Filtration Efficiency of the Ramathibodi Nasal Filter Evaluated by Rhinomanometry in High Concentration Level of Laser Smoke Particle

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Abstract

Under conditions with a high concentration level of laser smoke particles, the filtration efficiency of the Ramathibodi nasal filter was studied. Different kinds of filter material in the Ramathibodi nasal filter were evaluated in human adults with an anterior standard rhinomanometric method. The Ramathibodi nasal filter with three-layers of a half-face mask filter and a 4 mm thickness polyurethane foam put inside was applied in a simulated human airway. The experiment was conducted in the Otolaryngology Department, Ramathibodi Hospital from October to December 2001. The amount and size of laser smoke particles were measured by a laser diode portable dust monitor. The amount of residual laser smoke particles in the simulated human airway without the Ramathibodi nasal filter of PM2.5, PM10 and PM15 were 100.91 ± 7.65, 109.10 ± 7.87 and 120.18 ± 14.28 mcg/m^3 respectively. The amount of residual laser smoke particles in the simulated human airway with the Ramathibodi nasal filter of PM2.5, PM10 and PM15 were 85.55 ± 3.42, 92.18 ± 4.40 and 99.72 ± 5.02 mcg/m^3 respectively. The filtration efficacy of the Ramathibodi nasal filter showed a high statistically significant difference with a p-value of <0.001 for three particle sizes. High concentration of laser smoke particles in an operative room represented suspended particulate matters which are very dangerous for human healths. The Ramathibodi nasal filter as a personal respiratory protective device applied in human nasal vestibules could protect the human airway from atmospheric suspended particulate matter.

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

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The Ramathibodi nasal filter is an intranasal stent with filters that is applied in human nasal vestibules with minimal nasal obstructive symptoms. Nasal airway resistance through the Ramathibodi nasal filter was measured by a standard anterior rhinomanometry. An intranasal stent with three layers from outer filter layers of a half-face mask has been proposed for protecting the human airway from atmospheric suspended particulate matter[1]. Different kinds of filter material were tested. Polyurethane foam for the filters have proven to be effective in filtering hazardous dust and vapor with very low air flow resistant and high particle retention. It could be used in medical application such as artificial kidneys with blood and endothelial compatability[2,3]. A simulated human airway composed of a nasal model and a lung model machine with cyclical air flow pattern like that in a human respiratory system has been designed[4,5]. The measurement of amount and size of the suspended particulate matter with a laser diode portable dust monitor was accurate and practical[6]. Particles are most often measured to determine compliance with air quality standards, identify chemical compounds that might damage public health, apportion and qualify the chemical constituent of suspended particulate matter to their emitting source and evoluted cause of visibility impairment[7]. Respirable dust with a particle size of less than 2.5 micron (PM2.5) and less than 10 micron (PM10) was in consideration[8]. The amount of suspended particulate matter in Bangkok has increased dramatically during the past few years and the impact on human health has been stressed[9,10]. The high concentration level of laser smoke particles represented a critical air-polluted period with suspended particulate matter[11].

MATERIAL AND METHOD

The experiment was conducted in the Otolaryngology Department, Ramathibodi Hospital from October to December 2001. The Ramathibodi nasal filter was composed of a hollow, cylindrical, soft and medical grade silicone stent with outer layers of a half-face mask or surgical mask sealed at each end and/or HEPA or various thickness of polyurethane foam was put inside (Table 1). HEPA was applied from one layer of Thermovent HEPA (Sims Portex Limited, Smiths Industries Medical System, Hythe, Kent, UK). The length of the stent was 1.0 cm with an outer diameter of 1.3 cm and an inner diameter of 1.1 cm. Each intranasal stent with filters was tested in human volunteer for nasal airway resistance by standard anterior rhinomanometry (NR 6-2 rhinomanometer, Mercury Electronic Ltd., Scotland). Nasal obstructive symptom was assessed by a score of 10 to 0 which was the maximum and mimimum nasal airway resistance respectively. The selected device was used in the next part of the experiment.

There were 11 pairs of the Ramathibodi nasal filter with intranasal stent, three-layers of half-face mask at both ends with 4 mm thickness foam inside and 11 pairs of intranasal stent without filters. Each pair was attached to both inlet ends of a nasal model. The nasal model was the Y-type plastic hollow tube, 11.0 cm in length and 5.0 cm in width. The outlet diameter was 2.0 cm and the diameter two inlets was 1.5 cm. The outlet of the nasal model was connected to a lung model machine (Ventilog 2, Oranger, Germany) The lung model machine cycle rate was 15 times per minute, tidal volume of 700 ml and ratio of inspiratory to expiratory phase was 1:1 which mimicked the human respiratory situation. The air flow rate with laser smoke particles of 10.5 liters per minute through each pair of intranasals with filters was run for 1 min. The laser smoke particles in a sealed plastic box was created by CO_2 laser (Model 1060, Sharplan, Laser Industries Ltd., Tel Aviv, Isarel). The residual laser smoke particles in the simulated human airway were measured continuously for 1 min by a laser diode portable dust monitor (Series 1.104, Grimm Technologies Inc., Ainring, Germany). After each dust monitor measurement, the remaining laser smoke particles in the simulated human airway were cleaned for 3 min by a laser plume evacuator (X-plume, Sharplan, model 100, Laser Industries Ltd., Tel Aviv, Israel). The filtration efficiency of the Ramathibodi nasal filter under a high concentration of laser smoke particles was calculated.

