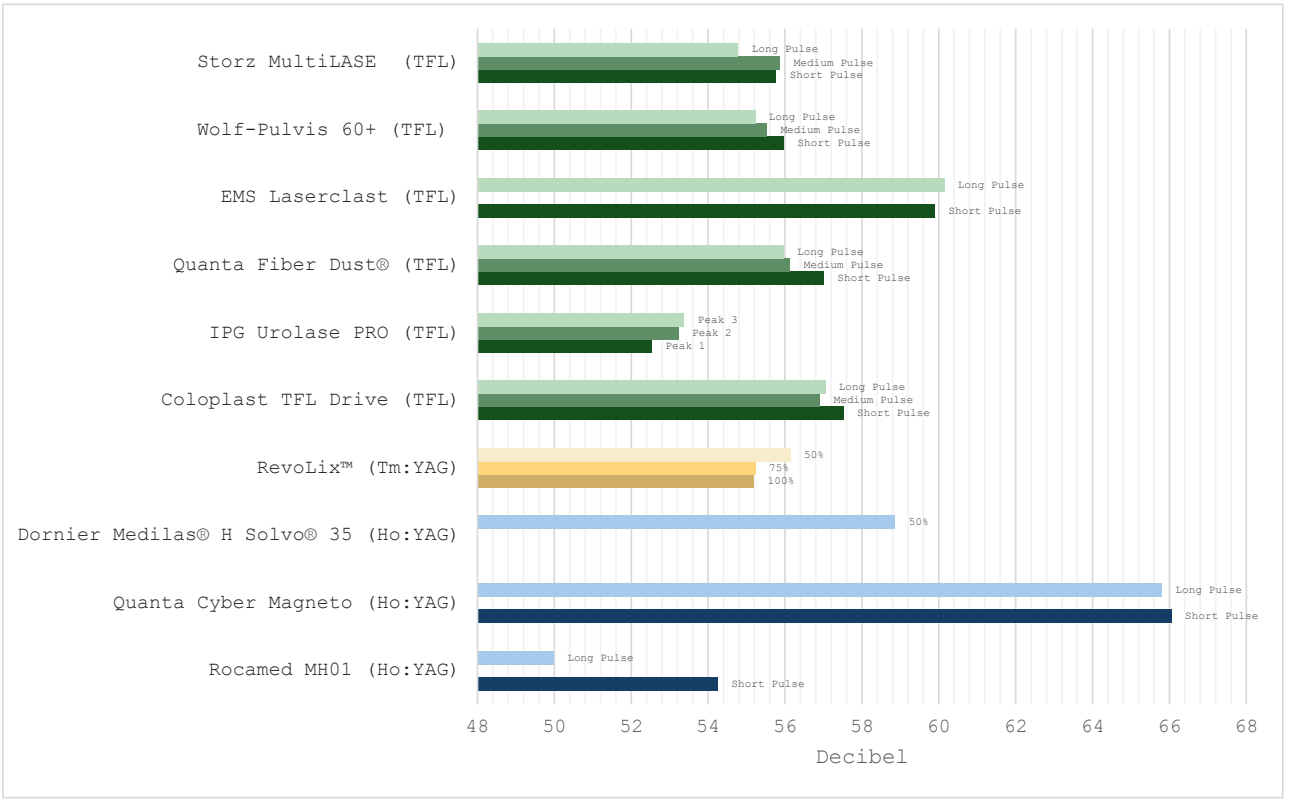

Figure 2. Comparison of decibel levels for various endourological laser systems at a setting of 0.5 J-20 Hz. Ho:YAG, Holmium: Yttrium Aluminum Garnet; TFL, Thulium Fiber Laser; Tm:YAG, Thulium: Yttrium Aluminum Garnet.

