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# Gaseous and Particulate Content of Laser Hair Removal Plume

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**IMPORTANCE** Potentially harmful chemicals are released when tissues are vaporized. Laser hair removal (LHR) causes heating and often vaporization of hairs, producing both a signature malodorous plume and visible particulates.

**OBJECTIVE** To characterize the chemical composition and quantify the ultrafine particle content of the plume generated during LHR.

**DESIGN, SETTING, AND PARTICIPANTS** In the laser center of a large academic hospital, discarded terminal hairs from the trunk and extremities were collected from 2 adult volunteers. The hair samples were sealed in glass gas chromatography chambers and treated with a laser. The laser plume was analyzed by gas chromatography–mass spectrometry (GC-MS). During LHR treatment, two 6-L negative pressure canisters were used to capture 30 seconds of laser plume, and a portable condensation particle counter was used to measure ultrafine particulates (<1 μm). Ultrafine particle concentrations were measured within the treatment room, within the waiting room, and outside the building.

**MAIN OUTCOMES AND MEASURES** The chemical content of the laser plume was analyzed with GC-MS and screened for aerosolized toxins using Environmental Protection Agency–certified methods. The ambient concentration of ultrafine particles during LHR was measured by condensation particle counters.

**RESULTS** Analysis with GC-MS identified 377 chemical compounds. Sixty-two of these compounds, of which 13 are known or suspected carcinogens and more than 20 are known environmental toxins, exhibited strong absorption peaks. During LHR, the portable condensation particle counters documented an 8-fold increase compared with the ambient room baseline level of ultrafine particle concentrations (ambient room baseline, 15 300 particles per cubic centimeter [ppc]; LHR with smoke evacuator, 129 376 ppc), even when a smoke evacuator was in close proximity (5.0 cm) to the procedure site. When the smoke evacuator was turned off for 30 seconds, there was a more than 26-fold increase in particulate count compared with ambient baseline levels (ambient baseline, 15 300 ppc; LHR without smoke evacuator for 30 seconds, 435 888 ppc).

**CONCLUSIONS AND RELEVANCE** These findings establish the concern that the burning-hair plume often present during LHR should be considered a biohazard, warranting the use of smoke evacuators, good ventilation, and respiratory protection, especially for health care workers with prolonged exposure to LHR plume.

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Many important surgical procedures involving thermal energy produce an aerosolized byproduct known as surgical plume, which has caused concerns regarding risks associated with long-term exposure.[1-4] Investigative reports[5] have led to efforts to minimize surgical plume exposure in the work environment. Numerous chemicals have been found in plumes generated by carbon dioxide and Nd:YAG laser tissue ablation, including benzene, formaldehyde, acrolein, carbon monoxide, and hydrogen cyanide.[6] Larger organic aerosolized particles, including cellular clumps, erythrocytes, human papillomavirus DNA, bacteriophage, bacteria, and human immunodeficiency virus DNA, have been identified in laser plume.[7-12]

Nanoparticles are increasingly studied[13,14] because of their toxic effects in humans. Nanoparticles, hereinafter referred to as ultrafine particles (UFPs), are less than 1000 nm in diameter. Ultrafine particles are found in increased concentration in cigarette smoke, car exhaust, and other environmental combustion. At the lower toxic levels, increased UFP concentrations have been linked to triggering reactive airway diseases, such as asthma. Urban areas around the world with high UFP counts are associated with increased mortality, lung cancer, and cardiopulmonary risks compared with regions with low UFP counts.[15-17] Ultrafine particles measuring less than 1 μm are the most concerning because of their ability to bypass biological filters and lodge deeply in the lung's alveolar space.

Developed in 1996 based on the theory of selective photothermolysis, laser hair removal (LHR) is one of the most popular cosmetic procedures worldwide.[18] The laser delivers a pulse of light absorbed by melanin in the pigmented hair shaft, which becomes hot. The desired result is thermal destruction of bulge cells surrounding the hair shaft. Laser hair removal often produces combustion of hairs with a characteristic malodorous and visible plume that lingers in the treatment room. Hair shaft contains proteins with a high sulfur content, waxes and oils from sebum, and chemicals absorbed from products such as shampoos and soaps. To our knowledge, there has been no previous analysis of the aerosolized content produced by LHR. In this study, we used several methods to qualitatively and quantitatively analyze the aerosolized chemical compounds and UFPs produced during LHR.

