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A Comparison of Flow Rates and Noise Levels for Two Commercial Smoke Evacuators

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Abstract

Background: Electrosurgical smoke can interfere with visibility in the surgical field and can potentially be a harmful irritant to operating room staff. Smoke evacuators with adequate flow rates can reduce smoke at the surgical site, but their acceptance into practice has been slow, in part due to their noise. This study compared the Megadyne Smoke Evacuator to a conventional device in terms of flow rate and noise levels.

Methods: In the first series of tests, the Megadyne Smoke Evacuator was compared to a conventional device for noise levels at full flow rates and at comparable flow rates. In the second series, using the conventional smoke evacuator, the Megadyne Telescoping Smoke Evacuation Pencil was compared to the conventional pencil for noise levels at a comparable flow rate.

Results: The Megadyne Smoke Evacuator provided 52% higher maximum flow rate and was 7.0 dBA (39%) quieter ($p<0.001$). At comparable flow rates, Megadyne was 14.5 dBA (63%) quieter ($p<0.001$). The Megadyne Telescoping Pencil provided higher flow rates, while producing 4.8 dBA (28%) less noise.

Conclusions: Potential health concerns have led to the promulgation of local and national regulations regarding the use of smoke evacuators during electrosurgery. Removing smoke effectively while maintaining a low level of background noise can improve the working environment of the operating room staff. This study shows that Megadyne Smoke Evacuator and Pencil provide higher flow rates while being quieter than a conventional device.

Keywords: Smoke • Evacuation • Plume • Particles • Noise levels • Flow rate

Introduction

Smoke evacuation has become recognized as an important part of electrosurgery procedures. Not only does it provide a clearer view of the surgical field, but it also can improve staff comfort by reducing unnecessary exposure to particles that may be released during the procedure. The use of smoke evacuators has been recommended by The Association of Perioperative Registered Nurses (AORN) [1,2] and The U.S. National Institute for Occupational Safety and Health (NIOSH) [3,4]. Smoke safety guidelines aid in establishing a safe environment for the perioperative team; however, standardized guidelines have not yet been established.

The sound of the motor running and other parts of the smoke evacuator can easily reach an uncomfortable level if it is not properly designed. Loud sound can overstimulate delicate hearing cells, leading to the permanent injury or death of the cells; once lost this way, hearing cannot be restored, causing an impaired perception of sound including sensitivity to sound or ringing in the ears [5]. The U.S. National Institute of Occupational Health sets a limit of a time-weighted average of 85 dBA over an 8-hour period as a safe limit to avoid noise-induced hearing loss. Noise levels above 70 dBA have been shown to interfere with communication or drown out the sound of other equipment or alarms. In an operating room it is recommended that noise levels ideally be below 60 dBA to ensure effective communication [6].

Adequate flow rate is an important consideration when using a smoke evacuator. The amount of the suction and airflow is important, to allow for effective smoke capture [7,8]. A modern smoke evacuator that has a well-designed pencil can effectively capture surgical smoke with a flow rate of 71-118 LPM (liters per minute) [9]. For procedures with dense smoke plumes, surgeons may want to consider the higher end of this range.

Although the risk to medical staff resulting from chronic exposure to smoke evacuator noise has not been substantiated, the use of smoke evacuation has been recommended by governmental and several state legislative bodies. Recent smoke evacuator technology has focused on making the devices quieter while delivering effective flow rates. This study was conducted to compare flow rates and noise levels between the new Megadyne Smoke Evacuator and Telescoping Smoke Evacuation Pencil (Figure 1) with a conventional device. Further, flow rates and noise levels were also compared for the conventional smoke evacuator using different smoke pencil designs.

Materials and Methods

The two smoke evacuators evaluated were the Megadyne Smoke Evacuation System which consists of the MESE1 Megadyne Smoke Evacuator with 251010J Megadyne Telescoping Smoke Evacuation Pencil (Ethicon, Inc., Cincinnati OH), and the Neptune Smoke Evacuator that is included in the Neptune 3 Waste Management System with 0703-047 Safe Air Telescoping Smoke Evacuation Pencil (Stryker, Inc. Kalamazoo, MI).