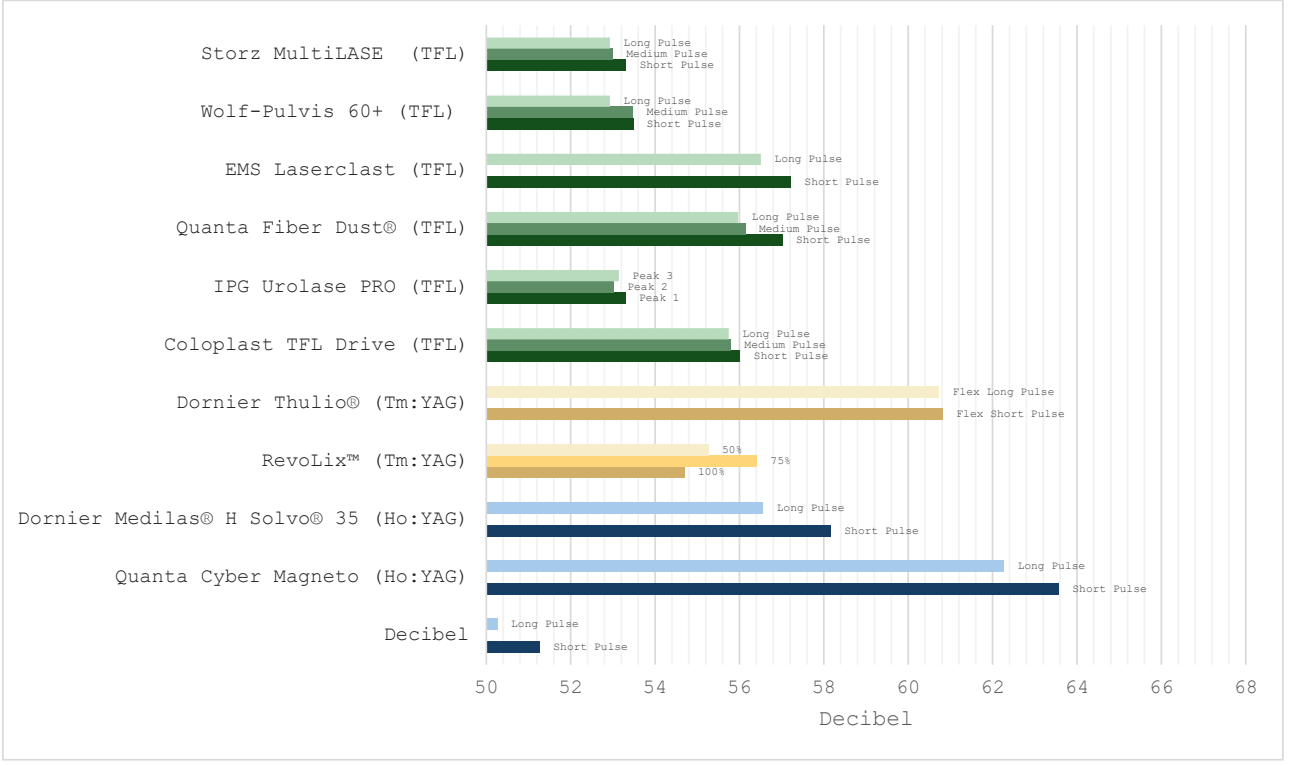

Figure 3. Comparison of decibel levels for various endourological laser systems at a setting of 1 J-10 Hz. Ho:YAG, Holmium: Yttrium Aluminum Garnet; TFL, Thulium Fiber Laser; Tm:YAG, Thulium: Yttrium Aluminum Garnet.

Table 1. Mean, lowest, and highest dBA values for each laser across all settings.

Laser Model	Laser Type	Lowest dBA	Highest dBA	Mean dBA
Quanta Cyber Magneto	Ho:YAG	63.57 ± 2.19	66.06 ± 1.92	65.19 ± 2.18
IPG Urolase PRO	TFL	52.45 ± 2.40	61.91 ± 4.84	54.45 ± 2.21
EMS Laserclast	TFL	57.22 ± 1.92	61.91 ± 4.84	59.65 ± 2.51
RevoLix	Tm:YAG	51.27 ± 2.50	61.19 ± 2.93	55.67 ± 1.77
Dornier Thulio	Tm:YAG	60.73 ± 3.39	61.19 ± 2.93	60.73 ± 3.39
Quanta Fiber Dust	TFL	53.56 ± 1.18	59.26 ± 2.57	56.71 ± 2.39
Dornier Medilas H Solvo 35	Ho:YAG	58.17 ± 2.17	58.17 ± 2.17	58.17 ± 2.17
Coloplast	TFL	54.26 ± 1.63	57.50 ± 1.47	56.02 ± 1.64
Wolf-Pulvis 60+	TFL	53.48 ± 1.78	57.47 ± 1.77	56.01 ± 1.77
Storz MultiLASE	TFL	53.31 ± 1.79	56.02 ± 1.64	55.89 ± 1.78
Rocamed MH01	Ho:YAG	51.27 ± 2.50	54.26 ± 1.63	53.23 ± 1.63

dBA, decibel in A scale; Ho:YAG, Holmium: Yttrium Aluminum Garnet; TFL, Thulium Fiber Laser; Tm:YAG, Thulium: Yttrium Aluminum Garnet.

