



Laser-Induced Smoke in Dermatologic Practice: A Survey to Explore Hazard Perceptions, Safety Measures and Unmet Needs

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Received: August 10, 2022

Accepted: November 23, 2022

Published online December 11, 2022

Abstract

Introduction: Inhalation of laser-induced smoke is a potential health hazard to exposed physicians and laser operators. To date, little is known about the perception of health hazards related to laser-induced smoke exposure among physicians and the actual use of safety measures to mitigate these risks.

Methods: In May 2020, 514 members of the European Society for Lasers and Energy-Based Devices (ESLD) were invited by email to participate in an online survey. The survey comprised 16 questions including multiple-choice and open-ended questions.

Results: Responses were received from 109 participants. The majority (90%) were aware of potential hazards and highlighted a desire for better protective measures (60%). A smoke evacuation system was frequently used with ablative lasers (66%) and fractional ablative lasers (61%), but less the case with non-ablative lasers (30%) and hair removal lasers (28%). The COVID-19 outbreak had no clear effect on the use of smoke evacuation systems. Prior to the COVID-19 outbreak, mainly surgical masks were used (40-57%), while high filtration masks (FFP1, FFP2 or FFP3) were used by only a small percentage (15-30%). Post COVID-19 outbreak, the use of high filtration masks increased significantly (54-66%), predominately due to an increase in the use of FFP2 masks. Reasons mentioned for inadequate protective measures were sparse knowledge, limited availability, discomfort, excessive noise, high room temperatures, and financial costs.

Conclusion: While there is considerable awareness of the hazards of laser-induced smoke among physicians and laser operators, a substantial number of them do not use appropriate protective measures. The implementation of regulations on safety measures is hampered by sparse knowledge, limited availability, discomfort, excessive noise, financial issues, and high room temperatures.

Keywords: Laser-induced smoke; Surgical smoke; Health hazards; Protective measures.



Introduction

With technical progress and increasing numbers of procedures in dermatologic practice, the use of lasers and electrosurgery has markedly increased, leading to repeated exposure of physicians to surgical smoke.^{1,2}

A growing body of evidence shows that surgical smoke is a potential risk to physicians and laser operators.^{3,4} Surgical smoke is generated when tissue is heated to the point of boiling. This leads to membrane rupture and

dispersal of cellular contents as fine particles. Surgical smoke contains not only burnt particles but also aerosols (< 5 μm) and liquid droplets (> 5 μm) that are diffused.^{5,6}

Substances of surgical smoke include toxic chemicals such as carbon monoxide, acrylonitrile, hydrogen cyanide and formaldehyde, in addition to biological and/or infectious components of human tissue.^{7,8}

Approximately 75% of surgical smoke consists of small particles between 0.07 and 0.31 μm, which may quickly

deposit in bronchioles and alveoli.^{9,10} Dose-dependent health complaints linked to inhalation of surgical smoke include headache, nausea, rhinitis, burning sensation in the nasopharynx, as well as more serious conditions such as asthma or pneumonia.^{10,11} Respiratory irritation, possible carcinogenesis, and infectious transmission are the most commonly mentioned (and feared) hazards associated with inhalation of surgical smoke.¹²⁻¹⁴ As previous studies demonstrate the presence of different viruses in surgical smoke, such as human papillomavirus (HPV), the onset of COVID-19 has highlighted the risk of potential virus transmission.¹⁵

There are currently no uniform regulations across different countries for laser procedures in dermatologic practice in the age of COVID-19.^{15,16} Although there are guidelines for respiratory protection at the workplace in many countries, these safety procedures are not generally adopted.^{17,18} Moreover, guidelines are mainly designed for and implemented in the operating room rather than in private practice where most dermatologic procedures are performed on a daily basis.¹⁹ As many institutions have not made the implementation of these guidelines rigorous, it is plausible that a substantial number of physicians and other health care workers are unaware of the health hazards of surgical smoke and subsequently fail to implement protective measures.^{19,20}

To date, little is known about the perception of health hazards of laser-induced smoke among physicians and laser operators and about the actual use of safety measures to mitigate these risks. The primary aim of this study was to assess current perceptions of health hazards of laser-induced smoke among members of the European Society for Lasers and Energy-Based Devices (ESLD). The secondary aim was to explore the actual use and the obstacles of protective measures in dermatologic practice. Additionally, the survey assessed the potential influence of the COVID-19 outbreak on the use of these protective measures.