Flow rates were determined using a thermal mass flow meter (TSI 4000 Series Thermal Mass Flow Meter, 22mm Taper Inlet Filter, TSI Incorporated, Shoreview, MN). Sound level measurements were taken with a Larson Davis 831C Sound Advisor Sound Level Meter (PCB Piezotronics, Depew NY) with a 377B02 microphone (1/2-inch free-field, pre-polarized, condenser) and PRM831 Microphone Preamplifier. Readings were obtained one meter from the front of the

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smoke evacuator with "A" frequency and peak weighting. Ambient noise levels were always less than 45 dBA.

In the first series of experiments, flow rates and noise levels were measured at the maximum flow rate for both smoke evacuators, and then with the Megadyne Smoke Evacuator set at a flow equivalent to the maximum flow rate for the Neptune 3. The Megadyne Smoke Evacuator was connected to the Megadyne Telescoping Smoke Evacuation Pencil, and the Neptune 3 was connected to the Stryker Safe Air Telescoping Smoke Evacuation Pencil.

The second series of experiments evaluated noise and flow levels for the two pencils with the Neptune 3 system. Based on preliminary testing, the flow rate for Megadyne pencil was substantially greater than the Neptune pencil at the same flow rate setting. Hence to achieve similar flow rates, the flow rates and noise levels were measured with Neptune 3 set at 100% flow rate with the Safe Air Telescoping Smoke Evacuation Pencil and at 50% flow rate with the Megadyne Telescoping Smoke Evacuation Pencil. Statistical comparisons were performed using Student's t-test or Mann-Whitney test with an alpha of 0.05. Loudness was evaluated as $2^{dBA/10}$.

Results

In the first series of experiments, at maximum flow settings, the Megadyne Smoke Evacuator provided 52.3% higher flow rate and was 7.0 dBA, or 39%, quieter than Neptune (Table 1 and Figure 2). At comparable flow rates (i.e., when Neptune was at its maximum flow setting, and Megadyne Smoke Evacuator was at open setting 1), the flow rates were not significantly different, while the Megadyne Smoke Evacuator was 14.5 dBA, or 63%, quieter.

Figure 1. The Megadyne smoke evacuator and telescoping smoke evacuation pencil.

Table 1. Flow rate and noise level comparisons between the Neptune 3 Waste Management (NEP) at maximum flow setting and Megadyne Smoke Evacuator (MEG) at maximum flow setting and at a setting that provides equivalent flow to NEP at the maximum setting. Statistical comparisons are to NEP Max. LPM: Liters Per Minute; dBA: Decibels, A-weighted.

Measure	NEP Max	MEG Max	p-value	MEG Equiv	p-value
Flow Rate (LPM)	71.9 ± 5.2	109.5 ± 3.4	<0.001	70.7 ± 2.9	0.561
Noise Level (dBA)	64.1 ± 0.6	57.0 ± 0.8	<0.001	49.6 ± 0.9	<0.001