Comparison of Noise Levels Among Laser Sources. In Table 1, we reported the mean, the lowest, and the highest dBA produced by all the lasers considering all the settings studied in order from the highest dBA laser to the lowest dBA laser.

A comparison of noise levels between different laser systems within the same laser source category is presented in Supplementary Tables 2, 3, and 4.

To identify the quietest laser systems within each category, noise emissions were measured under their most silent operating settings. Among the Ho:YAG lasers, the Rocamed MH01, operating at 0.5 J-20 Hz Long Pulse, exhibited the lowest average noise level at 50.0 ± 2.85 dBA. In the Tm:YAG category, the RevoLix, operating at 0.2 J-50 Hz 50%, recorded an average noise level of 54.48 ± 1.44 dBA, while within the TFL category, the IPG Urolase PRO, operating at 0.2 J-50 Hz 125 W, achieved an average noise level of 52.45 ± 2.40 dBA. The Rocamed MH01 (Ho:YAG) demonstrated the lowest noise emissions overall. Statistical comparisons showed that the noise level of the Rocamed MH01 was significantly lower than that of the RevoLix (Tm:YAG) (P = .003) but not significantly different from the IPG Urolase PRO (TFL) (P = .068). Similarly, the noise level of the IPG Urolase PRO was not significantly different from that of the RevoLix (P = .053).

To identify the loudest laser systems within each category, noise emissions were measured under their noisiest operating settings. The 0.2 J-50 Hz setting was found to produce the highest noise levels across all laser systems. Among the Ho:YAG lasers, the Quanta Cyber Magneto, operating in Short Pulse mode, produced the highest noise level at 66.06 ± 1.92 dBA. In the Tm:YAG category, the Dornier Thulio, operating in 50% pulse mode, recorded a noise level of 61.19 ± 2.93 dBA, while the TFL EMS Laserclast, operating in Long Pulse mode, reached 61.91 ± 4.84 dBA. The Quanta Cyber Magneto (Ho:YAG) demonstrated the highest noise emissions overall. Statistical comparisons showed that its noise level was significantly higher than that of the Dornier Thulio (Tm:YAG) (P = .003) and the EMS Laserclast (TFL) (P = .040). No significant difference was observed between the Dornier Thulio and the EMS Laserclast (P = .349). These laser noise measurements were compared to noise levels from common everyday objects, as shown in Supplementary Figure 2 to provide a relatable context.

DISCUSSION

Noise in the OR can adversely affect surgeons[12]; however, few studies have investigated the noise levels produced by various surgical instruments.[11,17-22] Our study represents the first evaluating noise emissions from various endourological laser sources used across various settings, offering insights into noise levels during both standby/ready and active lasering modes. Our findings reveal that noise levels vary significantly depending on the laser type and operational setting. In standby and ready modes, most laser systems tested produced sound levels below the 55 dBA threshold recommended for tasks requiring high concentration.[11] During active lasering, the Quanta Cyber Magneto (Ho:YAG), Dornier Thulio (Tm:YAG), and EMS Laserclast (TFL) were identified as the loudest laser systems within their respective categories. Under the noisiest settings (0.2 J-50 Hz), the Quanta Cyber Magneto produced the highest noise level at 66.06 ± 1.92 dBA. The Dornier Thulio and the EMS Laserclast followed with noise levels of 61.19 ± 2.93 dBA and 61.91 ± 4.84 dBA, respectively. Statistical comparisons revealed that the Quanta Cyber Magneto produced significantly higher noise emissions than both the Dornier Thulio (P = .003) and the EMS Laserclast (P = .040). In contrast, no significant difference was observed between the Dornier Thulio and the EMS Laserclast (P = .349).