## Methods

### Identification of Plume Chemicals

To simulate the plume production during an LHR treatment, discarded terminal hairs were collected from 2 adult volunteers in typical locations: axillae, back, and arms. The collected hair samples were stored, weighed, and sealed in air-tight, clear glass chambers. Two pulses were delivered through the clear glass with either an 810-nm diode laser (LightSheer; Lumenis) or 755-nm alexandrite laser (Gentlelase; Candela). The diode laser setting was 9-mm spot size, 30-millisecond pulse duration, and 30 J/cm$^2$ fluence. The alexandrite laser setting was 18-mm spot size, 3-millisecond pulse duration, and 20 J/cm$^2$ fluence. After the laser treatment, 2 mL of either hexane or chloroform was injected into the chamber to dissolve the plume content for gas chromatography-mass spectrometry (GC-MS) analysis. Controls for this experiment included untreated hair follicles submerged in the elution solvents of either hexane or chloroform. This study was approved by the institutional review board of Massachusetts General Hospital. The participants donated discarded hairs from shaving and provided verbal consent. There was no financial compensation.

### Key Points

**Question** What is contained in the plume produced by laser hair removal?

**Findings** In this study, 62 organic compounds were identified, including carcinogens and toxins. Three chemicals had estimated daily exposures that exceed Occupational Safety & Health Administration daily permissible limits, and ultrafine particles emitted without a smoke evacuator exceeded levels considered safe.

**Meaning** The burning-hair plume that develops during laser hair removal should be considered a biohazard, warranting the use of smoke evacuators, good ventilation, and respiratory protection, especially for health care workers.

The GC-MS analysis was carried out at the Boston University Department of Chemistry. The samples were analyzed by GC using mass selective detection for identification of organic compounds generated during thermal ablation of hair follicles.

### Quantification of Plume Chemicals

To quantify the concentration of aerosolized chemicals during LHR with the 755-nm alexandrite laser, two 6-L negative-pressure canisters were used to capture 30 seconds of plume generated by LHR and sent to an outside laboratory for standard Environmental Protection Agency (EPA) toxic organic (TO)-15 and modified 25C methods (ALS Environmental). The negative-pressure canisters can capture only 30 seconds of air sampling when the smoke evacuator is turned off.

### Measurement of UFPs Produced During LHR

Ultrafine particle concentration was measured by 2 portable condensation particle counters (CPCs) that were used during LHR treatment (Gentlelase). The measurements were performed outside the office building in Boston, Massachusetts; in the waiting room; and in the treatment room at baseline, during, and after an LHR treatment. Measurements were obtained with 1 CPC positioned near the face of the LHR practitioner and the other positioned near the face of the patient. A smoke evacuator (Acu-Evac IE; Acuderm Inc) with combined ultralow particulate air and activated charcoal filter was set at the maximum level (>3300 m/min) through a connector hose (3.3-cm diameter) with the mouthpiece 2.5 cm away from the treatment site. The evacuator was turned off for 30 seconds during the treatment to measure the change in particle concentration and then restarted.

## Results

### Identification of Plume Chemicals

The chemicals identified during LHR using GC-MS are listed in the **Box**. A total of 377 peaks were identified, each signifying a

### Box. Chemicals Identified by GC-MS With High Fidelity

- Acetamide
- Acetonitrile
- Acrylonitrile
- Anthracene
- Benzaldehyde
- Benzene
- Benzeneacetonitrile
- Butene
- Cholesterol
- Cycloalkanes (many)
- Cycloalkenes (many)
- Cyclopropane
- Decanoic acid
- Decanone
- Diethyl phthalate
- Dimethyl sulfide (trithiolane)
- Diphenyl ether
- Dodecanone
- Ethylbenzene
- 1-H indene
- 1-H-indole
- Isoquinoline
- Long-chain alkanes (many)
- Long-chain alkenes (many)
- Long-chain fatty alcohols (many)
- 2-Methyl pyridine
- Methyl salicylate
- Naphthalene
- Naphthalene carbonitrile
- Octadecanoic acid (stearic acid)
- Oleic acid
- Phenol
- Propene
- p-Xylene
- Quinoline
- Silane
- Siloxane
- Squalene
- Styrene
- Toluene
- Tricosane
- Trimethyl sulfate

Abbreviation: GC-MS, gas chromatography–mass spectrometry.

Table 1. Chemicals Identified Using the EPA TO-15 and 25C Methods

| Chemical | 30-s Concentration[a] LHR, μg/m$^3$ or ppmV[b] | 30-s Concentration[a] LHR, ppb | Estimated 8-h Concentration, ppm | OSHA-Permissible Limits, ppm |
|---|---|---|---|---|
| EPA TO-15 method | | | | |
| Acetonitrile | 1600 | 960 | 921.6 | 40 |
| Acrylonitrile | 350 | 160 | 153.6 | 2 |
| Ethylbenzene | 5 | 12 | 11.5 | 100 |
| Propene | 44 | 26 | 25 | 100 |
| Styrene | 53 | 13 | 12.5 | 100 |
| Toluene | 130 | 34 | 32.6 | 200 |
| 25C method | | | | |
| Carbon monoxide | 16 | NA | 15 360 | 50 |

Abbreviations: EPA, Environmental Protection Agency; LHR, laser hair removal; NA, not applicable; OSHA, Occupational Safety & Health Administration; ppb, parts per billion; ppm, parts per million; ppmV, ppm per volume; TO, toxic organic.

