The Potential Alveolar Hazard of Carbon Dioxide Laser-Induced Smoke

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Abstract

Carbon dioxide laser is a continuous wave laser, it is well known for its capacity of tremendous smoke production while contact with tissue. Smoke may cause nausea, vomiting, headache and airway irritation. Smoke particles 0.5-2 micrometers in diameter usually travel down the tracheobronchial tree and lodge in the alveoli posing a health hazard. The objectives of this study were to evaluate possible health hazards of carbon dioxide laser smoke in the operating room environment, by determining the size and density of smoke particles also determine the efficacy of surgical masks as a smoke protectant. Ten fresh specimens of papillomatous tissue obtained from the patients were lased by carbon dioxide laser in a continuous mode. The plume generated was collected by 0.45 micrometers pore size microfilter which was attached to the tip of a suction hose connecting the smoke evacuator. The effectiveness of 2 types of commonly used surgical masks were also determined by trapping the smoke after passing through each mask using the same model. Smoke particles were evaluated by scanning electron microscope. The smoke particle density of microfilter that directly trap plume averaged 6 particles/mm^2, particles ranging in size from 0.5-27 micrometers, of which 70 per cent were 0.8 micrometers. For the particles trapped after passing through both cotton and paper surgical mask, the size were ranging from 1.6-37 micrometers where 65 per cent were 3.7 micrometers and the particle density average 2.7/mm^2. We concluded that the smoke particles derived from carbon dioxide laser application are within the alveolar hazard zone. The conventional surgical masks may not be an effective tool against laser smoke hazard.

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To date lasers have become a conventional tool in surgical armamentarium. The mainstay laser systems employed for surgery belong to a continuous or quasicontinuous wave group i.e., carbon dioxide, KTP and Nd : YAG laser. All of these systems usually generate smoke when their beam contact tissue. Among them, carbon dioxide laser is the most widely used system, when used without a scanner to cut or vaporize tissue it usually produces a large volume of smoke. Based on its basic physical property, carbon dioxide laser offers many advantages to the surgical field. Despite all the adherent advantages, the potential alveolar hazard from smoke generated is well worth investigation. It has been found that 1 g of tissue lased by carbon dioxide laser produces 142 mg of smoke[1].

MATERIAL AND METHOD

Ten specimens measuring 0.5x0.5 cm each were obtained from patients who suffered from recurrent laryngeal papilloma by cup forceps just prior to definitive treatment. The specimens were then immediately immerged in normal saline solution, kept ready for laser irradiation. Shortly thereafter, each specimen was divided into 3 equal parts. The first part was vaporized by carbon dioxide laser at 10 watts in continuous mode. The plume generated was trapped by 0.45 micrometers pore size microfilter which was attached to the tip of a suction hose equipped to Sharplan (Israel) smoke evacuator, this device has a minimum flow rate of 280 liters per minute and a maximum of 940 liters per minute. In this study, the smoke evacuator was adjusted to it's maximum sucking capacity. The second and third part of the specimen were lased by a laser at the same parameters, but the resultant plume were now trapped by 2 layers of filter, the underlying layer was microfilter and the top layer was a cotton cloth surgical mask for the second part of the specimen and a paper surgical mask for the third part of specimen respectively. These 3 sets of filter systems obtained were therefore represented

1. direct smoke trapping
2. trapping smoke after passing cotton mask
3. trapping smoke after passing paper mask

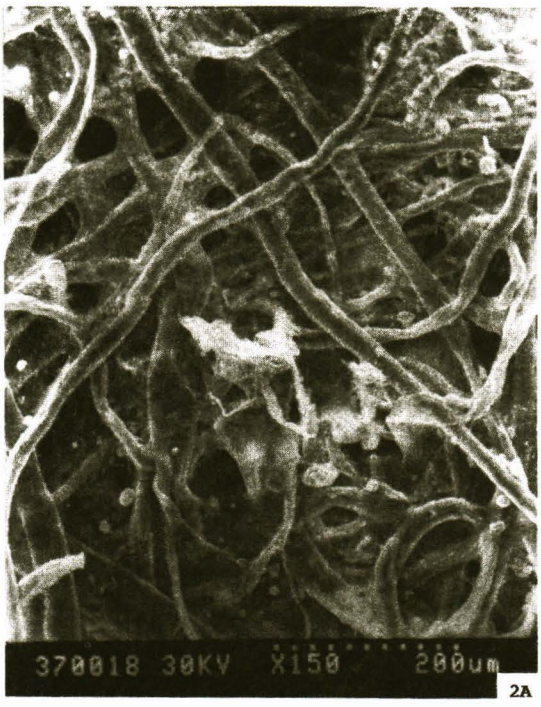
All of the microfilters were then transfered to the laboratory for smoke particles study. They were subjected to standard process of scanning electron microscopy (SEM). The size of smoke particles as well as the particle density were evaluated. Five SEM views random at the most populated area of each microfilter were studied, range and mean of particle size and average particle density were obtained from all specimens.

