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Water-pipe smoking effects on pulmonary permeability using technetium-99m DTPA inhalation scintigraphy

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Objective: Although extensive work has been done on cigarette smoking and its effects on pulmonary function, there are limited number of studies on water-pipe smoking. The effects of water-pipe smoking on health are not widely investigated. The aim of this study was to determine the effects of water-pipe smoking on pulmonary permeability. ***Methods:*** Technetium-99m DTPA inhalation scintigraphy was performed on 14 water-pipe smoker volunteers (all men, mean age 53.7 ± 9.8) and 11 passive smoker volunteers (1 woman, 10 men, mean age 43.8 ± 12). Clearance half-time (T 1/2) was calculated by placing a monoexponential fit on the time activity curves. Penetration index (PI) of the radioaerosol was also calculated. ***Results:*** PI was 0.58 ± 0.14 and 0.50 ± 0.12 for water-pipe smokers (WPS) and passive smokers (PS) respectively. T 1/2 of peripheral lung was 57.3 ± 12.7 and 64.6 ± 13.2 min, central airways was 55.8 ± 23.5 and 80.1 ± 35.2 min for WPS and PS, respectively ($p \leq 0.05$). $FEV_1/FVC\%$ was 82.1 ± 8.5 (%) and 87.7 ± 6.5 (%) for WPS and PS, respectively ($0.025 < p \leq 0.05$). ***Conclusions:*** We suggest that water-pipe smoking effects pulmonary epithelial permeability more than passive smoking. Increased central mucociliary clearance in water-pipe smoking may be due to preserved humidity of the airway tracts.

Key words: water-pipe smoking, pulmonary function, technetium-99m diethylenetriamine-pentaacetic acid, inhalation scintigraphy

INTRODUCTION

THERE IS EVIDENCE of a relationship between chronic tobacco smoking with lung infection,[1] obstructive pulmonary disease and primary lung cancer.[2,3] Although extensive work has been done on cigarette smoking and its effects on pulmonary function, there are limited number of studies on water-pipe (narghile, hubble-bubble, sheesha) smoking. The effects of water-pipe smoking on health are not widely investigated.

The original water-pipe came from India, but it was rather primitive as it was made out of coconut shell. Its popularity spread to first Iran and then the Arab world and Turkey. Its style has not changed for the last few hundred years. It consists of several sections, the pipe, head, body, hose and mouthpiece (Fig. 1). When a water-pipe is used, first the tobacco is set in the pipe and a bit of charcoal is placed on it. The mouthpiece located at the end of the hose is placed in the mouth, and the air in the space at the top of the bottle is inhaled, and so smoke passes through the water before reaching the mouthpiece. After dissolving soluble compounds (gases and particles, i.e. nicotine and tar)[4] cleansed by the water, the smoke collects in the empty space at the top of the bottle. Because the smoke reaching the airways is filtered and humidified, a rapid and short breathing pattern is used, some authors have proposed that water-pipe smoking as a habit less damaging to the respiratory system.[4]

The aim of this study was to determine the effects of water-pipe smoking on pulmonary permeability with technetium-99m diethylenetriaminepentaacetic acid

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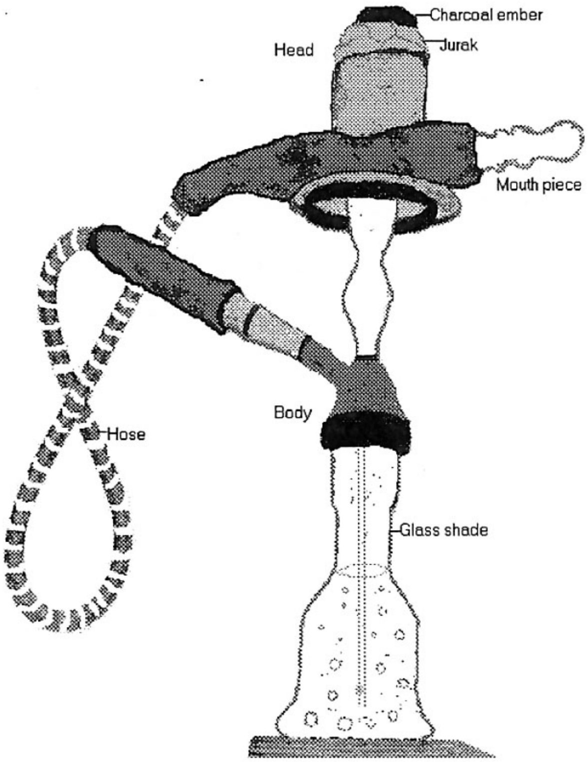

Fig. 1 A water-pipe illustration.