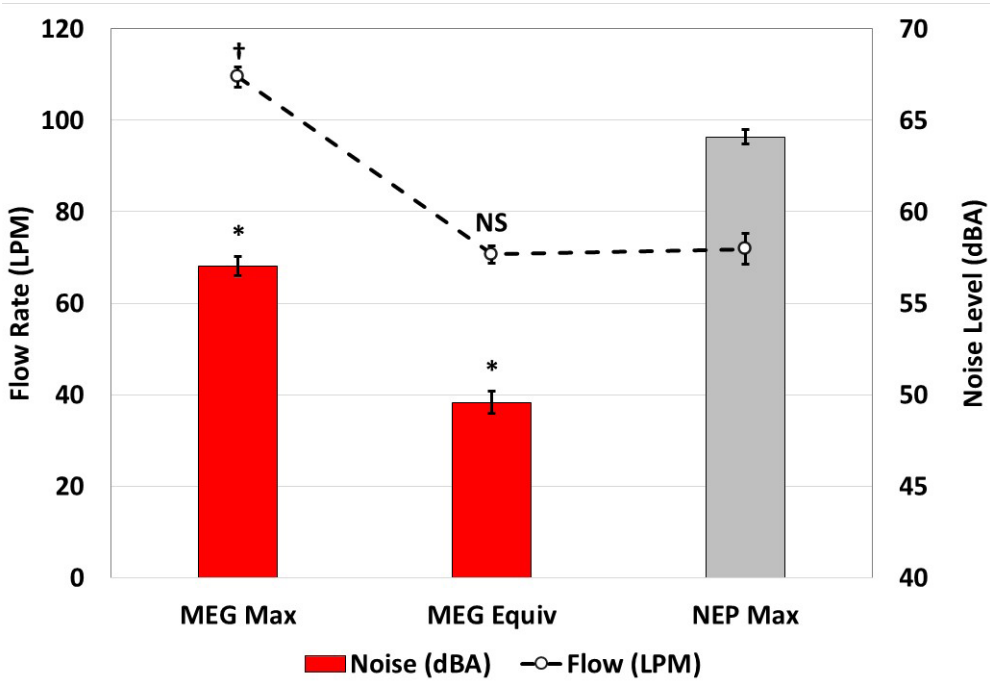

Figure 2. Flow rates and noise levels for the Megadyne Smoke Evacuator with Telescoping Smoke Evacuation Pencil (MEG) and Neptune 3 Waste Management System with SafeAir Smoke Evacuation Pencil (NEP) at maximum flow settings, and MEG at an equivalent flow setting to the NEP maximum. Error bars represent 95% confidence intervals. Flow rate for MEG at maximum setting is significantly greater than NEP. Noise levels for MEG at both settings are significantly lower than NEP. LPM: liters per minute, dBA: decibels, A-weighted, †: significantly different flow *vs.*NEP, *: significantly different noise level *vs.* NEP, NS: not significantly different from NEP.

Table 2. Flow rate and noise level comparisons for the Neptune 3 Waste Management System with Safe Air Smoke Evacuation Pencil (NEPP) at the maximum flow setting, and at 50% flow settings substituting with the Megadyne Telescoping Smoke Evacuation Pencil (MEGP). LPM: Liters Per Minute; dBA: decibels, A-weighted.

Measure	NEPP Max	MEGP 50%	p-value
Flow Rate (LPM)	71.9 ± 5.2	77.8 ± 0.7	0.009
Noise Level (dBA)	64.1 ± 0.6	59.3 ± 1.3	<0.001