Materials and Methods

Recruitment

For the purpose of this study, a survey was performed between May and June 2020. The survey was conducted online with a self-developed questionnaire comprising 16 questions including multiple-choice and open-ended questions. The board of the ESLD approved this questionnaire for distribution to its members (mainly dermatologists and plastic surgeons) in and outside of Europe.

The survey, distributed through Lime Survey, was emailed using the Society's mailing list (514 members at the time of implementation of this survey). The survey took approximately ten minutes to complete. Reminder emails were sent after three weeks. Responses were electronically stored in a database.

Survey Instrument and Development

The questionnaire (Supplementary File 1) was developed based on previous surveys that assessed physicians' perceptions towards (electro)surgical and laser-induced smoke.^{8,19,20} Additionally, we included new questions generated specifically for this study focusing on protective measures during different laser procedures.

The first section of the survey focused on respondent characteristics. The second and third sections covered perceptions about the awareness of health hazards of laser-induced smoke and the use of protective measures during various laser procedures. The laser procedures were classified into (1) ablative laser, (2) fractional ablative laser, (3) non-ablative laser (vascular, pigment, non-ablative fractional laser), and (4) hair removal laser. For each type of laser procedure, we questioned about the use of (1) protective masks, (2) the type of mask (surgical mask, high filtration mask including FFP1, FFP2 and FFP3), (3) smoke evacuation systems or (4) no protective equipment. FFP refers to Filtering Face Piece 1, 2 and 3, which is the European standard for high filtration masks with increasing filtration efficiency of 80%, 95%, and 99% respectively for particles of 0.3 μm . Surgical masks are not capable of filtering particulate matter < 5 μm .^{21,22}

Additionally, all these questions were asked referring to the situation before and after the COVID-19 outbreak.

In the last section of the survey, we questioned the obstacles (reasons for not using protective measures), preferences, and suggestions for the improvement of equipment.

Quantitative survey items utilized 'yes/no' questions, multiple-choice questions, and five-point Likert scales for the perception and obstacles concerning surgical smoke protection (1 = strongly disagree to 5 = strongly agree).

Qualitative survey items included free text responses.

Results

Respondent Characteristics

A total of 514 members of the ESLD were invited by email. Responses were received from 109 (21.2%) members from 40 countries. The main characteristics of the respondents are reported in Table 1 and Figure 1.

Respondents were mainly dermatologists (81%), the majority of whom came from Europe (57%). The majority was experienced to highly experienced (84%) with the use of lasers and had a private clinic as their primary practice setting (Table 1). The panel of respondents used a wide variety of different types of lasers on a regular basis (Figure 1).

Awareness About the Health Hazards of Surgical Smoke

Almost all respondents (90%) agreed or strongly agreed that laser-induced smoke is a potential health hazard. In relation to their own working environment, 74% of the respondents indicated that health hazards of laser-

Table 1. Respondent Characteristics

Characteristics	No. (%)
Number of respondents	109 (100)
Dermatologists	88 (81)
Aesthetic physicians	4 (4)
Plastic surgeons	3 (3)
Laser therapists/skin therapists	5 (5)
Other	9 (9)
Gender	
Male	43 (39)
Female	64 (59)
Not mentioned	2 (2)
Country of current practice	
Europe	62 (57)
Asia	27 (25)
North America	8 (7)
South America	5 (5)
Other	6 (6)
Years of experience with the use of lasers	
<5	17 (16)
5-10	25 (23)
10-15	20 (18)
>15	47 (43)
Major practice location	
Hospital	17 (16)
Private clinic	65 (60)
Both	27 (24)

induced smoke are already a topic of interest or concern among their team.

