

Effects of Plume Produced by the Nd:YAG Laser and Electrocautery on the Respiratory System

Barry L. Wenig, MD, Kerstin M. Stenson, MD, Bruce M. Wenig, MD, and
Diana Tracey, BS

*Department of Otolaryngology-Head and Neck Surgery, University of Illinois
College of Medicine, Chicago, Illinois 60612 (B.L.W., K.M.S., D.T.), and
Department of Otolaryngologic Pathology, Armed Forces Institute of Pathology,
Washington, D.C. 20306 (B.M.W.)*

Sprague-Dawley rats were exposed to Nd:YAG laser exhaust (contact and noncontact) as well as to electrocautery exhaust passed through smoke evacuation filters. Exposure periods for each group were equal and increasing in time. Histologic analysis revealed alveolar congestion and emphysematous changes in all modes. Controls exhibited similar change but to a milder degree. It appears that any plume produced by lasers or electro-surgical devices produces pathologic change in rat lungs and that effective smoke evacuation will help control these effects.

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Key words: smoke evacuation, Nd:YAG, electrocautery

INTRODUCTION

Lasers have assumed an increasingly important role in otolaryngology-head and neck surgery in the past 10 years, with numerous studies in the literature supporting the use of this modality of treatment for various head and neck diseases. Relatively little data, however, exist regarding the effects of the smoke or plume byproducts resulting from this surgery.

Most experienced laser surgeons employ a smoke evacuator during laser surgery to clear the surgical field and remove irritating odors. Pioneers in the field used operating room wall suction to eliminate the plume. However, this method was eventually found to be ineffective due to the clogging of the suction mechanism with particulate matter.

Baggish and his coworkers [1] were the first to study the effects of carbon dioxide laser plume on the lungs of rats. They found congestive interstitial pneumonia, bronchiolitis, and emphysema in rat lungs exposed to CO₂ laser plume for various periods of time. The purpose of this project is to create a similar rat model system in order to study the effects of electrocautery and the

Nd:YAG laser plume in both contact and noncontact modes on the respiratory system of rats to determine whether deleterious effects may result from prolonged exposure to noxious plume.

MATERIALS AND METHODS

Twelve Sprague-Dawley male rats, weighing 300-450 grams, were utilized for each mode of the project. A "smoke chamber" was constructed according to previously described dimensions[1]. This chamber measured 19 × 34 × 16 cm and was rectangular in shape with a sliding roof and 14 air hole perforations. In place of the wooden box originally described, the chamber constructed for this study was made entirely of lucite. The transparent walls offered an unobstructed view of

Accepted for publication October 7, 1992.

Address reprint requests to Dr. B.L. Wenig, Univ. of Illinois Eye and Ear Infirmary, 1855 W. Taylor St., Chicago, IL 60612.

This work was read in part before the Twelfth Annual Meeting of the American Society for Laser Medicine and Surgery, Lake Buena Vista, FL, May 8, 1992.

the animal's behavior. A 2 cm lucite pipe was fitted at each end of the chamber. One side was attached via plastic hose to a CLASS Model B-1 Smoke Evacuator (CLASS, Plano, TX), whereas the other end was placed 1-2 cm from the plume source via the plastic hose.

A 10 × 10 cm square of planed pigskin was vaporized utilizing the Nd:YAG laser (Surgical Laser Technologies, Oaks, PA) using both the contact and noncontact modes and electrocautery (Valley Lab, Boulder, CO). The smoke evacuator was set to draw smoke through the chamber at a rate of 10-25 cu.ft./min. The Nd:YAG laser was set on 15-20 Watts of power, continuous lasing mode and air cooling function using a touch control TCRHS handpiece (Surgical Lasers Technologies) for noncontact and the same handpiece with a frosted sapphire scalpel ERP6 for contact.

This study was designed in three phases for each lasing mode (contact, noncontact) and electrocautery. Any behavioral changes of the rats were monitored and recorded during and after plume exposure.

Phase I

Three rats were subjected to plume exposure for 2 minutes followed by 2 minutes of rest. This was repeated for a total of four treatments daily for 4 days.

Phase II

In this phase, three rats were exposed to plume for 4 minutes followed by 2 minutes of rest. Four sessions daily were conducted for 7 days.

Phase III

A similar format as Phase II was employed with the exception that the animals were exposed to daily plume sessions for a total of 14 days.

One rat was used as a control for each phase. All rats were housed in the test room for both Nd:YAG laser modes. In the cautery mode, the control rats were housed separately and one additional rat was housed in the test room as an environmental control.

After completion of each phase, the rats were euthanized and the cardiorespiratory system was removed en bloc. Specimens were fixed in 10% formalin, sectioned, and stained with hematoxylin and eosin. Blinded comparisons were made between control specimens and those exposed to plume.



Fig. 1. Lung parenchyma showing severe alveolar congestion, vascular hypertrophy and emphysematous changes. (hematoxylin and eosin, × 30).

RESULTS

Behavioral Changes

All rats exhibited similar behavior during smoke inhalation. Between 1-1 ½ minutes of smoke inhalation, the animals became sluggish and stopped active movements. Activity resumed within 2 minutes of the rest periods, but then again stopped completely during subsequent smoke exposure. No animal became cyanotic or died as a result of smoke exposure.

Histologic Analysis

I. Noncontact Nd:YAG laser mode. All lung parenchyma revealed alveolar congestion, emphysematous changes and blood vessel hypertrophy in varying degrees. These changes were not dependent on the length of plume exposure (Fig. 1).