Statistical analysis

Two sample cases, ordinal, independent samples, two-tailed test, non-parametric statistical test (The Mann-Whitney U test) were used and showed a high statistically significant difference with p-value <0.001 at alpha = 0.05.

RESULT

The Ramathibodi nasal filter with different kinds of materials was assessed in adult human nasal vestibules. Three-layers of a half-face mask filters

with a 4 mm thickness polyurethane foam in the Ramathibodi nasal filter was selected due to its low airway resistance which was not much different from the two-layers of a half-face mask filters with 3 mm thickness polyurethane foam in the rhinomanometric method and minimal nasal obstructive symptom (Table 1).

The residual amount of laser smoke particles in the simulated human airway without the Ramathibodi nasal filter of PM2.5, PM10 and PM15 was 100.91 ± 7.65, 109.10 ± 7.87 and 120.18 ± 14.28 mcg/m^3 respectively. The residual amount of laser smoke particles in the simulated human airway with the Ramathibodi nasal filter of PM2.5, PM10 and PM15 was 85.55 ± 3.42, 92.18 ± 4.40 and 99.72 ± 5.02 mcg/m^3 respectively. This difference is highly statistically significant with a p-value of <0.001 in all three particle sizes (Table 2).

DISCUSSION

The Ramathibodi nasal filter was proposed to protect the human respiratory system from atmospheric suspended particulate matters. The effect of air pollution on human health is demonstrated[12, 13]. Investigators evaluating inhaled particles in carcinogenesis bioassays observed excess tumours in animals that inhaled any high concentration of apparently inert so-called nuisance dust. Semivolatile and condensable toxic air pollution may be associated with particulate materials, especially PM10[14]. The amount of suspended particulate matter from four air-quality monitor centers in Bangkok and its vicinity for PM10 are above average over 24 hours (120 mcg/m^3) and yearly average (50 mcg/m^3). The suspended particulate matter amounts in 12 of 17 provinces are above average over 24 hours and in 14 of 17 provinces are above yearly average. The highest

Table 1. Rhinomanometric results and nasal obstructive symptoms (NOS) with different kinds of filter materials in the Ramathibodi nasal filter (RNF).

RNF	Inspiratory****	NOS******	Expiratory****
No RNF	0.245 ± 0.013	0	0.231 ± 0.074
Two-layers*	0.245 ± 0.006	2	0.238 ± 0.004
Three-layers*	0.251 ± 0.013	4	0.247 ± 0.022
Four-layers*	0.346 ± 0.007	8	0.338 ± 0.010
Two-layers*, 3 mm foam**	0.248 ± 0.013	2	0.220 ± 0.012
Two-layers*, 4 mm foam**	0.254 ± 0.024	4	0.230 ± 0.022
Two-layers*, 5 mm foam**	0.302 ± 0.018	8	0.281 ± 0.023
Three-layers*,4 mm foam**	0.251 ± 0.008	5	0.236 ± 0.009
One-layer*, HEPA***	0.315 ± 0.026	8	0.310 ± 0.010

* Outer layers of half-face mask filters
** Polyurethane foam with different thickness
*** High efficiency particulate air filter
**** Nasal airway resistance measured by rhinomanometer during inspiration and expiration
***** Score 0 = minimal,10 = maximal nasal discomfort

Table 2. The residual amount of laser smoke particles with PM2.5, PM10 and PM15 in the simulated human airway with and without the Ramathibodi nasal filter.

	PM2.5*	PM10*	PM15*
With filter**	85.55 ± 3.42	92.18 ± 4.40	99.72 ± 5.02
Without filter**	100.91 ± 7.65	109.10 ± 7.87	120.18 ± 14.28
P-value	<0.001	<0.001	<0.001

* Laser smoke particle residual amount (mcg/m^3) with size of less than 2.5,10 and 15 micron
** The Ramathibodi nasal filter (stent, three-layers half-face mask filter & 4 mm thickness polyurethane foam)