Table 1 PFT parameters for WPS and PS

PFT	WPS	PS
FEV_1	97.5 ± 5.2	100 ± 4.9
FVC	95.6 ± 4.3	94.7 ± 4.4
FEV_1/FVC	82.1 ± 8.5	87.7 ± 6.5*
PEFR	88.1 ± 5.7	97.6 ± 16.9
FEF_{25-75}	92.8 ± 7.9	100 ± 7.9
FEF_{25}	87.6 ± 7.2	99.0 ± 6.1
FEF_{50}	92.0 ± 8.9	98.4 ± 7.5
FEF_{75}	85.3 ± 8.3	100 ± 11.4
D_{LCO}	95.2 ± 9.4	96.3 ± 8.1
D_{LAdj}	98.4 ± 9.7	97.1 ± 8.2
D_{LCO}/V_A	86.7 ± 7.3	89.9 ± 4.9

The results are expressed as mean ± SD of predicted % values for each PFT.
* : $p < 0.05$

(Tc-99m DTPA) aerosol inhalation scintigraphy which is a simple, sensitive and noninvasive test commonly employed to assess pulmonary epithelial membrane permeability.

MATERIALS AND METHODS

Water-pipe and passive smoker volunteers after a routine physical examination were tested for pulmonary functions. The pulmonary functions of each participant were analyzed with the same spirometer (Sensor Medics V-max 22). After a detailed explanation of the pulmonary function test (PFT) techniques, the result of the best one of three reproducible tests was accepted. The measured (actual) and percentage of predicted (predicted %) values of forced expiratory volume in 1 sec (FEV_1), forced vital capacity (FVC), peak expiratory flow rate (PEFR), FEV_1/FVC ratio, forced expiratory flow in 25%, 50% and 75% of forced vital capacity (FEF_{25}, FEF_{50}, FEF_{75}, respectively), D_{LCO}, D_{LCO}-adj and D_{LCO}/V_A of each participant were measured.

Inhalation scintigraphy was performed on 25 volunteers with a mean age of 49.2 ± 12.2 years, all of whom provided informed consent. There were 14 water-pipe smokers (all men, mean ± S.D. age = 53.7 ± 9.8 years) and 11 passive smokers (1 woman, 10 men, mean ± S.D. age 43.8 ± 12.9 years). There was no significant difference between the mean age of the two groups. All water-pipe smokers smoke 1 or 2 times everyday (mean ± S.D. smoking duration 23.7 ± 8.3 years). The last time they had smoked was one day before the inhalation scintigraphy. Passive smokers are the individuals who do not smoke but are exposed to intensive cigarette smoke in the living or working environment (a smoker spouse, friend or spending much time at cafes). The duration of passive smoking of the PS is (mean ± S.D.) 21.4 ± 5.2 years. Water-pipe smoking habit requires an instrument present in special cafes, in this respect, water-pipe smokers stay everyday at least a few hours in this environment and become passive smokers at the same time. Therefore we selected our control group among passive smokers. All of the volunteers were healthy without any significant lung or other system disease or cigarette smoking history.

Tc-99m DTPA aerosol inhalation scintigraphy was performed to all volunteers by using the Ventiscan Biodex III aerosol delivery system, which produces submicronic particles (MMAD: 0.5 μm, GSD: 1.8), at an O_2 flow rate of 10–12 *l*/min. 1,480 MBq Tc-99m DTPA (Mallincrodt Medical, Holland) in 4–5 m*l* of 0.9% NaCl solution was placed in the nebulizer and inhaled for 3 min in the supine position. The labeling efficiency by instant thin-layer chromatography (ITLC) of Tc-99m DTPA was 95% and did not change after nebulization. Approximately 10% total activity was administered during a 3 min inhalation. Imaging was performed in the posterior projection for 30 min. One-minute frames were acquired in a 64 × 64 matrix (zoom factor of 1.33) using a Camstar XR/T gamma camera (General Electric, St Albans, UK). Regions of interest (ROIs) were drawn over the whole lung, excluding the central airways, and around the periphery and medial part of the lungs on the first-minute image to generate clearance curves. To obtain a pure alveolar ROI and to exclude the entire bronchial activity, the outer third of each lung was used as the peripheral lung region and the inner two-thirds of each lung was used as the central lung region. The brightness of the image was increased to