[a] Samples were obtained when the smoke evacuator was turned off.

[b] Chemicals identified using the EPA TO-15 method are measured in micrograms per cubic meter; carbon monoxide, identified using the 25C method, is measured in parts per million per volume.

chemical compound captured. Sixty-two chemicals had peak levels at 90% confidence or above, suggesting a greater quantity of the chemicals found in the aerosolized sample. For each hair sample, 4 sets of data were collected, each set from a different laser source (long-pulsed alexandrite or diode) and a different solvent (hexane or chloroform). Chloroform captured 62 chemicals; hexane captured 47 chemicals. The laser source used did not significantly affect the chemicals that were identified.

Of these 62 chemicals, 13 are suspected or known to be carcinogenic (**Table 1**), including benzene, ethylbenzene, benzeneacetonitrile, acrylonitrile, acetonitrile, quinoline, isoquinoline, styrene, diethyl phthalate, 2-methyl pyridine, naphthalene carbonitrile, acetamide, and propene. More than 20 of these chemicals are known environmental toxins potentially causing acute toxic effects on exposure; these included p-xylene, phenol, toluene, benzaldehyde, benzenedicarboxylic acid (phthalic acid), and long-chain and cyclic hydrocarbons. Cholesterol, a component of sebum, was found in all samples of the plume and 1 sample contained methyl salicylate.

## Quantification of Plume Chemicals

During the 30 seconds of air sampling, EPA TO-15 and 25C methods detected 7 airborne chemicals (**Table 2**). The TO-15 method identified elevated levels of acetonitrile, acrylonitrile, toluene, ethylbenzene, styrene, and propene, and the EPA 25C method identified an elevated level of carbon monoxide. Most of the chemicals detected by GC-MS are not among those screened by EPA methods, which are tailored specifically for evaluation of industrial pollutants.

## Measurement of UFPs Produced During LHR

The CPCs, measuring the amount of UFPs emitted over time, showed substantial increases in airborne UFPs during a typical LHR procedure. There were 15 300 particles per cubic centimeter (ppc) in the waiting area of the clinic. During an LHR procedure, the CPC positioned at the level of the laser practitioner measured between 69 976 and 129 376 ppc, with an incremental increase during the procedure (**Figure**). The CPC positioned at the level of the patient's face, who was lying prone on the table for treatment of his back, measured a larger increase from 32 301 to 142 019 ppc (Figure) when the treatment was closer to his face. The CPC count dropped to 99 740 ppc as the treatment was moved farther from the patient's face.

When the smoke evacuator was turned off, the UFP count at the level of the practitioner increased to 435 888 ppc. At the level of the patient, the UFP count increased to 145 386 ppc. Once the smoke evacuator was restarted, the UFP count returned to 123 230 ppc. At the end of the procedure, the UFP count slowly declined as the evacuator was turned on to a baseline level of 37 497 ppc. The CPCs were moved into the waiting area and then outside the building to simulate the patient leaving the LHR treatment room. The measurement decreased to its baseline value of 15 300 ppc in the waiting area and 7007 ppc outside the building.

## Discussion

This study investigated the gaseous and particulate plume of LHR. Gas chromatography–mass spectrometry identified 62 organic compounds, of which 13 are suspected or known carcinogens and more than 20 are recognized irritants and toxins. With the smoke evacuator turned off for only 30 seconds during LHR, high levels of environmental toxins (including carbon monoxide) were detected. In the same period, a portable CPC captured more than a 26-fold increase in airway-irritating particulates.

In the first part of this study on LHR plume, nearly all of the compounds detected through GC-MS were aromatic or long-chain hydrocarbons. The hydrocarbons are likely produced by thermal combustion of carbon-containing organic tissue. Many of the compounds contain aromatic benzene rings and are derivatives of benzene. In organic tissue, benzenes are found in aromatic amino acid products, such as tryptophan. Table 1 lists the chemical compounds identified by the GC-MS and EPA methods and their corresponding toxic effects in humans and animals.

