Efficacy of the Ramathibodi Nasal Filter in a Simulated Human Airway Evaluated by a Laser Diode Portable Dust Monitor Under Low Laser Smoke Particle Concentration

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Abstract

The Ramathibodi nasal filter attached to a simulated human airway was proposed to filter laser smoke particles. The simulated human airway composed of nasal and pharyngeal model, airway passage and lung model machine which mimicked the human respiratory system. The laser smoke particles represented a suspended particulate matter in a highly air-pollutted area such as at a main roadside in Bangkok. The experiment was done in the Department of Otolaryngology, Ramathibodi Hospital, from January to March 2000. The simulated human airway got an equal amount of laser smoke particles in a sealed plastic box for 1 min. The residual amount of laser smoke particles in a closed system of the simulated human airway was measured by a laser diode portable dust monitor for 1 min in each cycle and calculated as a mean and standard deviation. Without the Ramathibodi nasal filter of 39 sample pairs, the amounts of PM15, PM10 and PM2.5 were 52.3 ± 6.8, 43.0 ± 4.9 and 37.0 ± 3.5 mcg/m^3 respectively. With the Ramathibodi nasal filter of 39 pairs sample, the amounts of PM15, PM10 and PM2.5 were 48.1 ± 9.9, 39.1 ± 9.1 and 33.2 ± 7.2 mcg/m^3 respectively. Ramathibodi nasal filter efficacy for all laser smoke particle sizes evaluated statistically using *t*-test showed significant differences from those without the filter. Filtration efficacy should be tested further in higher concentrations of laser smoke particles and applied in human nasal vestibules under a critical air-polluted condition.

Key word : Simulated Human Airway, Laser Smoke Particles, Ramathibodi Nasal Filter, Laser Diode Portable Dust Monitor

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A simulated human airway was modified for testing the pattern of laser smoke particles distribution in the human respiratory tract. The simulated human airway composed of nasal and pharyngeal model, airway passage and lung model machine which mimicked the human airway system[1,2]. The Ramathibodi nasal filter was proposed to be applied in human nasal vestibules to prevent the suspended particulate matter which increased dramatically[3]. Laser smoke particles in an operative room had similar size and amount as the suspended particulate matter in a highly air-polluted area such as at the main roadside in Bangkok[4]. The laser smoke particle concentrations of PM15, PM10 and PM2.5 were selected due to their health impactions[5]. An air quality index (AQI), of the United States Environmental Agency, of 100 for PM10 corresponds to a PM10 level of 150 micrograms per cubic meter (averaged over 24 hours) and for PM2.5 corresponds to a PM2.5 level of 40 micrograms per cubic meter (averaged over 24 hours). The AQI value above 100 is applied for level of unhealthy concern for sensitive groups[6]. The cautionary statements for PM10 applied to people with respiratory disease, such as asthma, should limit outdoor exertion and for PM2.5 applied to people with respiratory disease, the elderly and children should limit prolonged exertion. The laser smoke particles were measured by a laser diode portable dust monitor[7].

MATERIAL AND METHOD

The experiment was performed in the Department of Otolaryngology, Ramathibodi Hospital from January to March 2000. The Ramathibodi nasal filter is composed of two kinds of filter material sealed at both ends and put inside a hollow medical grade silicone stent. The materials were foam and face mask filters. A pair of Ramathibodi nasal filters were fitted at both inlets of a nasal and a pharyngeal model for each test. The simulated human airway was a Y - shaped nasal and pharyngeal model, a corrugated airway passage and lung machine model (Lung machine model Ventilog 2, Oranger, Germany) which mimicked the human respiratory system. The inlets of the nasal and pharyngeal model were connected to two holes of a small sealed plastic box. A low concentration of laser smoke particles created by a carbondioxide laser (Model 1060, Sharplan, Laser Industries Ltd., Tel Aviv, Israel) with 10 shots of power 10 W, single pulse and 0.5 sec duration at a specimen put in the box through a laser hand-piece connected to a third hole in the box. The simulated human airway was run for 1 min after the laser evaporation stopped in order to get the laser smoke particles into the simulated human airway. A laser diode portable dust monitor (Series 1.104, Grimm Technologies Inc., Ainring, Germany) measured the residual amount of laser smoke particles in the simulated human airway as a closed system for 1 min immediately after the lung machine model of the simulated human airway was stopped (Fig. 1). The remaining laser smoke particles in the simulated human airway after each dust monitor measurement was cleaned for 3 min by a laser plume evacuater (Model 100, X-plume, Sharplan, Laser Industries Ltd., Tel Aviv, Israel) prior to the next cycle. All data were analysed by specific software in a computer using the *t*-test statistical method (Fig. 2). There were 39 sample pairs with Ramathibodi nasal filter and 39 sample pairs without Ramathibodi nasal filter.

