



CHARACTERIZATION AND REMOVAL OF ELECTROSURGICAL SMOKE

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Electrosurgical smoke has been recognized as a definite nuisance in the OR for at least a decade,¹ and several studies imply that viable human bloodborne pathogens can be transferred via smoke plume particulate. These particulates include not only HIV and human papilloma virus, but the probably more pervasive hepatitis and increasingly antibiotic-resistant tuberculosis.²

Though investigators of electrosurgical smoke have so far been unable to identify substances classified as deleterious in other environments,³ the acknowledged ill effects of the plume have prompted widespread use of smoke evacuation devices. Our studies investigate the size and dispersive aspects of the plume and the efficacy of various smoke evacuation devices. Earlier reported results indicate that, with no smoke removal, particulate concentration increased from the baseline (typically near 60,000 particles per cubic foot) to approximately one million per cubic foot approximately five minutes after electrocautery commenced for breast reduction.⁴ The concentration remained there with minor variations until electrocautery was complete. In addition, our earlier results indicate that concentration levels are this high throughout the OR—all OR occupants are subjected to a particle concentration comparable to that of the surgeon.⁵ It takes approximately 20 minutes for the OR ventilation system to return particle concentrations to the original baseline level.⁶

MATERIALS AND METHODS

In this current study, we measured particle concentrations of electrosurgical smoke using a laser particle counter capable of differentiating and counting particles in a range of sizes. Particulate counts are given in numbers of particles in the air sampled at the particle counter flow rate of 1

IN BRIEF

△ Previous studies indicate that airborne particulate rises to nearly one million particles per cubic foot during electrocauterization breast reduction surgery without smoke removal, that this concentration is found essentially throughout the OR, and that a typical smoke removal device reduces particulate counts by only 60%.

△ The studies described in this article evaluate particulate concentration and size distribution as they relate to time and OR location, both with and without smoke removal.

△ This article reports the authors' investigations of the smoke-generating potential of two common surgical procedures and the concentration reduction potential of frequently used smoke reduction devices.

△ For all smoke removal systems tested so far, significant particulate remained throughout the OR.

cubic foot per minute (cfm) and are available both as numbers of particles in each size range (ie, differential concentration) and as number of particles in all ranges (ie, cumulative concentration).

We obtained particle counts during several mammoplasty-related procedures: breast reduction—long considered a worst-case smoke-generating procedure—and breast implant removal and replacement. We conducted several experiments while the same surgical team performed these disparate procedures in succession on a single patient during a single session. The surgical procedures typically involved approximately 60 minutes of electrocautery, during which smoke production was more-or-less constant, with few periods of interruption. Time intervals reported in this article refer to the electrocautery session(s), not to the surgical procedure *in toto*, and are measured from the initiation of cutting.

Four smoke removal schemes were evaluated—one that has a smoke removal tube attached to the electro-surgical device (ie, system #1) and three smoke removal systems with smoke removal tubes held at the point of generation by an OR assistant, so that pickup is under active agent control (ie, systems #2, #3, and #4).

RESULTS

Figure 1 shows additional cumulative particle concentration data, obtained during this study, for breast reduction with no smoke removal. The observed cumulative particle concentration profile verifies our previous results.

Figure 2 shows the cumulative particle concentration trace during a combination breast reduction/implant removal and replacement, performed sequentially during a single session (the time of change-over from the breast-reduction side to the implant side is not noted), while smoke removal system #1 was employed. Though particle

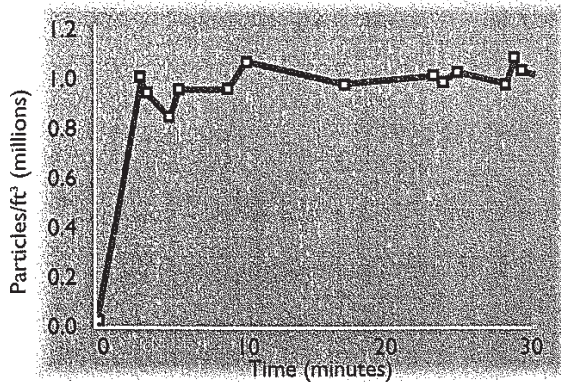


Figure 1: Cumulative particle concentration for breast reduction, no smoke removal. Particle concentration climbs to and remains near one million particles per cubic foot within five minutes after electrocautery begins.

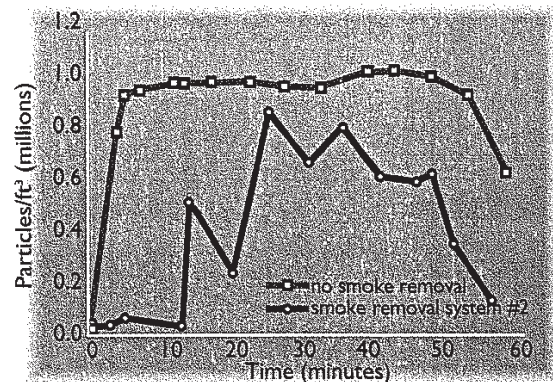


Figure 3: Cumulative particle concentration for breast reduction, with and without smoke removal system #2 (hand-held). The concentrations with this smoke removal system do not differ significantly from that of system #1.