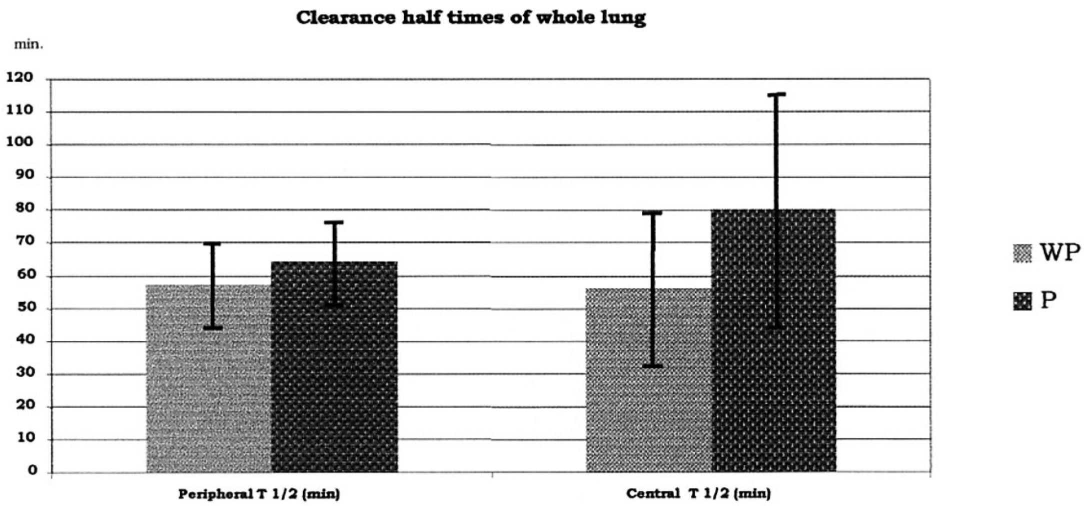

Fig. 2 Clearance half times of Tc-99m DTPA from the peripheral and central regions of the lungs. Faster central clearance of WPS compared to PS is clearly demonstrated. WPS: Water-pipe smokers. PS: Passive smokers.

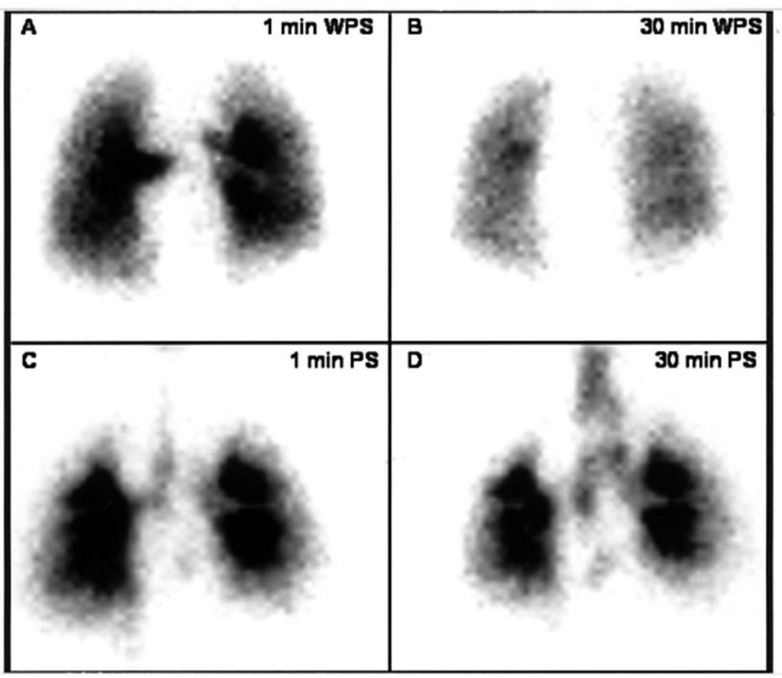

Fig. 3 Tc-99m DTPA aerosol inhalation scintigraphy of a water-pipe smoker and a passive smoker is shown. A is the 1 min and B is the 30 min image of a water-pipe smoker's scintigraphy. C and D legends are the 1 min and the 30 min image of a passive smoker's scintigraphy respectively. Central airways deposition and increased clearance were observed in WPS.

visualize body background and the lung periphery to permit correct definition of the peripheral ROIs. Time-activity curves were generated and corrected for Tc-99m decay. Clearance half-time (T 1/2) was calculated by placing a mono-exponential fit on the curves. T 1/2 of whole lung was calculated as the mean of the left and right lung. Penetration index (PI) was also calculated by dividing the peripheral total counts by the sum of the peripheral and central total counts on the first-minute image, so that the distribution of inhaled aerosol could be quantified (PI = peripheral total counts/peripheral to central total counts). The Mann-Whitney U test was used for unpaired data. P value less than 0.05 was considered statistically significant.