RESULTS

The residual amount of laser smoke particles in the simulated human airway in each cycle was measured and calculated as mean and standard deviation. The residual amount of laser smoke particles in the simulated human airway without the

Fig. 1. Ventilog lung machine on the right, nasal with pharyngeal model and airway passage attached to the laser evaporization box at the center, laser diode portable dust monitor and accessories on the front left, laser smoke particle generator on the left.

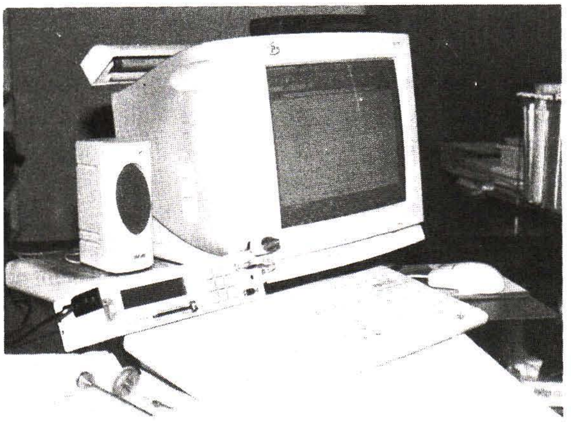

Fig. 2. Laser diode portable dust monitor connected to the computer for data analysis by specific software.

Table 1. Amount of residual laser smoke particles with the sizes of PM15, PM10 and PM2.5 in the simulated human airway with or without Ramathibodi nasal filter.

	PM15 *	PM10 *	PM2.5 *
With filter **	48.1 ± 9.9	39.1 ± 9.1	33.2 ± 7.2
Without filter **	52.3 ± 6.8	43.0 ± 4.9	37.0 ± 3.5
p-value	0.016	0.001	0.002

* Amount of the laser smoke particle sizes of less than 15, 10 or 2.5 micron in mcg/m^3

** Ramathibodi nasal filter of 39 sample pairs, without Ramathibodi nasal filter of 39 sample pairs

Ramathibodi nasal filter of PM15, PM10 and PM2.5 were 52.3 ± 6.8, 43.0 ± 4.9 and 37.0 ± 3.5 mcg/m^3 respectively. The amount of laser smoke particles in the simulated human airway with the Ramathibodi nasal filter of PM15, PM10 and PM2.5 were 48.1 ± 9.9, 39.1 ± 9.1 and 33.2 ± 7.2 mcg/m^3 respectively. The statistical method using the *t* - test showed significant differences for all three laser smoke particle sizes. The filtration efficacy of Ramathibodi nasal filter is shown in Table 1.

DISCUSSION

The Ramathibodi nasal filter was proposed to be used in human nasal vestibules. The filtration efficacy of the personal respiratory protective device was testified for the prevention of suspended particulate matter in the human airway(8). Public health studies of air pollution-induced health effects are an important ingredient for decisions with respect to the management of air quality. First, they are to be used to derive air quality standards from the air quality guidelines. Secondly, they serve to assess the causal link between observed health effects in the population and the causative agents in the air. Thirdly, they can be used to estimate ideal (in the sense of not being expressed in monetary terms) or economic damage functions that are necessary to assess the magnitude of the ideal or economic damages to human health. The latter are necessary for a sensible cost-benefit analysis in which the costs of control measures to reduce air pollution are compared with the costs of health effects. The laser smoke particles representing suspended particulate matter of PM15, PM10 and PM2.5 were selected due to their health impactions(9,10). Particles less than 2.5 micrometer in diameter are referred to as "fine" particles. The source of fine particles include all types of combustion (motor vehicles, power plants, wood burning, etc.) and some industrial processes. Particles with diameters between 2.5 and 10 micrometers are refered to as "coarse." Sources of coarse particles include crushing or grinding operations, and dust from paved or unpaved roads(11). Particles less than 10 micrometers in diameter tend to pose the greatest health concern because they can be inhaled and accumulate in the respiratory system. Reported rates of chronic cough, bronchitis, and chest illness were positively associated with all measures of particulate pollution TSP, PM15 and PM2.5. Frequency of earache also tended to be associated with particulate concentrations, but no associations were found with asthma, persistent wheeze, hay fever, or nonrespiratory illness. The rates of respiratory illnesses and symptoms were elevated among children living in cities with high particulate pollution. Children with hyperreactive airways may be particularly susceptible to other respiratory symptoms when exposed to these pollutants(12). The simulated human airway which mimicks the human respiratory system could be used to predict each particle size retention in the human airway(13). The real time measurement of each particle amount and size by a laser diode dust portable monitor was practical and accurate(14). The Ramathibodi nasal filter efficacy for laser smoke particles was shown to be statistically significantly different from that without the filter. The filtration efficacy was applied for three particle sizes of PM15, PM10 and PM2.5. The filtration efficacy for a higher concentration of laser smoke particles should be tested further(15). The filter could also be used in human nasal vestibules during a heavy air-polluted period(16,17).