RESULT

The size of smoke particles from microfilters that directly trap smoke from all specimens were in the range of 0.5-27 micrometers where 70 per cent were about 0.8 micrometers and the particle density averaged 6 particles/mm^2 (Fig. 1).

The microfilter that trapped smoke after passing through both paper and cotton surgical masks also similarly showed a lot of particles ranging from 1.6-37 micrometers where 65 per cent were 3.7 micrometers and the particle density averaged 2.7 particles/mm^2 (Fig. 2).

Fig. 1. Scanning electron photomicrograph demonstrating smoke particles directly trapped from the laser treated specimen. Note numerous spherical shape particles in different size.



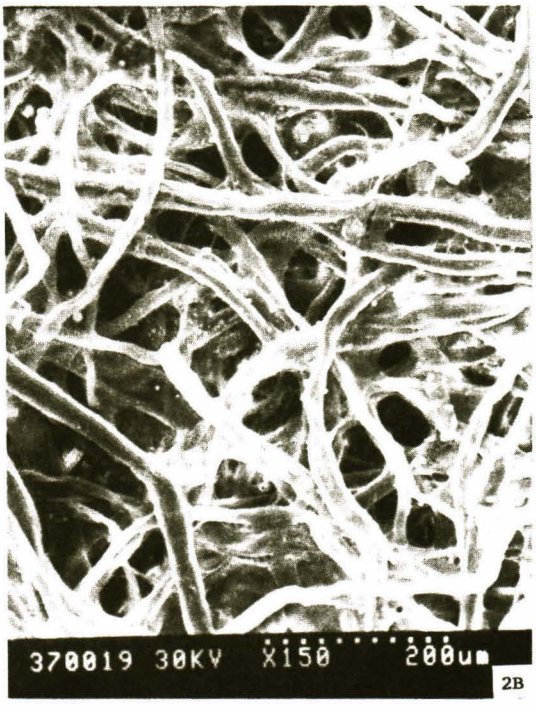


Fig. 2. Scanning electron photomicrograph demonstrating smoke particles trapped after laser plume had been filtered through A) paper mask B) cotton mask C) cotton mask at higher magnification. Note that there were still quite a number of spherical shape particles, which represented the particles passing through surgical mask, many of which were in the alveolar hazard zone.

DISCUSSION

It was well demonstrated that after being inhaled, different sizes of particles will lodge in different locations in the airway[2,3]. Those that are larger than 30 micrometers will lodge in the nose, mouth and upper trachea. Those of 10-29 micrometers will deposit in the bronchioles; 3-9 micrometers will lodge in the alveolar duct, 0.5-2 micrometers will reach the alveoli and those smaller than 0.5 micrometers will not deposit but float freely in the breathing air.

The size of particles from a laser plume derived from an animal study was reported by previous investigators to be 0.54 micrometers[4], and 77 per cent of the particles were smaller than 1.1 micrometers[5]. This coincides with the result in this study, these were therefore in the alveolar hazard zone. Baggish et al[6] did an animal study and demonstrated that laser smoke had many effects in the lung i.e., interstitial pneumonia, bronchiolitis, emphysema and lymphocytic infiltration. Freitag et al[4] studied the plume effect in animal trachea

after breathing in a closed environment containing smoke from a carbon dioxide laser. He demonstrated 72 per cent reduction in tracheal mucus velocity, increased neutrophil in the secretion from 2.3 per cent to 45.6 per cent and a slight decrease in oxygen saturation.

