An Analysis of Surgical Smoke Plume Components, Capture, and Evacuation

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ABSTRACT

Chronic exposure to surgical smoke can transmit viruses; lead to respiratory illness; and increase the risk of more serious conditions, including Alzheimer disease, collagen and cardiac diseases, and cancer. Despite this, surgical smoke plume capture and evacuation devices are often used sporadically or not at all, and do not necessarily reduce costs per procedure. In addition, the current choices for smoke plume capture are varied, and health care providers may make decisions about what type of method to use based on marketing materials rather than facts, leaving most clinicians and managers frustrated and cynical about supporting the effort to capture surgical smoke plume. This article presents current data and information that purchasing teams can use to help choose the best available technology for their practice patterns. It also provides analysis to help those responsible for choosing smoke evacuation systems make rational decisions in their quest to provide a clean, safe environment in the OR. *AORN J* 99 (February 2014) 289-298. © AORN, Inc, 2014. http://dx.doi.org/10.1016/j.aorn.2013.07.020

Key words: *surgical smoke, plume, smoke evacuation, surgical plume capture.*

Perioperative personnel using electrosurgery and other smoke-generating equipment create surgical plume daily; however, those who are exposed to plume often remain skeptical of its harmful effects, largely because many lack knowledge about these effects, and those who understand this have a difficult time convincing others to use smoke evacuation.[1] In addition, the surgical literature has remained static during the past 25 years, simply restating the chemical and particulate components of the plume.[1] To support the risks of inhaling surgical plume, research has relied on studies of transmission of human papilloma virus via inhaling plume,[1,2] the incidence of respiratory illnesses among perioperative nurses,[3] and the presence of by-products in plume that are known to produce cancer and which the National Institute for Occupational Safety and Health claims are mutagenic and carcinogenic.[4,5]

The environmental health literature reveals that nanoparticles, which comprise 80% of surgical smoke, are the real danger of inhaled smoke.[6] These particles, also called "ultrafine particles," are less than 100 nanometers (nm) in size (ie, 0.1 micron). Those between 20 and 80 nm are not well phagocytized by alveolar macrophages when inhaled, allowing these entities to cross the alveolar membranes by a process of translocation,

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enter a person's blood and lymphatic circulatory systems, and travel to various distant organs.[7] When chronically exposed to surgical smoke, research results have indicated that individuals may be exposed to increased risk of diseases that include Parkinson disease and Alzheimer disease; collagen and cardiac diseases; and lung, breast, and prostatic cancers.[8] It is this information, which has not found its way into surgical and nursing journals, that should make efficient capture and evacuation of surgical plume an OR priority. It is the purpose of this article to provide data-driven information to surgical facility personnel that will explain the options and the rationale for cost-effective purchase of available products.

BACKGROUND

The history of smoke plume or bioaerosol removal in the OR and the rationale for making the effort has been previously reported,[9,10] but an explanation of terms is often needed. Smoke capture is the ability to gather the plume produced during a surgical procedure and route it to a collection site. Examples of devices that are used to capture plume include smoke evacuation suction wands and electrosurgical unit (ESU) pencils that are attached to tubing, which is, in turn, connected to smoke evacuation filters. It is commonly accepted that Wyman Stackhouse introduced the original smoke evacuator system to the OR in the mid 1980s for the purpose of collecting laser-generated smoke plume, although Stackhouse never published. His system consisted of a 6-inch hard plastic attachment that he called a *wand* that fit into the end of the smooth-bore tubing, sometimes called *respiratory tubing* because it is commonly used by anesthesia professionals in respiratory breathing circuits. The wand had a 7/8-inch internal diameter (ID) tube that was joined to 8 feet of 7/8-inch ID smooth-bore tubing attached to suction. Stackhouse established the 7/8-inch ID standard for tubing that remains the standard for adapters present on today's filters and evacuators. Currently, wands consist of a cuffed end of 7/8-inch ID flexible tubing that is covered by a latticed screen to prevent sponges or tissue from being sucked into the tubing (Figure 1).