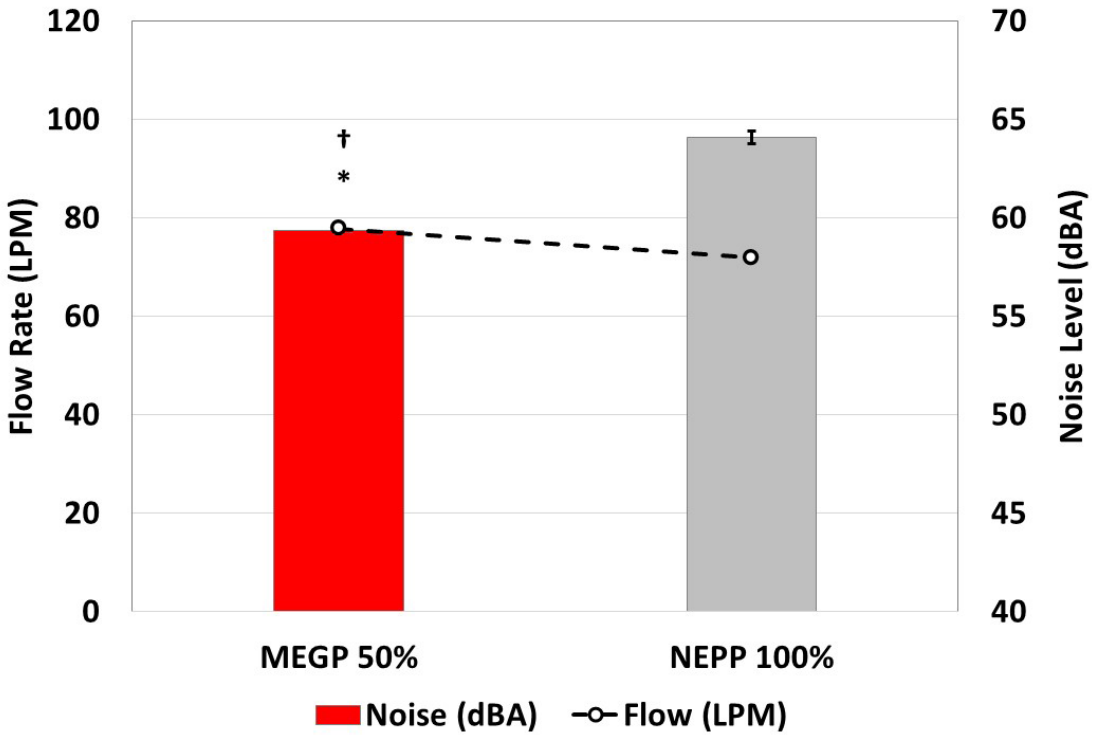

Figure 3. Flow rates and noise levels for Neptune 3 waste management system with Safeair smoke evacuation pencil (NEPP) at maximum flow settings, and Megadyne telescoping smoke evacuation pencil (MEGP) at 50% flow settings. Error bars represent 95% confidence intervals. Flow rates for MEGP at 50% are significantly greater than NEPP at 100%. Noise levels for MEGP are significantly lower than NEPP. LPM: liters per minute, dBA: decibels, A-weighted, †: significantly different flow *vs*.NEPP, *: significantly different noise level *vs*.NEPP.

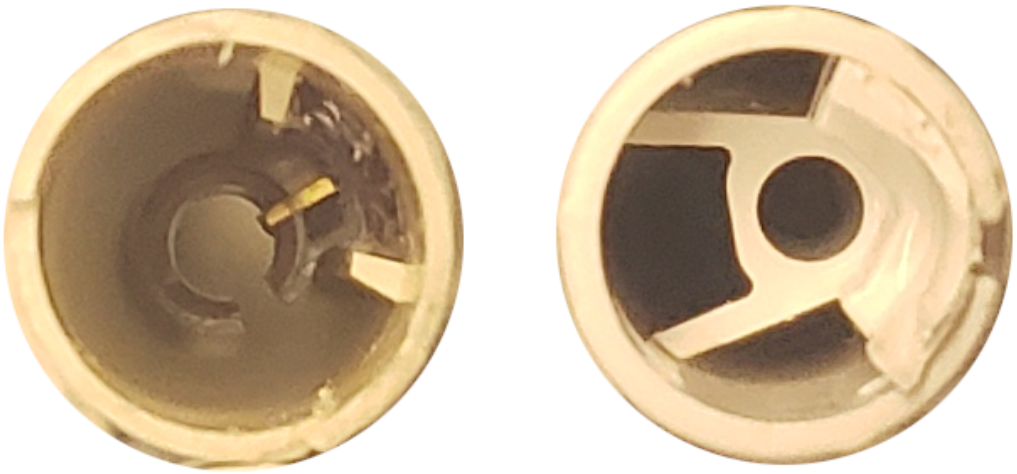

Figure 4. Cross-section of the Megadyne pencil (left) and Safeair pencil (right). The point of attachment is in the center of the electrosurgical device. The free area around the point of attachment is greater for the Megadyne pencil, providing less restriction to flow.