The NIOSH recommended that the exposure limit be 85 dBA as an 8-hour TWA, with a 3 dBA exchange rate. This means that for every 3 dBA increase, the allowable exposure time is reduced by half.[10] OSHA, by contrast, is a regulatory agency that dictates a less conservative but legally enforceable exposure limitation of 90 dBA over an 8-hour TWA. For every 5 dBA increase, allowable

exposure time is reduced by half.[9] It is important to realize that a reduction by 3 dBA equals to an approximately 50% reduction of the resented noisiness.[23,24] Because the human ear perceives sound pressures of equal intensity but unequal frequency differently, they are commonly weighed against so-called rating curves. In German regulations, it is suggested to collect the A-rated sound pressure levels.[23] Because of their wide dynamic range, sound pressures are displayed logarithmically.

All the endourological lasers tested emitted sound levels below the exposure limits recommended by NIOSH and OSHA. Nonetheless, this issue warrants attention, as sound levels above 60 dBA exceed the threshold for normal communication, and 55 dBA is considered the upper limit for tasks requiring high concentration, such as "decisions under time pressure" or "decisions with severe consequences."[11] Therefore, lasers activated at various settings during procedures may disrupt intrateam communication and reduce the concentration of surgeons in the OR.

In the urological field, some studies have suggested that the noise produced by extracorporeal shock wave lithotripsy can harm the hearing of both OR personnel and patients, recommending hearing protection.[20,22] However, Terlecki et al have contradicted this, finding the noise levels to be within the range considered safe by OSHA standards.[19] Xu et al found that noise from the laser emitter during HoLEP disrupts intrateam communication and affects the concentration of surgeons in the OR; however, no hearing damage was detected.[18] Moore et al conducted intraoperative noise measurements during a patient case series of ureteroscopy and laser lithotripsy using both TFL and Ho:YAG lasers, concluding that TFL laser lithotripsy was significantly quieter than the standard holmium laser during retrograde ureteroscopy.[21]

This study has limitations that warrant attention. First, more advanced sound level meters would be necessary to improve measurement accuracy. However, two studies have demonstrated that smartphone applications provide an accessible, cost-effective, and reliable noise level assessment.[25,26] Second, despite accounting for background noise, acoustics and sound transmission can vary depending on room size and layout, suggesting that measurements could slightly change in an anechoic chamber that would eliminate any residual background noise interference. Additionally, lasers with the same wavelength from different manufacturers produced varying sound levels, and sound levels from a single laser can also vary depending on the target material. Finally, we tested settings for the use of flexible ureteroscopy rather than for prostate enucleation, which warrants further research.

CONCLUSION

This study found that all endourological lasers generally produced sound levels below the 55 dBA threshold in standby and ready modes, allowing for effective communication within the OR. However, certain laser systems approached this threshold, suggesting that specific models may require further evaluation with professional-grade sound measurement tools to verify noise levels accurately. During activation, all lasers tested produced sound levels below the 85 dBA limit recommended by NIOSH, indicating that these devices pose minimal risk of exceeding occupational exposure limits. Nonetheless, considering the potential for noise-related distractions, clinicians should remain aware of the variability in noise emissions among different laser systems. Future research is warranted to understand better the practical impact of laser noise exposure on surgical teams' concentration, communication, and well-being.

Disclosures

None.

Ethical Declaration

Not required.

CRediT Authorship Contribution Statement

Johan Cabrera: Data curation. **Aideen Madden**: Data curation. **Alberto Quarà**: Writing – original draft, Formal analysis, Data curation, Conceptualization. **Luigi Candela**: Methodology, Data curation. **Mariela Corrales**: Supervision, Formal analysis. **Alejandra Bravo-Balado**: Writing – original draft, Data curation. **Federico Zorzi**: Formal analysis. **Olivier Traxer**: Writing – review & editing, Validation, Supervision, Methodology, Data curation, Conceptualization. **Stefano Moretto**: Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Federic Panthier**: Writing – review & editing, Supervision, Methodology, Data curation, Conceptualization. **Steeve Doizi**: Writing – review & editing, Supervision, Methodology. **Berthe Laurent**: Supervision.

Data Availability

Authors have full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Declaration of Competing Interest

The authors have no conflict of interest to declare.

Acknowledgment

None.

Appendix A. Supporting Information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.urology.2025.01.045.

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