Figure 1. A surgical smoke evacuation system wand consisting of a cuffed end of 7/8-inch internal diameter flexible tubing that is covered by a latticed screen prevents sponges or tissue from being sucked into the tubing. *Photograph printed with permission from Nascent Surgical, LLC.*

The ESU pencil (Figure 2) with suction evacuation tubing is a monopolar electrode pencil with a 3/8-inch ID tube attached with an orifice that can be placed at varying distances from the tip of the electrode. The tubing length can vary between 8 and 10 feet. The newest capture device available is based on cell foam technology.[11] It has an open cell

Figure 2. An electrosurgical unit pencil with attached smoke evacuation tubing can be placed at varying distances from the tip of the electrode. *Photograph printed with permission from Nascent Surgical, LLC.*

Figure 3. With cell foam smoke capture device technology, smoke enters the open cell foam, in green, which is placed close to the incision. *Photograph printed with permission from Nascent Surgical, LLC.*

foam core sandwiched between layers of nonporous plastic to retain the smoke within the device and to prevent loss of suction power (Figure 3). It has an uncovered edge that serves as the entry site for captured smoke. The smoke then travels via a 1.25-inch ID tubing to a suction source required by all of the capture devices. The unique characteristics of these three devices are summarized in Table 1.

Smoke evacuation is the ability to capture the smoke generated at the surgical site and remove it to an area away from the surgical team where it can be filtered. The plume passes through a filter or filters, after which it is returned to ambient OR air. Examples of such devices are desktop suction pumps called local exhaust ventilators (Figures 4 and 5). The use of local exhaust ventilators is recommended by professional organizations[12] and governmental health agencies.[5] These machines are attached to ultra-low particulate (penetration) air (ULPA) filters that include activated charcoal that absorbs and deodorizes chemicals and the odors present in the plume. These ULPA filters remove 99.9995% of contaminants 0.12 microns or larger in diameter.[13] They act to trap the larger particles present in smoke by intercepting them, and smaller particles are trapped as they diffuse in the filter. They are made from microscopically sized fibers and glass. Less commonly, surgical smoke is removed to a distant site without recirculation of the filtered air. These central evacuation systems remove the smoke directly to a remote site without using filters, and the capture device connects through tubing to a control panel that controls the flow rate (Figure 6). The capture device usually is located in a boom or tower that descends from the OR ceiling where the valves and the tubing that carries the smoke to a distant site are located.

Factors That Influence Smoke Capture

The ability to capture plume during surgery depends on several factors, including the

- distance of the device from the source of smoke production,
- power of the suction source and its ability to produce a requisite minimum volume of airflow,[14]

TABLE 1. Comparison of Capture Devices That Use Standard Local Exhaust Ventilators at Maximum Power[a]

Smoke capture method	Average smoke capture efficiency (%)[b]	Involvement by clinician	Possible vision obstruction	Possible hand fatigue	Disposable
Wand	95%	Yes	Yes	Yes	Yes
Electrosurgical unit pencil suction	51.4%	Yes	Yes	Yes	Yes
Cell foam technology	99.5%	No	No	No	Yes

[a] *Unpublished author data, Schultz L, Olson B. November 21, 2011.*
[b] *Surgimedics Surgifresh Model smoke evacuator used for suction along with the Surgifresh ultrafine particulate air filter.*

Figure 4. In using a desktop smoke evacuation unit with an ultra-low particulate air filter in place, the filter's female connection receives 7/8-inch internal diameter tubing. ***Photograph printed with permission from Nascent Surgical, LLC.***

- internal diameter of the tubing that connects the capture device to the filter system placed in line with the suction machine, and
- amount of smoke produced during the procedure.