Benzene, a known carcinogen, and its related compound toluene are byproducts of different forms of organic combustion, such as in cigarette smoke and car exhaust.[19] Long-term benzene exposure has been linked to acute myelogenous leukemia, aplastic anemia, bone marrow abnormalities, and infertility.[20,21] 2-Methyl pyridine, structurally related to benzene with nitrogen in the aromatic ring instead of a carbon, can cause dizziness and headache when absorbed into the human body.[19] In animal studies,[22] exposure to *N*-methyl pyridine has been linked to damage to dopaminergic neurons, leading to Parkinson disease–like symptoms. Diethyl phthalate is commonly found as a plasticizer used to bind cosmetics and fragrances.[19] Although the compound has low toxic potential, animal studies[23] have found that exposure inhibits androgen biosynthesis in males and leads to teratogenicity in rats.

Numerous nontoxic compounds were also identified in the GC-MS analysis. Diphenyl ether and benzaldehyde are common cosmetic fragrances used in soaps.[19] Compounds such as 1-H indole and trimethyl sulfate are byproducts of tryptophan and keratin disulfide bonds, respectively. Compounds likely deriving from the sebaceous glands were also identified, including cholesterol, squalene, and oleic acid. Analysis of 1 hair sample consistently showed methyl salicylate. Salicylate is a component of many analgesic creams used for muscle aches. On questioning, the donor reported applying a salicylate-containing analgesic cream for muscle aches. Trimethyl sulfate and dimethyl sulfide are likely the main source of the signature malodor, reminiscent of rotten egg, associated with LHR.

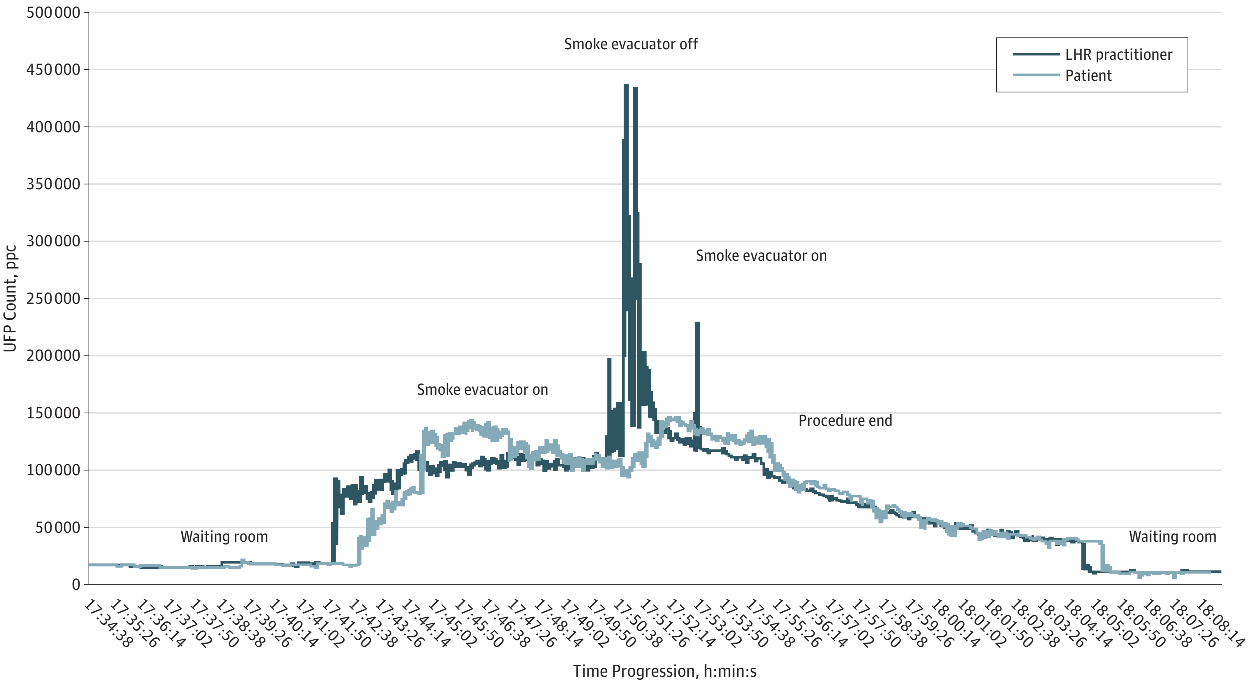
To quantify environmental toxins, the EPA TO-15 method was used as an analytical procedure to measure a subset of 97 of the 189 hazardous air pollutants listed in the Title III of the Clean Air Act Amendment of 1990.[24] The negative-pressure canisters captured 30 seconds of plume produced without the smoke evacuator. The results showed high levels of acetonitrile, acrylonitrile, toluene, ethylbenzene, styrene, and propene in parts per billion, which is below the Occupational Safety & Health Administration (OSHA)–permissible limits. However, when adjusted with an estimated 8-hour daily production of plume, the results showed that acetonitrile and acrylonitrile concentrations (921.6 and 153.6 ppm, respectively) may