Use of Protective Measures in the Workplace (Before and After the COVID-19 Outbreak)

The data on the use of protective measures before and after the COVID-19 outbreak are listed in Table 2.

Before the COVID-19 outbreak, a surgical mask was the most frequently used protective mask during laser procedures. Surgical masks were used in 40-57% of the procedures. These masks were used more frequently during ablative laser procedures (57%) than during fractional ablative procedures (48%), non-ablative laser procedures (42%) and hair removal laser procedures (40%). After the COVID-19 outbreak, the use of surgical masks decreased for all procedures except for non-ablative laser treatments (54%). High filtration masks (FFP1, FFP2 or FFP3) were used by only a small percentage before COVID-19. Their use depended on the type of procedure, being the highest in ablative lasers (30%) and the lowest in hair removal lasers (15%). Interestingly, after the COVID-19 outbreak, the use of high filtration masks increased significantly (54-66%), predominantly due to an increase in the use of FFP2 masks with frequencies of 43% for both ablative and fractional-ablative procedures, 37% for non-ablative procedures, and 39% for hair removal laser procedures.

A smoke evacuation system was frequently used with ablative lasers (66%) and fractional ablative lasers (61%) but less the case with non-ablative lasers (30%) and hair removal lasers (28%). The COVID-19 outbreak had no clear effect on the use of smoke evacuation systems among our respondents. Remarkably, some respondents did not use any protective measure with ablative lasers

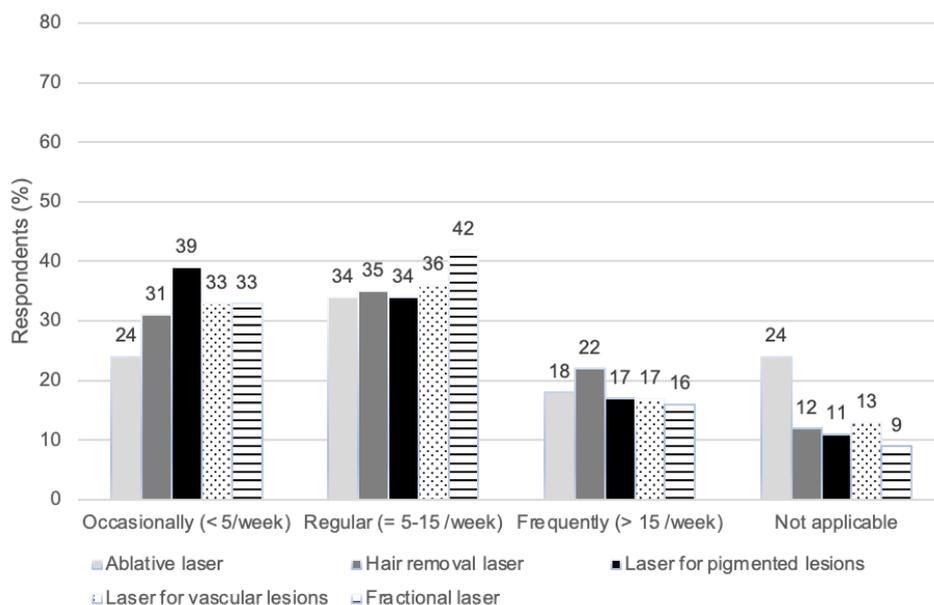
**Figure 1.** Respondent Characteristics Regarding the Frequency of Use of Different Laser Types

Table 2. Summary of Percentage of Respondents Using Protective Measures During Laser Procedures Before and After the COVID-19 Outbreak