leading disease of Thailand in 1995, 1996 and 1997 are 314.36, 348.04 and 386.82 per 1,000 population for the respiratory system[15,16]. The half-face or surgical mask filter is a common personal respiratory protective device but facial leakage can happen. The filtration efficacy of intranasal stent with filters have been evaluated with laser smoke particles in the operative room[17]. Particle generation in the laboratory is difficult and specialized references must be consulted. Laser smoke particles are composed of a suitable amount and size of suspended particulate matter[11]. The laser diode portable dust monitor is reliable, convenient and has real time measurement[18]. With many measurements all but the most severe analytical errors will usually be overwhelmed by errors in extrapolating the data from a limited time period to a much longer time period. The pollutant action levels at specified concentration may be in minutes rather than days or years[19]. The air flow rate of 8.0-10.0 liters per minute is an adult minute volume ventilation under a sedatory situation. During exercise, when a large volume is inhaled at a higher velocity, impaction of the particle in the large airway and sedimentation and diffusion in the smaller airways and alveoli increase. The Ramathibodi nasal filter with stent, three outer layer of half-face mask and polyurethane foam had a low resistant air flow, acceptable nasal obstructive symptom and a high statistically significant filtration efficiency. The device was designed for human nasal vestibules during non air-conditioning public transportation or at the main roadsides of Bangkok in a heavy traffic congested area[8,9].

SUMMARY

The Ramathibodi nasal filter was applied in adult human nasal vestibules with acceptable flow resistant through it assessed by the standard anterior rhinomanometric method. The filtration efficiency of the Ramathibodi nasal filter was tested in a high concentration of laser smoke particles situation. The simulated human airway composed of nasal model and lung model machine. The residual amount and size of laser smoke particles in the simulated human airway were measured by the laser diode portable dust monitor. The Ramathibodi nasal filter should be used as a personal respiratory protective device in humans in a critical air-polluted area of Bangkok. The more effective filter materials for suspended particulate matters are under further investigation.

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การประเมินประสิทธิภาพของวัสดุกรองรามาธิบดีด้วยเครื่องตรวจวัดการไหลเวียนของอากาศผ่านช่องจมูกในภาวะฝุ่นละอองปริมาณสูงจากการใช้เลเซอร์

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การทดสอบประสิทธิภาพของวัสดุกรองรามาธิบดีภายใต้ภาวะฝุ่นละอองปริมาณสูงจากการใช้เลเซอร์ในห้องผ่าตัดซึ่งมีผลต่อสุขภาพของมนุษย์ เริ่มด้วยเครื่องตรวจวัดการไหลเวียนของอากาศผ่านช่องจมูกในผู้ใหญ่ขณะที่ใส่วัสดุกรองชนิดต่าง ๆ กัน คัดเลือกวัสดุกรองรามาธิบดีชนิดที่มีแผ่นกรองชั้นนอกของแผ่นกรองสำหรับปิดปากและจมูก 3 ชั้นติดที่ปลายของท่อซิลิโคนทางการแพทย์และวัสดุกรองชนิดโฟมความหนา 4 มม ใส่อยู่ภายใน สำหรับต่อในเครื่องเลียนแบบทางเดินหายใจมนุษย์ วัดปริมาณและขนาดของฝุ่นด้วยเครื่องตรวจวัดฝุ่นเลเซอร์ไดโอดชนิดหิ้วได้ การทดลองกระทำ ณ ภาควิชาโสต ศอ นาสิกวิทยา คณะแพทยศาสตร์โรงพยาบาลรามาธิบดี ระหว่างเดือนตุลาคม ถึง ธันวาคม พ.ศ. 2544 ปริมาณฝุ่นที่มีขนาดเล็กกว่า 2.5, 10 และ 15 ไมครอน ซึ่งเหลือค้างในเครื่องเลียนแบบทางเดินหายใจมนุษย์ขณะไม่ได้ใส่วัสดุกรองรามาธิบดีเท่ากับ 100.91 $\pm$ 7.65, 109.10 $\pm$ 7.87 and 120.18 $\pm$ 14.28 มคก/ลบม ตามลำดับ ส่วนปริมาณฝุ่นขนาดเล็กกว่า 2.5, 10 และ 15 ไมครอน ซึ่งเหลือค้างในเครื่องเลียนแบบทางเดินหายใจมนุษย์ขณะที่ใส่วัสดุกรองรามาธิบดีเท่ากับ 85.55 $\pm$ 3.42, 92.18 $\pm$ 4.40 and 99.72 $\pm$ 5.02 มคก/ลบม ตามลำดับ ซึ่งมีความแตกต่างกันอย่างมีนัยสำคัญทางสถิติ โดยมีค่า p–value<0.001 สำหรับขนาดของฝุ่นทั้ง 3 ขนาด วัสดุกรองรามาธิบดีเป็นเครื่องป้องกันระบบทางเดินหายใจเฉพาะบุคคลซึ่งได้รับการออกแบบสำหรับใส่ในช่องจมูกส่วน vestibules เพื่อป้องกันฝุ่นละอองจากมลภาวะอากาศรอบข้าง

คำสำคัญ : ฝุ่นละอองปริมาณสูงจากการใช้เลเซอร์, วัสดุกรองรามาธิบดี, เครื่องเลียนแบบทางเดินหายใจมนุษย์, เครื่องมือตรวจวัดการไหลเวียนของอากาศผ่านช่องจมูก, เครื่องตรวจวัดฝุ่นเลเซอร์ไดโอดชนิดหิ้วได้

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