Table 2. Identified Chemical Compounds With Potential Health Hazards

| Chemical | Health Hazard |
|---|---|
| Benzene and ethylbenzene | Cancer, especially bone marrow; acute exposure can cause dizziness, headache, and CNS depression |
| Benzeneacetonitrile, acrylonitrile, and acetonitrile | Cancer; acute high-level exposure causes breathing difficulty, nausea/vomiting, seizures; severe toxicity can cause coma |
| Quinoline and isoquinoline | Cancer; lethargy, respiratory distress leading to coma; skin irritation; possible corneal injury |
| Styrene | Cancer associated with chromosomal damage at lower exposure; skin and eye irritation at high exposure |
| 2-Methyl pyridine | Cancer; toxic effects include GI disturbance, headache, leading to varying degrees of liver damage and CNS suppression; skin and eye irritant |
| Propene | Cancer; toxic effects at low levels include intoxication, paresthesia, and inability to concentrate; high-level exposure leads to CNS depression |
| Diethyl phthalate | Possible carcinogen; toxic effects of acute exposure include dizziness, nausea, headache, polyneuropathy, spasm, and allergic reaction similar to asthma; inhibits androgen synthesis and causes teratogenicity |
| Acetamide | Possible carcinogen; skin and mucous membrane irritation |
| Naphthalene carbonitrile | Possible respiratory tumors; toxic effects include agitation, lethargy, seizures, hemolysis, and blood dyscrasias |
| Benzaldehyde | Unknown carcinogenicity; irritant and CNS depression with limited exposure; seizures and respiratory failure with high-dose exposure |
| Benzenedicarboxylic acid (phthalic acid) | Unknown carcinogenicity; skin and eye irritation |
| Methyl salicylate | Unknown carcinogenicity; respiratory distress leading to CNS toxic effects including seizures and coma |
| Long-chain alkanes, long-chain alkenes, and polycyclic hydrocarbons | Unknown carcinogenicity; toxic exposure can lead to CNS depression, seizures, and coma (eg, cyclododecane, dodecanol, propane); some may cause skin and eye irritation |
| Toluene | Unknown carcinogenicity; bone marrow suppression with long-term exposure |
| p-Xylene | Unknown carcinogenicity; acute inhalation can result in CNS disturbance including short-term memory loss |
| Phenol | Unknown carcinogenicity; toxic at high levels, leading to delirium, coma, and death; can be absorbed through skin |

Abbreviations: CNS, central nervous system; GI, gastrointestinal.

Figure. Ultrafine Particle (UFP) Count Assessed From the Angle of the Laser Hair Removal (LHR) Practitioner and Patient



Time-series measurement of UFP concentration during an LHR treatment. The UFP concentration varied significantly when measured from the angle of the LHR practitioner vs the angle of the patient. ppc indicates particles per cubic centimeter.

exceed the OSHA-permissible limits (40 and 2 ppm, respectively). Acetonitrile is usually a byproduct of acrylonitrile production.[19] Acetonitrile can be metabolized into hydrogen cyanide, which is highly toxic. Large exposure via inhalation can result in symptoms similar to those of cyanide poisoning, including breathing difficulty, nausea, vomiting, and seizures. The effect of acrylonitrile is similar to that of acetonitrile in leading to cyanide poisoning via inhalation exposure.[19] Moreover, acrylonitrile has been found[19] to be carcinogenic in animal studies and cytotoxic to human mesenchymal stem cells. Ethylbenzene, toluene, and styrene are benzene derivatives, as described above. Short-term benzene exposure can lead to skin, eye, and respiratory irritation; dizziness; and headache. Long-term high-level benzene exposure has been associated[19] with acute myelogenous leukemia and bone marrow abnormalities. Propene is a nonaromatic hydrocarbon, often found in the fossil fuel refining process. Propene produces a low level of acute toxic effects, resulting in anesthetic effect of dizziness upon high exposure. However, long-term exposure to propene is known to be carcinogenic, as demonstrated in animal studies.[19]