Factors that indirectly influence the ability to remove smoke include personnel availability, incision length, and the attitudes of the surgical team toward smoke evacuation.

Unpublished 2013 data from Olson and Schultz indicate that the 7/8-inch (22-mm) ID wand connected via tubing to a smoke evacuator and capable of generating 45 cubic feet per minute (cfm) of airflow at full power captured 99% of smoke at 1 inch from the source versus 53% when placed 3 inches from the smoke source. The importance of distance reflects the fact that heated smoke rises rapidly and disperses in all directions due to Brownian motion[15] and available air currents. The only way to gather the smoke is to have suction airflow capable of capturing the ambient air above the dispersed smoke, which then pulls the plume toward the device.

Figure 5. The ultra-low particulate air filter attaches in front of the lattice in some smoke evacuation units. ***Photograph printed with permission from Nascent Surgical, LLC.***

Schultz et al[14] showed the need to achieve a minimum airflow of 17 to 22 cfm under ideal conditions to capture smoke effectively after it has left the surgical wound. To prevent loss of smoke in the event of diminished suction, a minimum airflow of 25 to 35 cfm is recommended.[16] This airflow needs to be calculated to include all components in the system (eg, a high-resistance filter or capture system could decrease the net airflow below effective levels).

An important but often overlooked component that can either limit or improve acceptable airflow is the ID of the system's tubing. A tube that is too small also can be a source of an unacceptable noise level. Most evacuation tubing is either smooth bore or corrugated because tubing with these internal surfaces does not produce significant noise, whereas collapsible expansion tubing can produce a loud noise that is an unacceptable distraction to perioperative personnel. The effect of tubing diameter on airflow has been demonstrated by data from

the manufacturers of the ESU pencil that is now in common use as a smoke capture device. This product has a 3/8-inch ID tubing that is attached to a monopolar electrode. The tube orifice is located 1 to 1.5 inches from the tip of the electrode. This generates 3.5 to 5.0 cfm of airflow when connected to an in-line ULPA filter and then to the wall suction.[17] If perioperative personnel connect this device to a dedicated smoke evacuator, however, airflow increases to 11 to 15 cfm with an accompanying improvement in capture efficiency.[18]

Some smoke evacuation systems may use a slightly wider (eg, 25-mm or 1.2-inch ID) tubing because, given the same suction strength, the additional width can increase airflow by 5% to 10% compared with a 22-mm (7/8-inch) ID tubing (David Mulder, engineering manager, Semiconductor and Integrated Venting Solutions, Donaldson Company, Minneapolis, MN, personal communication, March 2011). Some facilities may use older suction devices that lack adequate airflow, and this larger diameter and enhanced flow can mean the difference between effective and ineffective smoke capture.

After smoke is captured, to the extent that a device's efficiency allows, various pathways for removal (ie, evacuation) are possible. Typically, the wand or the cell foam—based devices rely on a desktop or standalone smoke evacuation unit. These usually are capable of the required 25 to 35 cfm of airflow or more. Should they only be able to generate 20 to 25 cfm of airflow, then the plume may not be able to travel more than 2 to 3 inches to the collection device. Higher flow units, however, allow movement of smoke across longer distances and provide higher capture efficiency. For example, the RN circulator can either connect the ESU pencil suction tubing to the OR wall suction or attach it directly to a dedicated smoke evacuator that, as mentioned previously, enhances its efficiency. If the RN circulator attaches the pencil suction tubing to wall suction, then an in-line ULPA filter should be used to prevent particulates from entering the tubing within the wall. Alternatively, it can be attached to a suction canister that has a high-efficiency particular air (HEPA) filter in its top entry port that can trap particulates.