	Before COVID-19 Outbreak (%)	After COVID-19 Outbreak (%)
Ablative laser		
Surgical mask	59 (57)	23 (22)
FFP1 mask	9 (9)	12 (12)
FFP2 mask	11 (11)	45 (43)
FFP3 mask	10 (10)	11 (11)
Smoke evacuation system	69 (66)	68 (65)
No protection	14 (13)	4 (4)
Fractional ablative laser		
Surgical mask	49 (48)	25 (25)
FFP1 mask	7 (7)	11 (11)
FFP2 mask	10 (10)	43 (43)
FFP3 mask	11 (11)	10 (10)
Smoke evacuation system	62 (61)	57 (56)
No protection	11 (11)	3 (3)
Non-ablative laser*		
Surgical mask	45 (42)	55 (54)
FFP1 mask	11 (10)	10 (10)
FFP2 mask	5 (5)	38 (37)
FFP3 mask	9 (8)	8 (8)
Smoke evacuation system	32 (30)	38 (37)
No protection	28 (26)	11 (11)
Hair removal laser		
Surgical mask	39 (40)	34 (37)
FFP1 mask	6 (6)	7 (8)
FFP2 mask	4 (4)	36 (39)
FFP3 mask	5 (5)	6 (7)
Smoke evacuation system	28 (28)	30 (33)
No protection	23 (24)	7 (8)

FFP, filtering face piece.

* The non-ablative laser group consists of pigment, vascular, and non-ablative fractional laser procedures.

(13%), fractional ablative lasers (11%), non-ablative lasers (26%) and hair removal lasers (24%). After the COVID-19 outbreak, the non-use of protective measures was much lower, 4%, 3%, 11% and 8% respectively.

Perceptions Concerning the Use of Safety Measures

A total of 60% of the respondents stated they would like to have more or better protective measures concerning laser-induced smoke, although the majority of this 60% considered their taken safety measures as sufficient. Among the remainder who felt that they did not make sufficient use of safety measures, the three most commonly given reasons were: “safety measures are not incorporated in our process yet”; “the safety measures are distracting during the procedure”; “the procedure time is too short/the smoke development is too low”.

To increase the use of protective measures, more knowledge on the hazards of laser-induced smoke and protection was recommended. Respondents also indicated an increased need for FFP3 masks. Furthermore, according to their experience, more comfortable masks are needed. Masks should not be distracting during the laser procedure, and the nose and mouth should be covered without fogging the goggles and blocking breathing. Additionally, respondents emphasized a demand for improved smoke evacuation systems.

The noise of smoke evacuation systems was also reported as an obstacle to the more frequent use of these systems. 72% of all respondents agreed or strongly agreed that the noise of smoke evacuation systems is annoying/disturbing.

More than half of the respondents (53%) were concerned about hearing damage from continued exposure to noisy devices, and 51% of them were disturbed by the increased room temperature due to lasers and smoke evacuation systems. Only 15% did not experience noise and increased room temperature as obstacles. Built-in protection equipment in laser devices is seen as an important facilitator during laser procedures. Suggestions included integration of a smoke evacuation system into the handpiece, automated positioning, and a cooling system for stabilizing room temperature. The high cost of smoke evacuation systems was seen as a barrier and there was a preference for more durable evacuation systems in the future.

Discussion

This survey indicates that most physicians and laser operators who perform laser treatments are aware of laser-induced smoke hazards, yet a substantial number of them do not use appropriate protective measures such as smoke evacuation systems and/or high filtration masks during laser procedures. Overall, 60% of all respondents indicated they would desire more or better protective measures.