The EPA 25C method measures the level of carbon monoxide. During the 30-second period when the smoke evacuator was turned off, the carbon monoxide level was 16 ppm per volume (ppmV). Assuming a time-linear increase in carbon monoxide production during an 8-hour day, the estimated carbon monoxide level may reach as high as 15 360 ppmV, far exceeding the 50 ppmV OSHA limit. Even at a low exposure of 35 ppmV for 6 to 8 hours, carbon monoxide induces toxic effects including headache and dizziness. When produced in significant quantities, carbon monoxide can cause adverse effects, such as headache, fatigue, and nausea, in laser practitioners. According to OSHA, the maximum permissible exposure to carbon monoxide should be less than 50 ppmV for no longer than 8 hours.[25] In addition, the National Institute for Occupational Safety and Health (NIOSH) recommends a ceiling level for carbon monoxide of 200 ppmV that should never be exceeded.[26]

Ultrafine particles are defined as being 1 μm (1000 nm) or less. The main exposure to UFPs is through inhalation.[13] Because of their small size, UFPs have the highest potential to be deposited into the deepest alveolar space, undergo interstitialization, or be absorbed directly into the bloodstream.[13] Exposure to UFPs, even if through nontoxic compounds, may cause oxidative stress, inflammatory mediator release, and lung disease and other respiratory disorders.[14] In our study, the level of UFP exposure was the highest for the laser practitioner who was closest to the center of plume formation. A 2-fold increase in UFP concentration was found in the waiting area compared with outside the building. Once the laser procedure was started and the smoke evacuator exhaust was turned on, the UFP concentration increased by 8-fold. When the smoke evacuator was turned off for 30 seconds, the UFP counter measured a nearly 4-fold sudden increase. Thus, when the evacuator was off, the UFP count was more than 26 times higher than the baseline level and 64 times higher than outside the building. The measured exposure to the patient was much less pronounced since the treatment was applied to his back. The UFP count to the patient increased only 8-fold when the evacuator was turned off. The amount of UFP exposure is proportionate to the distance from the center of plume production.

We acknowledge limitations of our study. Many chemicals have different levels of solubility in different solvents. Therefore, it is likely that there are other chemicals produced during LHR that are not soluble in hexane or chloroform. In addition, the EPA air sampling volume allowed for only 30 seconds of air sampling, and the estimated daily exposures were extrapolated based on the 30-second data. Finally, the TO-15 and 25C methods measure a small fraction of chemicals identified in the GC-MS data.

Currently, the clinical settings and training levels of laser practitioners vary from board-certified physicians in large medical centers to aestheticians in spas. There is no regulatory minimum requirement for air ventilation during a laser treatment other than those required by local building codes.

In general, smoke evacuators have dual functions: to neutralize and filter the chemical gases generated and to filter out particulates of small sizes.[27,28] NIOSH reported[26] that more than 500 000 health care workers are exposed to laser and surgical smoke every year. Plumes that occur during dermatologic surgical procedures have been documented.[29] Currently, NIOSH can issue warnings about surgical smoke and recommendations, but it lacks regulatory power.[26,30] OSHA recommends laser smoke evacuation and filtration but also cannot require their use.[25]

Smoke evacuators contain a suction unit (vacuum pump), filter, hose, and inlet nozzle.[27] The smoke evacuator should have high efficiency in aerosolized particle reduction and a capture velocity of approximately 30 to 45 m/min at the inlet nozzle.[28] The velocity of the particles being drawn to the smoke evacuator drops as the fourth power of distance away from the suction source.[28] Therefore, the evacuator typically needs to be within 5.0 cm of the site of plume generation.[28] In many cases, organic combustion leads to a high velocity jet in a particular direction, especially for lasers with liquid nitrogen or air spray cooling. If the spray were pointed away from the smoke evacuator, most of the plume would escape the evacuator. Therefore, it is important to position the evacuator entrance directly in front of the spray. Although this positioning would be technically simple, most laser manufacturers do not provide smoke evacuators that are integrated with the laser delivery hand piece. The findings of the present study suggest that integrated smoke evacuators would be useful to reduce plume risks.

Room suction systems pull air at a slower speed and can be equipped with both a particulate air filter (high-efficiency particulate air or ultralow particulate air) and a carbon filter. Generally speaking, a room suction system is not a substitute for the use of smoke evacuators, which are more effective at capturing laser plume.

Respiratory masks worn by patients and LHR practitioners are another protection, although they are effective only when worn properly. The N95 and N99 masks, which filter at least 95% and 99% of airborne particles, respectively, have a high filtration rate of particles less than 1 μm. For filtering of harmful chemicals, charcoal-impregnated masks, commonly used by painters, are available. However, since the laser plume has been shown to contain many carcinogens, charcoal masks alone may be inadequate without smoke evacuators. The masks need to fit securely and be checked for peripheral leakage.