Not all procedures need powerful suction (eg, laparoscopic procedures), but all procedures that produce smoke need smoke capture. Procedures that produce little smoke can be adequately serviced with an ESU pencil suction when only monopolar cautery is used. A wand or the newer cell foam—based products can capture smoke when other heat transfer devices (eg, lasers, bipolar cautery) are used. Additionally, if the patient's incision is small (eg, 1 to 2 inches) and if the ESU pencil suction interferes with the surgeon's vision, then the scrub person can attach a regular suction tube with or without the modified cuffed wand end to the drape near the surgical site, and this can serve as an effective method of smoke capture. A recently unpublished study showed that a suction wand is capable of efficiently capturing 95% to 99% of smoke, assuming adequate levels of suction, when the tube's orifice is located within 2 inches of the smoke source (Olson B, Schultz L, unpublished data, 2013). In such situations, the assistants would not need to follow and capture the smoke plume and they can then devote their full attention to the surgeon's needs.

REASONS THAT SMOKE EVACUATION IS NOT USED

A dismissive attitude toward the risks of smoke inhalation is often the decisive factor in choosing not to use smoke evacuation devices. Refusal by a surgeon to allow smoke evacuation is usually a reflection of

- concern that an altered protocol could negatively affect the surgical result,
- anxiety associated with any change to routines,
- a lack of knowledge about sources that recommend the removal of smoke,
- a lack of enthusiasm for smoke removal on the part of administrators or nursing personnel,
- distraction caused by the noise generated by the smoke evacuator,

Figure 6. The control module of a central smoke evacuation system accepts the evacuator tubing, and the smoke is conveyed to a remote site through a conduit located in the tower and the ceiling. ***Photograph printed with permission from Nascent Surgical, LLC.***

- unavailability of devices that achieve high efficiency capture, or
- devices that require the surgeon's involvement.

All of these factors can be overcome by education, use of quieter smoke evacuators, and use of capture devices that remove smoke without requiring staff members to set them up. After educators and vendors present educational material to surgeons and other perioperative personnel, they often become strong advocates of the use of smoke evacuation.

Factors that affect acceptance of these units by perioperative personnel include noise levels and ease of use. Use of these units must require minimal effort because a complicated setup can be seen by clinicians as unnecessary interference with other preparation needed before surgery can begin. Staff members' acceptance of the technology also requires cooperation from the surgeons with whom they work. In general, surgeons want no disturbance of their protocols or ability to see or access the surgical site and want a noise level that does not distract them from concentrating. Thus, ease of connecting the capture device to the ULPA filter, which is attached to a smoke evacuator that does not exceed 50 to 55 decibels, has been found to be acceptable to most clinicians.[19]

The heart of any effective smoke or bioaerosol collection system is the ULPA filter that traps aerosolized particles as small as 0.12 microns or 120 nm in size. Should a prefilter be part of the circuit, perhaps as a component of the ULPA filter, then some 96% of particulates as small as 0.3 microns in diameter are trapped, which in turn prolongs the useful life of the ULPA component. Such ULPA filters typically function for as many as 20 uses or for 20 to 30 hours before replacement is recommended by the manufacturer. After smoke plume is filtered, the air is then returned to the OR environment. An intermediate method of smoke

evacuation is where a ULPA filter has been incorporated into a tower or boom in the ceiling directly over the OR bed. An example of this is the unit manufactured by Berchtold (Charleston, South Carolina), during the use of which, the smoke passes through the filter that is within the boom and the suction source is remote. The smoke is then removed from the room after filtration.