In the second series of experiments, using the Neptune 3 Waste Management System with both pencils, the Megadyne Telescoping Smoke Evacuation Pencil at 50% flow settings provided 8.2% higher flow and 4.8 dBA, or 28% lower noise than the SafeAir Smoke Evacuation Pencil set at the maximum flow rate (Table 2 and Figure 3).

Discussion

A smoke evacuation system is dependent upon the mechanism used to create air flow resulting in smoke collection near the blade tip. The Neptune 3 uses a fan type mechanism to draw the air. This type of mechanism is beneficial for creating high flow rate conditions; however, flow can be diminished due to system resistance. System resistance can occur due to capture device restrictions, kinked tubing, clogged filters, or worn fan components. The Megadyne Smoke Evacuator mechanism uses a scroll pump. A scroll pump does not produce as high of a flow rate as a fan of similar size; however, it can overcome system resistance with its ability to create a higher level of vacuum draw. System flow consistency is held constant from beginning to end of filter life and any variations within the capture device.

The primary pencil restriction to flow is at the attachment to the electrosurgery device. As seen in Figure 4, the free area around the point of attachment is greater for the Megadyne pencil, providing less restriction to flow than the Safe Air pencil.

The results of this study highlight the benefits of the Megadyne Smoke Evacuator design. In the first experiment, the Megadyne system provided higher flow rates and quieter operation, attributable to the features of a scroll pump, which overcomes the resistance of the pencil without a noticeable increase in turbulent flow. Even at its highest flow setting, the noise level for Megadyne was less than 60 dBA. At a flow rate equivalent to Neptune's highest flow rate, Megadyne was quieter at less than 50 dBA. In the second experiment, the more open design and lower resistance of the Megadyne Telescoping Smoke Pencil allowed higher flow rates at significantly lower noise levels.

Several studies have noted the potential hazards of noise from smoke evacuators. In one study, mean noise level from using a smoke evacuator was 75 dBA, and reached peak levels of 86.9 dBA [10]. Although, overall noise levels did not exceed NIOSH-recommended exposure limits, the authors noted that surgeons may be exposed to high noise levels due to equipment-related noises caused by movement of equipment, clanging and dropping of metal instruments, and use of electric or air-powered surgical instruments and background music. A study by Gioutsos K, et al. [11] found noise levels of up to 68 dBA, depending upon the method of aspiration while Seipp HM, et al. [6] found noise levels up to 69 dBA. These levels may not be responsible for permanent hearing loss, but they may interfere with operating room conversation. The Megadyne smoke evacuator was found to have noise levels lower than 60 dBA at the highest flow rate.

Smoke evacuators capture and filter smoke that is generated during electrosurgical procedures that help to reduce the surgical team's exposure to plume. A smoke evacuation system should be selected depending on the needs of the facility. The suction power of the smoke evacuator generates a threshold minimum volume of airflow. For evacuation of laser smoke using an intake at a distance from the site of smoke creation, a minimum airflow of 720-1020LPM has been recommended [8]. When capturing electrosurgery smoke, it is possible to use lower flow rates if the smoke capture device is close to the source of the smoke. The Megadyne system can be effective at a low flow rate (although still significantly higher than the competitor's) because the telescoping portion extends to within a few centimeters of the blade tip. Noise pollution remain a challenge in the operating rooms. Mean noise levels for smoke evacuation units in operating rooms are typically 60–70 dBA [12]. Loud noise can disrupt concentration during surgery and even lead to negative outcomes [13]. Ideally, smoke evacuation devices should be as quiet or quieter than background noise levels.

Conclusion

The Megadyne Smoke Evacuator has been shown to be quieter than a widely-used device while providing higher flow rates with a larger capacity for smoke evacuation. Our findings add to the current understanding of smoke evacuators flow rate and acceptable noise emission rates. As states move toward legislating smoke-free surgical procedures, the Megadyne smoke evacuator can help maintain compliance.

Acknowledgement

None.

Conflict of Interest

This work was funded and performed by the manufacturer of the Megadyne Smoke Evacuator (Ethicon, Inc.). The authors report no other conflicts of interest in this work.

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