## Conclusions

Plume produced during LHR contains potentially hazardous organic compounds and UFPs in quantities that may cause health problems ranging from airway irritation to cancers over time. Long-term cumulative effects of inhaling these potentially harmful chemicals and UFPs are unknown. We suggest that, at a minimum, an effective local exhaust system equipped with chemical extraction and particulate capture be used by practitioners who regularly perform LHR.

### ARTICLE INFORMATION

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### REFERENCES

1. DesCoteaux JG, Picard P, Poulin EC, Baril M. Preliminary study of electrocautery smoke particles produced in vitro and during laparoscopic procedures. *Surg Endosc*. 1996;10(2):152-158.

2. Barrett WL, Garber SM. Surgical smoke—a review of the literature: is this just a lot of hot air? *Surg Endosc*. 2003;17(6):979-987.

3. Gates MA, Feskanich D, Speizer FE, Hankinson SE. Operating room nursing and lung cancer risk in a cohort of female registered nurses. *Scand J Work Environ Health*. 2007;33(2):140-147.

4. Gatti JE, Bryant CJ, Noone RB, Murphy JB. The mutagenicity of electrocautery smoke. *Plast Reconstr Surg*. 1992;89(5):781-784.

5. Nahen K, Vogel A. Plume dynamics and shielding by the ablation plume during Er:YAG laser ablation. *J Biomed Opt*. 2002;7(2):165-178.

6. Kokasa JM, Eugene J. Chemical composition of laser-tissue interaction smoke plume. *J Laser Appl*. 1989;2(9):59-63.

7. Sawchuk WS, Weber PJ, Lowy DR, Dzubow LM. Infectious papillomavirus in the vapor of warts treated with carbon dioxide laser or electrocoagulation: detection and protection. *J Am Acad Dermatol*. 1989;21(1):41-49.

8. Tomita Y, Mihashi S, Nagata K, et al. Mutagenicity of smoke condensates induced by $CO_2$-laser irradiation and electrocauterization. *Mutat Res*. 1981;89(2):145-149.

9. Ediger MN, Matchette LS. In vitro production of viable bacteriophage in a laser plume. *Lasers Surg Med*. 1989;9(3):296-299.

10. Ziegler BL, Thomas CA, Meier T, Müller R, Fliedner TM, Weber L. Generation of infectious retrovirus aerosol through medical laser irradiation. *Lasers Surg Med*. 1998;22(1):37-41.

11. Baggish MS, Poiesz BJ, Joret D, Williamson P, Refai A. Presence of human immunodeficiency virus DNA in laser smoke. *Lasers Surg Med*. 1991;11(3):197-203.

12. Garden JM, O'Banion MK, Bakus AD, Olson C. Viral disease transmitted by laser-generated plume (aerosol). *Arch Dermatol*. 2002;138(10):1303-1307.

**13**. Kumar S, Verma MK, Srivastava AK. Ultrafine particles in urban ambient air and their health perspectives. *Rev Environ Health*. 2013;28(2-3):117-128.

**14**. Bräuner EV, Forchhammer L, Møller P, et al. Exposure to ultrafine particles from ambient air and oxidative stress-induced DNA damage. *Environ Health Perspect*. 2007;115(8):1177-1182.

**15**. Donaldson K, Li XY, MacNee W. Ultrafine (nanometer) particle mediated lung injury. *J Aerosol Sci*. 1998;29(1):553-560.

**16**. Pope CA III, Thun MJ, Namboodiri MM, et al. Particulate air pollution as a predictor of mortality in a prospective study of US adults. *Am J Respir Crit Care Med*. 1995;151(3, pt 1):669-674.

**17**. Pope CA III, Burnett RT, Thun MJ, et al. Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution. *JAMA*. 2002;287(9):1132-1141.

**18**. Grossman MC, Dierickx C, Farinelli W, Flotte T, Anderson RR. Damage to hair follicles by normal-mode ruby laser pulses. *J Am Acad Dermatol*. 1996;35(6):889-894.

**19**. US National Library of Medicine. TOXNET: Toxicology Data Network. http://www.toxnet.nlm.nih.gov. Accessed January 3, 2015.

**20**. Agency for Toxic Substances & Disease Registry. Toxic substances portal: benzene. http://www.atsdr.cdc.gov/phs/phs.asp?id=37&tid=14. Published August 2007. Accessed June 5, 2016.

**21**. American Cancer Society. Benzene and cancer risk. http://www.cancer.org/cancer/cancercauses/othercarcinogens/intheworkplace/benzene. Updated January 5, 2016. Accessed June 5, 2016.

**22**. Bachurin SO, Tkachenko SE, Lermontova NN. Pyridine derivatives: structure-activity relationships causing parkinsonism-like symptoms. *Rev Environ Contam Toxicol*. 1991;122:1-36.