Another variation of a central smoke evacuation system transports the contaminated smoke plume, which is vented directly off-site without the use of a filter. At that site, the plume enters a collection tank where particulates of all sizes are washed down a drain connected to the sewer system. These units are powered by a turbine that generates the suction needed to provide smoke removal for all ORs within a facility. With this method, no filters are needed except an occasional HEPA filter that traps whatever particulates might possibly escape the collection tank. These HEPA filters remove 99.97% of particles 0.3 microns in diameter or larger and are made from similar materials and trap particles by the same mechanisms as do ULPA filters.[13] These systems do not allow for any plume to re-enter the OR suite after processing. As shown in Table 2, nanoparticle penetration of ULPA filters increases as airflow increases to levels that are used clinically.[20] Specifications for ULPA filters were determined at airflow rates that mimic breathing rates, which are approximately one-tenth those used for smoke evacuation.[21] Analysis of the data indicates continued rebreathing by perioperative team members of nanoparticles derived from smoke, which argues for central disposal of captured plume. Desktop to central smoke evacuation systems are compared in Table 3. Further, should a central system be installed, the capital outlay can be recaptured within one to two years by avoiding replacement of ULPA filters. After the capital costs are returned, the per-use cost of evacuation is reduced to the cost of the capture device alone (Table 4).

TABLE 2. Ultra-low Particulate Air Filter Particle[1]

Suction power setting	Percentage particle penetration	Nanoparticle penetration
Specified	99.9995%	0%
50%	99.883%	234 times greater than expected based on published penetration percentages
100%	99.842%	315 times greater than expected based on published penetration percentages

1. Schultz LS, Olson B. Efficiency of ULPA Filters During Smoke Evacuation at Clinical Flow Rates. Unpublished data, August 27, 2013.

TABLE 3. Comparison of Smoke Evacuation Techniques

	Desktop units[a]	Central units[b]
Noise based on manufacturer's published specifications[c]	55 dB maximum	60 dB maximum
Airflow	22-55 cfm	30-55 cfm
Nanoparticle capture[d]	Partial	Near complete (98% to 100%)
Uses ultra-low particulate air filters	Yes	No

dB = decibel; cfm = cubic feet per minute.

[a] Desktop units: Stryker Medical: 22 cfm with 7/8-inch tubing; Buffalo Filter: 44 cfm with 7/8-inch tubing; Surgimedics: 55 cfm with 1 1/3-inch tubing.
[b] Central evacuation units: Bechtold Corp: 30 cfm with 7/8-inch tubing; Central Vacuum system: 45 cfm with 7/8-inch tubing.
[c] Decibel units: Buffalo Filter: 49 dB to 62 dB; Stryker Neptune II: 55 dB; Bechtold Central system: 49 dB to 60 dB; Central Vacuum system: 50 dB to 55 dB.
[d] Olson B, Schultz L. Particle Technology Laboratory. Department of Mechanical Engineering, University of Minnesota. Data obtained May 15, 2013. Unpublished data.

Ambulatory Takeaways

Smoke Evacuation in an Ambulatory Surgery Center

More complex and longer procedures are being performed in ambulatory surgery centers, and this equates to more surgical smoke being produced. Reasons for not evacuating surgical smoke typically center around how the device affects the surgical procedure because they can be noisy, take up space, and obstruct the surgeon's view. However, because exposure to surgical smoke can be as toxic as exposure to cigarettes and other carcinogens,[1] the decision should focus on protecting all surgical team members and patients.

A systematic process should be conducted to choose smoke evacuation products. In addition to surgeon preference, important variables to consider include type and length of procedure, visibility at the surgical field, and amount of smoke produced. Another consideration is cost—standardizing products can help keep costs down. It is important to include surgeons in product selection to help ensure compliance, and industry partners are key in product selection, support, and subsequent education.

There are many new products available for surgical smoke evacuation, including an integrated electrosurgical unit pencil with smoke evacuation tubing, although the expense may be difficult to justify in centers in which minimally invasive procedures are primarily performed. Centralized smoke evacuation systems are ideal in inpatient facilities in which multiple open procedures are performed, but this option may not be practical or cost effective in an ambulatory surgery center setting. Using in-line filters with standard suction is an inexpensive way of evacuating surgical smoke in the ambulatory setting. In addition, evacuating smoke within 1 inch of the surgical incision and using a 7/8-inch corrugated tubing can be effective, although noise may be a limiting factor. Additional options include using an electrosurgical unit pencil adapter in which the pencil snaps into an adapter integrated with smoke evacuation tubing.