SUMMARY

The Ramathibodi nasal filter was designed as a personal respiratory protective device for suspended particulate matter. The particle sizes of PM15, PM10 and PM2.5 were stressed due to their effect on human health. The filtration efficacy of the filter for all three particle sizes was statistically significantly different from that without the filter. The filter device should be tested in a higher concentration of laser smoke particles and applied in human nasal vestibules instead of the simulated human airway during a critical air-polluted period.

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ประสิทธิภาพของวัสดุกรองรามาธิบดีในเครื่องเลียนแบบทางเดินหายใจมนุษย์ประเมินในภาวะฝุ่นปริมาณต่ำจากการเผาไหม้ของเลเซอร์โดยตรวจวัดด้วยเครื่องตรวจวัดฝุ่นชนิดหิ้วได้ชนิดเลเซอร์ไดโอด

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วัสดุกรองรามาธิบดีซึ่งสอดใส่ในเครื่องเลียนแบบทางเดินหายใจมนุษย์เพื่อทำการกรองฝุ่นจากการเผาไหม้ของเลเซอร์ เครื่องเลียนแบบทางเดินหายใจมนุษย์ประกอบด้วยหุ่นจำลองช่องจมูกและลำคอ ท่อทางเดินหายใจและเครื่องเลียนแบบปอดซึ่งจะทำงานแทนระบบทางเดินหายใจของมนุษย์ ส่วนฝุ่นจากการเผาไหม้ของเลเซอร์จะใช้แทนฝุ่นที่มีอยู่ในอากาศขณะมีมลภาวะสูง การทดลองกระทำ ณ ภาควิชาโสต นาสิก ลาริงซ์วิทยา คณะแพทยศาสตร์ โรงพยาบาลรามาธิบดี ระหว่างเดือนมกราคมถึงเดือนมีนาคม พ.ศ. 2543 เครื่องเลียนแบบทางเดินหายใจมนุษย์จะเก็บปริมาณและขนาดของฝุ่นที่คงที่จากการเผาไหม้ของเลเซอร์ด้วยระยะเวลา 1 นาที ปริมาณและขนาดของฝุ่นจากการเผาไหม้ของเลเซอร์ที่ตกค้างในเครื่องเลียนแบบทางเดินหายใจมนุษย์จะตรวจวัดด้วยเครื่องตรวจวัดฝุ่นชนิดหิ้วได้ชนิดเลเซอร์ไดโอดโดยเป็นระบบปิดครั้งละ 1 นาที ค่ามัชฌิมเลขาคณิตและค่าเบี่ยงเบนมาตรฐานขณะไม่ได้ใส่วัสดุกรองรามาธิบดี จำนวน 39 คู่ตัวอย่างจะตรวจพบฝุ่นจากการเผาไหม้ของเลเซอร์ที่มีขนาดเล็กกว่า 15, 10 และ 2.5 ไมครอน เท่ากับ 52.3 ± 6.8, 43.0 ± 4.9 และ 37.0 ± 3.5 ไมโครกรัมต่อลูกบาศก์เมตร ตามลำดับ เมื่อเปรียบเทียบกับขณะที่ใส่วัสดุกรองรามาธิบดีจำนวน 39 คู่ตัวอย่างจะเท่ากับ 48.1 ± 9.9, 39.1 ± 9.1 และ 33.2 ± 7.2 ไมโครกรัมต่อลูกบาศก์เมตรตามลำดับ ซึ่งมีค่าที่แตกต่างกันอย่างมีนัยสำคัญทางสถิติทั้ง 3 ค่าด้วยการทดสอบด้วย *t*-test ควรทดสอบประสิทธิภาพของวัสดุกรองรามาธิบดีภายใต้สภาวะที่มีฝุ่นจากการเผาไหม้ของเลเซอร์ปริมาณสูงขึ้น การประยุกต์ใช้เครื่องป้องกันทางเดินหายใจส่วนบุคคลนี้สอดใส่ในช่องจมูกส่วน vestibule ของมนุษย์ขณะอยู่ในบริเวณที่มีปัญหามลภาวะทางอากาศ

คำสำคัญ : เครื่องเลียนแบบทางเดินหายใจมนุษย์, ฝุ่นจากการเผาไหม้ของเลเซอร์, วัสดุกรองรามาธิบดี, เครื่องตรวจวัดฝุ่นชนิดหิ้วได้ ชนิดเลเซอร์ไดโอด

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