RESULTS

PFT results and T 1/2 values of WPS and PS are shown in Table 1 and Figure 2. FEV_1/FVC (%) value was found to be significantly decreased in water-pipe smokers ($0.025 < p \le 0.05$). No significant difference was observed in PI of Tc-99m DTPA in either WPS (0.58 ± 0.14, mean ± S.D.) or PS (0.50 ± 0.12, mean ± S.D.) group, but there were significant differences between total central and peripheral pulmonary clearance rates of WPS and PS ($p \le 0.05$). Central airways deposition and increased clearance were observed in all WPS as shown in Figure 3.

DISCUSSION

The measurement of DTPA lung clearance is a sensitive and noninvasive method such that acute as well as chronic changes in lung permeability can be measured with standard equipment.[5] According to our knowledge, there is no published article about the effects of water-pipe smoking on lung clearance determined with inhalation scintigraphy in the literature and we think this is the first reported study on that subject.

Various sensitive tests have shown that prolonged exposure to smoking brings about changes in the small airways and reduces pulmonary functions. The pulmonary function test parameters such as FEV_1, FVC and FEV_1/FVC are standard for defining airway obstruction. Zahran and Baig in their study had clarified significant decreases in FEV_1/FVC% and MMEF of cigarette and water-pipe smokers as a result of partial obstruction of the small airways.[6] Kiter et al. suggested in their study that small airway obstruction is more significant in cigarette smokers than water-pipe smokers when compared to nonsmokers. The result of the study was that water-pipe smoking does not affect pulmonary functions as seriously as cigarette smoking. There are three hypothesis on this issue which still need further investigations: 1-Due to the intermittent nature of the smoking, water-pipe allows healing of small airway inflammation. 2-Due to rapid and short smoking pattern, smoke does not reach the peripheral airways. 3-Due to the filtration of smoke, damaging effects decrease.[4]

In this study we found significantly decreased $FEV_1/$ FVC (%) in water-pipe smokers and PI of WPS was higher than PS though it was not statistically significant. Decreased FEV_1/FVC (%) and higher PI values determine that large and central airway pathology is more considerable than small airway obstruction for WPS.

The faster central clearance of WPS than PS attracts attention. Although it is difficult to explain the reasons for this without clarifying the possible mechanisms in detail, there may be a number of mechanisms responsible for augmenting secretion and mucociliary transport. Inhalation of high humidity water-pipe smoke may enhance mucociliary clearance. Hirsch et al. investigated the impairment of mucociliary transport by dry air breathing and the restoration of function with subsequent humidification of inspired air in anesthetized dogs.[7] The breathing of dry air through an uncuffed endotracheal tube produced almost complete cessation of the flow of tracheal mucus after 3 h. Subsequent breathing of air at 38 degrees C with 100% relative humidity restored tracheal mucous velocity to control values. Histological examination of the trachea at the end of the 3-h dry air breathing period revealed focal areas of sloughing of the ciliated epithelium and submucosal inflammation. They reported that an artificial heat and moisture exchanger placed at the proximal end of an endotracheal tube partially protects against the suppression of tracheal mucous velocity caused by dry air breathing.[7] Puchelle et al. have analyzed the effect of varying the inspired air humidity on a rheological property and transport capacity of airway mucus in 10 mongrel dogs. Their results suggest that lowering the absolute humidity of air induces a decrease in the transport capacity.[8]

Inhalation pattern of water-pipe smoking is taking shorter and more superficial breaths compared to that of cigarette smoking.[4] We suggest that water-pipe smoking affects pulmonary epithelial permeability more than passive smoking. Rapid and short smoking pattern may cause more injury at central airways and less damage to the peripheral lung (alveolar capillary membrane). Compared to passive smokers, increased central mucociliary clearance in water-pipe smoking may be due to preserved humidity of the airway tracts. We believe further investigation is necessary to confirm our findings about mucociliary clearance.

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