During laparoscopic procedures, surgical smoke often is evacuated because of poor visibility at the surgical field. Pausing and venting smoke to room air when visibility is compromised exposes surgical team members to surgical plume. There are several options available to evacuate laparoscopic-produced smoke. Some do not require suction or a smoke evacuator because intra-abdominal pressure vents smoke through a filter before it is introduced into the OR.

A key factor in deciding what smoke evacuation method to use is the effectiveness of the method. If perioperative personnel can see or smell smoke, then the method being used is either not appropriate or not working correctly. When collecting baseline data on compliance with evacuating surgical smoke, evaluation of appropriate procedures for which to use smoke evacuation, multidisciplinary evaluation of products, education, implementation, and data collection on compliance and continued sustainability would be a meaningful process improvement project.

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1. 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.

TABLE 4. Surgical Smoke Capture System and Central Suction Financial Analysis Tool[a]

Surgical facility smoke evacuation needs	ESU pencil system	Cell foam–based smoke capture system
Number of ORs	20	20
Procedures per day per room	2	2
Operating days per year	260	260
Percentage of open procedures	60%	60%
Capital equipment costs		
Central suction turbine		$152,487
OR equipment per OR		$2,500
Tubing and fixtures		$28,200
Disposables costs per procedure		
Electrosurgical unit pencil	$37.50	$0
ULPA filters	$23.25	$0
Cell foam–based surgical smoke capture system unit		$37.50
Disinfectant		$0.25
Initial training costs		
Central vacuum		$3,000
Module		$500
Annual servicing costs		
Central vacuum		$1,000
Module		$800
Financing[b]		
Bank interest (monthly)		0%
Repayment period (mo)		1 (up-front cost paid in full)
Monthly cost to hospital		
Amortized capital equipment and training expense		$234,187
Open procedure disposables expense	$31,590	$19,630
Servicing expense		$150
Total monthly cost to hospital for term of loan	$31,590	$253,967
Total monthly cost to hospital after repayment	$31,590	$19,780
Payback period (mo)		18.8

ESU = electrosurgical unit; ULPA = ultra-low particulate air.

[a] *Suggested average retail pricing from ESU "pencil" distributors, from Central Vacuum central smoke evacuation system distributors, and from Nascent Surgical, LLC. Final actual prices are proprietary and subject to individual hospital-company negotiation.*

[b] *Currently showing up-front costs paid in full on installation.*

CONCLUSION

Surgical plume evacuation requires a more robust discussion than simply talking about dry eyes, a sore throat, or respiratory illnesses. There needs to be a greater awareness that the smoke and vapor contain the same contaminants as blood or other potentially infectious materials and that smoke potentially can transmit bacteria and viruses when inhaled. Whereas regulations about bloodborne pathogen transmission protect team members from blood and body fluid contamination,[22] they do not regulate the use of smoke evacuation or protect perioperative nurses and surgeons from inhalation of surgical plume. In addition to posing an inhalation risk, research may demonstrate the possibility that smoke plume is a source of wound contamination. The ideal smoke evacuation system to protect surgical team members and patients is one that captures as much surgical smoke as possible and evacuates it to a remote site without recirculation of that air into the OR. Smoke evacuation systems must be tested and documented to be high quality and cost effective. AORN