More over, smoke by itself may cause nausea, vomiting and headache even inhaled for a short period of time. This study was not designed to cope with the controversial issue of smoke biologic hazard, of which some investigators[7-9] showed a positive result and some demonstrated a negative result[10-14].

This study has also demonstrated that smoke particles could even pass through both types of currently available surgical masks in quite a large amount, among these also include the particles in the alveolar hazard zone. These amounts of particles will inevitably go down to the bronchioles and alveoli. From this standpoint one could question the role of the surgical mask as a protective device against laser smoke. Even worse when considering some amount of smoke that usually finds it way to the nose bypassing the mask by way of a dead space beside the nose. The definite conclusion for this regard probably should be cautiously drawn since the negative pressure exerted by the smoke evacuator as well as air flow rate were not designed to conform with average normal human range. The aspirating pressure or air flow rate of the evacuator employed in this study was several times higher than that of humans. However, the small pore size of the microfilter definitely hampered airflow, thus, markedly diminishing the airflow rate. This was apparently evidenced in the experiment by a very slow smoke flow rate. Nevertheless it was not known whether this flow rate was close to that of humans. To verify this issue further study is required.

SUMMARY

Upon contact with tissue, a carbon dioxide laser produces smoke particles, the size of which are in the alveolar hazard zone. The conventional surgical masks alone might not be a safety measure against laser smoke hazard. A good quality of smoke evacuator is absolutely an essential device for laser surgery employing a plume-evoked system.

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อันตรายของควันที่เกิดจากการใช้คาร์บอนไดออกไซด์เลเซอร์ ต่อถุงลมปอด

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เมื่อคาร์บอนไดออกไซด์เลเซอร์ ตกกระทบถูกเนื้อเยื่อจะทำให้เกิดควันจำนวนมาก เป็นที่ทราบกันว่าอนุภาคที่มีขนาด 0.5–2 ไมโครเมตร สามารถตกค้างและเป็นอันตรายต่อถุงลมปอดได้ ยังไม่มีหลักฐานยืนยันชัดเจนว่า หน้ากากสามารถป้องกันผงควันจากเลเซอร์ได้ บทความนี้มีจุดประสงค์เพื่อศึกษาขนาดของผงควันว่าอยู่ในช่วงที่เป็นอันตรายต่อถุงลมปอดหรือไม่ และศึกษาประสิทธิภาพของหน้ากากในการป้องกันผงควันดังกล่าว วิธีการคือ ดักควันที่เกิดจากการยิงเนื้องอกหงอนไก่ที่ได้จากผู้ป่วย ด้วยคาร์บอนไดออกไซด์เลเซอร์ โดยใช้แผ่นกรองที่มีขนาดช่องกรอง 0.45 ไมโครเมตร โดยส่วนที่ 1 ใช้แผ่นกรองอย่างเดียว ส่วนที่ 2 และ 3 ดักควันหลังจากให้กรองผ่านหน้ากากชนิดที่ทำด้วยกระดาษและผ้า ตามลำดับ แล้วทำการศึกษาขนาดและความหนาแน่นของผงควันด้วยกล้องจุลทัศน์อีเลคตรอน ผลปรากฏว่าผงควันที่ไม่ผ่านหน้ากากมีขนาด 0.5–27 ไมโครเมตร ซึ่งร้อยละ 70 มีขนาด 0.8 ไมโครเมตร มีความหนาแน่นเฉลี่ย 6 อนุภาค/มม^2 ส่วนผงควันที่ดักได้หลังจากให้ผ่านหน้ากากชนิดกระดาษและผ้า ยังมีผงควันขนาด 1.6–37 ไมโครเมตร โดยร้อยละ 65 มีขนาด 3.7 ไมโครเมตรและความหนาแน่นเฉลี่ย 2.7 อนุภาค/มม^2

สรุปว่าผงควันจากการใช้คาร์บอนไดออกไซด์เลเซอร์ จัดอยู่ในประเภทที่มีอันตรายต่อถุงลมปอด หน้ากากที่ใช้กันอยู่ในปัจจุบันอาจไม่มีประสิทธิภาพเพียงพอในการป้องกันอันตรายดังกล่าว

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