**23**. Fisher JS. Environmental anti-androgens and male reproductive health: focus on phthalates and testicular dysgenesis syndrome. *Reproduction*. 2004;127(3):305-315.

**24**. US Environmental Protection Agency. 1990 Clean Air Act Amendment summary: Title III. https://www.epa.gov/clean-air-act-overview/1990-clean-air-act-amendment-summary-title-iii. Updated October 27, 2015. Accessed June 5, 2016.

**25**. US Department of Labor. Occupational Safety & Health Administration (OSHA). Chemical sampling information. https://www.osha.gov/dts/chemicalsampling/toc/toc_chemsamp.html. Accessed January 3, 2015.

**26**. Centers for Disease Control and Prevention; National Institute for Occupational Safety and Health. Control of smoke from laser/electric surgical procedures. http://www.cdc.gov/niosh/docs/hazardcontrol/hc11.html. Updated June 6, 2014. Accessed January 3, 2015.

**27**. Hunter JG. Laser smoke evacuator: effective removal of mutagenic cautery smoke. *Aesthetic Plast Surg*. 1996;20(2):177-178.

**28**. Smith JP, Moss CE, Bryant CJ, Fleeger AK. Evaluation of a smoke evacuator used for laser surgery. *Lasers Surg Med*. 1989;9(3):276-281.

**29**. Oganesyan G, Eimpunth S, Kim SS, Jiang SI. Surgical smoke in dermatologic surgery. *Dermatol Surg*. 2014;40(12):1373-1377.

**30**. NIOSH Health Hazard Evaluation and Technical Assistance Reports. Health hazard evaluation: University of Utah Health Sciences Center. http://www.cdc.gov/niosh/hhe/reports/pdfs/1988-0101-2008.pdf. Published February 1990. Accessed January 3, 2015.

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NOTABLE NOTES

# The Ancient Remedies of Alopecia

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A healthy head of hair has always been symbolic of youth, beauty, and vitality. Some cultures even attribute magical value to hair—from which “spells” to curse or to bless may be concocted.

There are many superstitions surrounding hair and hair loss. The commonest in North America seems to concern disposal of hair combings; if a bird acquires the combings, the owner will die, go mad, or lose all his or her hair.

To lose one’s hair in a male pattern or female pattern can be extremely distressing. Modern therapy involves the use of topical minoxidil (2% and 5%) and oral finasteride. It is interesting to discover the unusual and even revolting remedies of the past.

In the Roman ages, the ashes from the charred genitals of an ass were mixed together with one’s urine as a concoction that was rubbed onto the scalp.[1] Application of animal dung (mouse, hedgehog, chicken) persisted even until the 18th century in official pharmacopoeia.[2] At one time, bat’s blood was also recommended in both England and North Carolina.

Other bizarre hair treatments included a “miracle ageing brew” recorded in the 20th century from Shropshire, England, composed of nettle, dandelion flowers, roots fermented overnight with yeast.[3] In Native American folk medicine, yucca had been used as hair tonic. The consumption of kelp and horseradish was also thought to be curative. Interestingly, the Japanese, known for abundant dark hair, supplement their diet with kelp.

Alopecia is regarded by Chinese physicians to be a “blood deficiency,” with “generation of internal wind or invasion of external wind that affects the head.” The belief that there is “wind” influence in the etiology of the hair loss is reflected in the Chinese name for the disease, which is “*you-feng*,” or oil-wind in Chinese. Oil, taken to represent glossiness in Chinese symbolizes a smooth shiny scalp due to hair loss.

According to the book *Oriental Materia Medica*, the herb *Swertia japonica* is believed to enhance blood supply to the skin. Another popular Chinese tincture is “Lily Brand Hair Tonic,” which is made with capsicum extract and is similar to a Chinese home remedy involving red chilies soaked in wine. The action of capsicum is believed to promote local circulation via capillary dilation.

In Indian culture, mustard, coconut, amla, and almond oil are used among various Ayurvedic hair oils. Both beneficial and harmful skin effects have been ascribed to these agents. Mustard oil has been implicated in pityriasis rosea-like eruptions while almond oil application caused contact dermatitis in an atopic child.

These are but some of the weird and fantastical “cures” for baldness—whether they worked in the past is entirely speculative.

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**1**. Souter K Cure Craft. *Traditional Folk Remedies and Treatment From Antiquity to the Present Day*. Saffron Walden, England: C. W. Daniel; 1995.

**2**. Salmon W. *The Compleat English Physician*. London, England; 1693.

**3**. Prince D. *Grandmother’s Cures: An A-Z of Herbal Remedies*. London, England: Fontana; 1991.