References

1. Ulmer BC. The hazards of surgical smoke. *AORN J.* 2008;87(4):721-734.
2. Hallmo P, Naess O. Laryngeal papillomatosis with human papillomavirus DNA contracted by a laser surgeon. *Eur Arch Otorhinolaryngol.* 1991;248(7):425-427.
3. Ball K. Surgical smoke evacuation guidelines: compliance among perioperative nurses. *AORN J.* 2010;92(2):e1-e23.
4. Sagar PM, Meagher A, Sobczak S, Wolff BG. Chemical composition and potential hazards of electrocautery smoke. *Br J Surg.* 1996;83(12):1792-1796.
5. Control of smoke from laser/electric surgical procedures. Centers for Disease Control and Prevention. http://www.cdc.gov/niosh/docs/hazardcontrol/hc11.html. Accessed September 3, 2013.
6. Buzea C, Pacheco II, Robbie K. Nanomaterials and nanoparticles: sources and toxicity. *Biointerphases.* 2007;2(4):MR17-MR71.
7. Nemmar A, Hoet PH, Vanquickenborne B, et al. Passage of inhaled particles into the blood circulation in humans. *Circulation.* 2002;105(4):411-414.
8. Iwai K, Mizuno S, Miyasaka Y, Mori T. Correlation between suspended particles in the environmental air and causes of disease among inhabitants: cross-sectional studies using the vital statistics and air pollution data in Japan. *Environ Res.* 2005;99(1):106-117.
9. O'Connor JL, Bloom DA. William T. Bovie and electrosurgery. *Surgery.* 1996;119(4):390-396.
10. Barrett WL, Garber SM. Surgical smoke—a review of the literature. *Bus Brief Global Surg.* 2004:1-7. http://www.penadapt.com/PDF/Barrett-Garber.pdf. Accessed August 12, 2013.
11. Schultz LS, Drogue J. Unique devices for efficiently removing surgical plume. *Surg Serv Manage.* 2000;6(4):8-12.
12. AORN position statement on workplace safety. In: *Perioperative Standards and Recommended Practices*. Denver, CO: AORN, Inc; 2010:756-757.
13. Lee KW, Mukund R. Filter collection. In: Baron PA, Willeke K, eds. *Aerosol Measurement, Principles, Techniques and Applications*. New York, NY: Wiley-Interscience; 2001:197-229.
14. Schultz LS, Hickok DF, Graber JN, Stephens WE. The use of lasers in general surgery. A preliminary assessment. *Minn Med.* 1987;70(8):439-442.
15. Kaluza S, Balderhaar JK, Orthen B, et al. *European Risk Observatory Literature Review: Workplace Exposure to Nanoparticles*. Bilbao, Spain: European Agency for Safety and Health at Work; 2012:18. https://osha.europa.eu/en/publications/literature_reviews/workplace_exposure_to_nanoparticles. Accessed October 11, 2013.
16. Hunter JG. Laser smoke evacuator: effective removal of mutagenic cautery smoke. *Aesthetic Plast Surg.* 1996;20(2):177-178.
17. Watson DS. *Surgical Smoke: What Do We Know*. Dublin, Ireland: Covidien; 2009. http://www.buffalofilter.com/PDF/Surgical%20Smoke%20Plume%20What%20Do%20We%20Know.pdf. Accessed November 13, 2013.
18. de Boorder T, Noordmans HJ, Grimbergen M, Been S, Verdaasdonk R. Quantitative comparison of three electrosurgical smoke evacuation systems. SPIE the International Society for Optics and Photonics. http://spie.org/x648.xml?product_id=842574. Accessed October 18, 2013.
19. Ray CD, Levinson R. Noise pollution in the operating room: a hazard to surgeons, personnel, and patients. *J Spinal Disord.* 1992;5(4):485-488.
20. Mostofi R, Wang B, Haghighat F, Bahloul A, Jamie L. Performance of mechanical filters and respirators for capturing nanoparticles—limitations and future direction. *Ind Health.* 2010;48(3):296-304.
21. Bruske-Hohlfeid I, Preissler G, Jauch K-W, et al. Surgical smoke and ultrafine particles. *Occup Med and Toxicol.* 2008;3(31):1186-1191.
22. Occupational safety and health standards: bloodborne pathogens. *Fed Regist.* 1991;56(235):64004. Codified at 29 CFR §1910.1030, https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=standards&p_id=10051. Accessed October 11, 2013.

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