The study found that smoke evacuation systems were used by only 66% of those performing ablative laser treatment, which is remarkable given the high amount of generated smoke. As expected, a lower percentage of use of smoke evacuation systems was found with fractional ablative lasers (61%), non-ablative lasers (30%) and hair removal lasers (28%). While laser-induced smoke is clearly visible and detected by repulsive odor in ablative laser procedures, smoke is also relevant in non-ablative procedures.²³ With hair removal lasers, a substantial increase in ultrafine particle concentration has already been found in the laser room one minute after starting the procedure. Smoke evacuation systems were able to limit the increase in ultrafine particles.²⁴

Although it is known that surgical masks do not provide sufficient protection against ultrafine particles, they were

often used with ablative lasers (57%), fractional ablative lasers (48%), non-ablative lasers (42%), and hair removal lasers (40%).^{17,19,20} Surgical masks do not filter particulate matter <5 µm and they only confer little protection to the respiratory tract against aerosols and viral particles.²¹ The common use of surgical masks is problematic when utilized in situations that require high filtration masks. On average, the protection factors of high-filtration masks are 12 to 16 times greater than those of surgical masks.²⁵ According to Wizner et al, physicians may not be aware of the selection of the adequate mask nor know the specific type of filtration mask they use.²⁶

This study shows a substantial difference in the use of protective measures before and after the COVID-19 outbreak. Before the COVID-19 outbreak, predominantly surgical masks were used (40%-57%), while FFP2 masks (4%-11%) and FFP3 masks (5%-11%) were less frequently used. Conversely, after the COVID-19 outbreak, the high filtration masks played a more significant role, especially in the use of FFP2 masks, increasing minimal fourfold for all procedures. After the COVID-19 outbreak, these FFP2 masks were used by about 40% of the respondents (Table 2). These changes probably reflect protective measures against primary infection with the coronavirus rather than generic laser-induced smoke protection. Therefore, it is likely that once the COVID-19 pandemic has passed, the extra protective measures may be reversed or somewhat relaxed.

According to a survey by Edwards and Reiman, the inconsistent application of protective measures is due to differences in guidelines concerning the safe use of lasers.²⁷ In our study, the most cited reason for insufficient protection of participants was safety measures yet not being incorporated into the working procedures. These results are in line with a similar recent study by Michaelis et al who concluded that changes in the standard working procedures with a focus on occupational health and safety are recommended in the future.¹⁹

In our study, we also noted that physicians were concerned about distraction by masks during laser procedures. This statement has also been found in previous studies on electrosurgical smoke.^{2,10,28}

For example, physicians have difficulties with the fog effect while breathing in the mask or experience impaired vision. Other difficulties include the disturbing noise and increased room temperature produced by smoke evacuation systems and the absence of a smoke evacuation system integrated into the handpiece. In addition to practical concerns over comfort, the cost of smoke evacuation systems and the price difference between surgical masks and high-filtration masks were also mentioned as obstacles to the use of protective measures. Although no statistical analysis and uniform conclusions can be drawn from these comments, the findings warrant further research and adaptation in dermatologic practice.

There are some limitations to our study. We only surveyed ESLD members, which may limit the external validity of the study. The results may not apply to other laser physicians and users. Moreover, only one-fifth of the ESLD members responded (despite a reminder after three weeks), which may further contribute to a selection bias. In the future, it would be interesting to compare results from other groups of laser physicians.

In summary, this study indicates that many physicians do not use smoke evacuation systems and/or high filtration masks during laser procedures, and some physicians do not use them even with ablative lasers. A more cautious approach was seen due to the COVID-19 outbreak. Despite awareness on the health hazards of laser-induced smoke, protective measures are not consistently implemented and are hampered by lack of knowledge, limited availability, financial costs, discomfort, excessive noise, and high room temperatures.

Therefore, we recommend, first of all, international and national guidelines that will give guidance on the use of protective measures per type of laser procedure. Secondly, we advise more education on the risks of laser-induced smoke and the benefits of smoke evacuation systems and high filtrations masks for physicians and laser operators. Finally, we encourage technical changes to smoke evacuation systems and high-filtration masks that make their use more comfortable and practical when performing laser treatments. Continuous feedback from physicians is of importance to target the barriers of use and to increase compliance with guideline recommendations.

Conflict of Interests

There are no conflicts of interest.

Funding

None.

Supplementary Files

Supplementary File 1. Survey Questions for examining current perceptions of the health hazard of laser-induced smoke and its management among members of the ESLD.

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