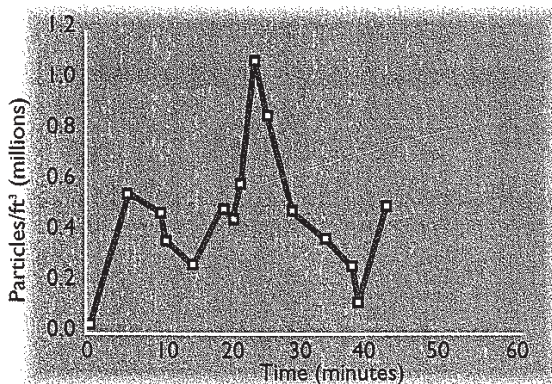


Figure 2: Cumulative particle concentration for breast reduction and implant removal/replacement, smoke removal system #1. Concentration falls on average to below 500,000 particles per cubic foot, but episodes of higher concentration still occur.

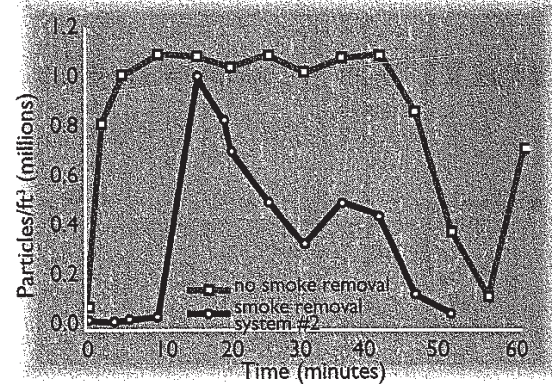


Figure 4: Cumulative particle concentration for implant removal/replacement, with and without smoke removal system #2. The concentrations generated here do not differ significantly from those generated during breast reduction.

concentration was reduced during most of the procedure, significant particulate remained throughout the surgical procedure. In fact, it reached nearly one million particles per cubic foot—the level obtained without smoke removal—during one interval.

Figure 3 shows the cumulative particle concentration traces for two sequential breast reduction procedures superimposed, one without smoke removal and one with system #2 employed. Figure 4 shows similar cumulative particle concentration traces for two sequential breast implant removal and reimplantation (of a different prosthesis) procedures superimposed, one without smoke removal and one with system #2 employed.

Figure 5 shows the cumulative particle concentration traces for two sequential breast reduction procedures superimposed, one during which smoke removal system #3 was used, and one during which system #4 was employed.

DISCUSSION

Though breast reduction surgery is smoke intensive—particle concentrations near one million per cubic foot—our present study suggests that concentrations from other electrocautery procedures (eg, breast implant removal and replacement) can rise to the same level, depending on the magnitude of cutting required, as shown in Figure 4.

Previous results⁷ and Figure 2 suggest that smoke removal

devices mounted on the ESU device do not totally eliminate particulate. In general, reductions are greater than 50%, but with significant deviations both upwards and downwards. Possible reasons for the large increases in particle concentration include

- ▲ blockage of the smoke removal tube with tissue or residue,
- ▲ removal of the tube while significant particulate is still escaping from the electrocautery site, and
- ▲ an unfavorable orientation of the tube relative to the plume.

Figures 3 through 5 suggest that hand-held smoke removal systems are not significantly better than smoke evacuation tubes attached to the electrocautery device. Figures 3 and 4 also suggest that hand-held systems may not produce a constant level of smoke reduction, but rather a lower average level, with occasional episodes of large increases in particle concentrations. (This is similar to the results obtained with a system using a smoke evacuation tube attached to the electrocautery device.) These episodes of degraded operation occur at random, but the instances of lower particle concentrations suggest that these favorable operating conditions are possible and lower levels could be achieved more consistently.

CONCLUSIONS AND RECOMMENDATIONS

For all smoke removal systems tested so far, significant particulate remained throughout the OR. Further studies

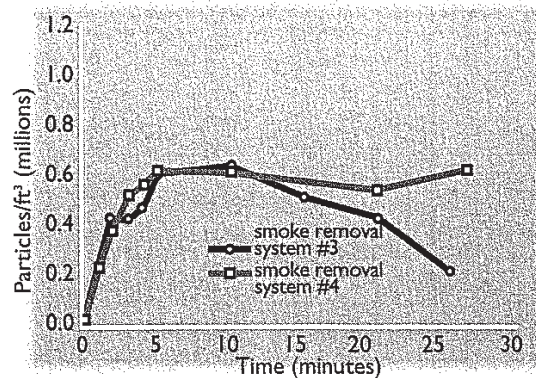
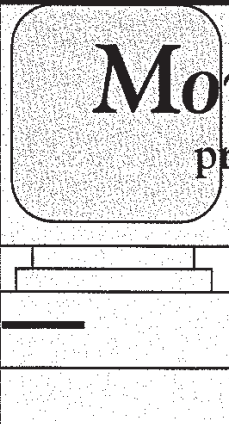


Figure 5: Cumulative particle concentration for breast reduction, smoke removal systems #3 and #4. There is no significant difference in particle reduction between these two systems.

are needed to determine the parameters that influence the efficiency of smoke removal systems. The operation of all available smoke removal systems should be investigated in a clinical setting, under as identical conditions as possible. The relationship between particle size and viability should be investigated, although earlier studies confirm the viability of filter-retained particulate.⁸ The effectiveness of current surgical masks in filtering out smoke particles also should be investigated. △



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