II. Contact Nd:YAG laser mode. All lung parenchyma showed muscular hypertrophy of blood vessels, alveolar congestion, and focal emphysematous changes. Control rats showed milder degrees of the above changes (Fig. 2). The changes were not exacerbated as the length of plume exposure increased.

III. Monopolar electrosurgical (bovie) mode. Similar changes were observed in this mode as with the previous modes with notable exceptions. Two of the three control rats, which were housed separately from the test room, revealed completely normal lung parenchyma. The other control rat showed diffuse severe alveolar



Fig. 2. Lung parenchyma showing milder, focal pathologic changes. (hematoxylin and eosin, $\times 30$).

congestion. However, the parenchyma of this specimen did *not* have muscular hypertrophy of the vasculature. Finally, the lung tissue of the environmental control rat revealed mild degrees of vascular hypertrophy, alveolar congestion, and emphysematous changes.

DISCUSSION

A smoke evacuator is basically a vacuum pump with one or more filters to remove particles from the plume. The best filter is of no help if the smoke plume generated by the laser or electro-surgical device is not captured. The most important factor in plume capture is creation of a vortex, which requires a high flow and intake velocity to draw the air into the nozzle, through the hose, and the through the evacuator where it passes through the filter. The filtered airstream is recirculated back to the operating room through a vent at the rear or bottom of the evacuator housing. High efficiency, particulate air filters are essential in smoke evacuation since they have a 99.97% efficiency in capturing particles of $0.3 \mu\text{m}$ and larger. Ultra low pressure filters capture submicron particles greater than $0.12 \mu\text{m}$.

From its inception as a surgical tool, the acrid smoke plume produced by laser interaction with tissue has been recognized as potentially hazardous. The hazards of the plume fall into two categories: biological and chemical. Lobraico et al. [2] produced the first clinical study attempting to identify the possible risks of laser plume with

respect to human papilloma virus (HPV). In response to results of a questionnaire, these authors concluded that an association existed between the use of the CO₂ laser for treatment of verrucous lesions and the development of such lesions by physicians administering the treatment. Shortly thereafter, Garden et al. [3] demonstrated that intact viral DNA can be recovered over a wide range of CO₂ laser parameters in both the in vitro and in vivo settings. These authors were unable, however, to resolve the question of the potential infectivity of the recovered material. In a contradictory study, Abramson et al. [4] showed that HPV DNA cannot be detected in the smoke plume from vaporization of laryngeal papillomas unless direct suction contact is made with the tissue during surgery. Recent studies documented the ability of lasers to disperse viable bacteriophage [5] as well as to isolate viral DNA in laser smoke [6]. It is probable that the latter is related to the concentration of the viruses in the lesion.

Little attention has been directed toward electrocautery smoke, and most physicians employ this surgical modality quite freely. Recently, concern has been raised regarding the mutagenicity of the smoke. Gatti et al. [9] tested airborne smoke particles produced during routine breast surgery and found the smoke to be mutagenic to the TA98 Salmonella Typhimurium strain. They questioned whether the smoke actually served as a serious health risk to operating room personnel.

Potentially hazardous chemicals apparently are also present in smoke plume. Both CO₂ and Nd:YAG lasers, even at low power densities, have produced benzene, formaldehyde, and acrolein. [7] These chemicals, although small in quantity, can be severely toxic and may account for the pulmonary changes noted in this and previous studies [1,8].

Baggish et al. [1] showed that the severity of pulmonary pathology increased proportionately with the duration of CO₂ laser plume. These authors concluded that the fine particulate matter contained in the laser vapor appeared to play a key role in the development of congestive interstitial pneumonia. In a follow-up study, the senior author routed plume through a smoke evacuator before connection to a rat chamber [8]. One phase routed the plume through a single filter while a second phase utilized a cartridge filter plus an ultra low penetration air (ULPA) filter. Phase 1 showed pathology similar to, but less severe than, unfiltered plume. No pulmonary pathology was

erved in this latter group. Recommendations based on these data included the use of a two filtration system in addition to placement of an evacuation tube within inches of the laser site.

The data in the present study reveal that Nd:YAG laser and electrocautery plume produce harmful effects on the lungs of rats, including muscular hypertrophy of vessel walls, alveolar congestion, and emphysematous changes. These pathologic changes were not observed to be more severe as the length of plume exposure increased.

The results of the first two modes were reviewed before the third cautery mode was initiated. The control rats in this mode, housed outside of the test room, revealed normal lung parenchyma. One control rat showed severe alveolar congestion without vascular hypertrophy, possibly due to concurrent illness. Moreover, the environmental control rat manifested the same mild degrees of pathologic changes seen in the control rats of the previous Nd:YAG laser modes. When comparing the three modes of plume production, there was no difference in the pathologic changes seen in the lung tissue.

The exhaust from a single filter smoke evacuator when connected directly to the rat chamber has been shown to produce pathologic lung changes in rats, although less severe than unfiltered plume [1]. Due to the confines of the small, albeit ventilated test room in this study, it seems that the undirected exhaust from the smoke evacuator produced the milder lung pathology seen in control rats of modes I and II.

In conclusion, the present study reveals that both laser and electrocautery plume produce pathologic changes in the lungs of rats. It appears that exhaust from a single filter smoke evacuator produces milder degrees of pathologic changes and that a double filtration system may be more

reliable in limiting these changes. The present data, previous research, and prudence strongly support the use of an efficient smoke evacuator to protect patients and operating room personnel from the harmful effects of any type of plume that may be generated in an operating room setting.

ACKNOWLEDGMENT

Support for this project was provided by the Baxter Healthcare Corp.

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