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Original Article

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Abstract

Objective: To examine the relationship between CO levels and putative factors including smoking status among residents of Karachi, an urban center with very high levels of air pollution.

Methods: Two hundred and eighteen volunteering subjects were asked to maximally exhale into a Smokerlyzer™ breath CO analyzer. Each of the volunteers was also asked to reply to a questionnaire-based interview seeking demographic information as well as details of exposure to tobacco, traffic fumes and other air pollutants.

Results: Out of the 218 participating subjects, 75% were males and 27% were current or ex-smokers. The mean CO level was 2.92 parts per million (ppm). Cigarette smoking was the only factor found to influence CO levels. Number of cigarettes smoked per day was directly related to CO levels, while time since the last smoke was inversely related. There was no difference in CO levels between ex-smokers and never-been-smokers. Years of residence in Karachi, quantitative exposure to traffic and perception of occupational exposure to air pollutants were not associated with CO levels.

Conclusions: Smoking status, number of cigarettes smoked per day and time since last smoke correlated well with exhaled breath CO levels, in spite of high air pollution levels. This tool therefore continues to provide a valid and real-time assessment of a subject's current smoking status (JPMA 58:75;2008).

Introduction

Cigarette smoking is responsible for considerable morbidity and morbidity worldwide.[1,2] With increasing medical evidence as well as public awareness vis-à-vis the same, smoking cessation programmes are assuming ever-increasing importance.

Accurate determination of smoking status is important in order to establish the efficacy of interventions aimed at smoking cessation. For a patient who is undergoing a cessation programme, a tool that takes into account recent smoking habits needs to be employed in order to promptly detect a relapse. The question of smoking status also assumes vital importance in certain instances of medical decision-making, e.g. a physician may decide against placing a prospective candidate on the lung transplant eligibility list in case the patient does not exhibit abstinence from smoking.[3]

So what is a reliable and convenient means of assessing current smoking status? There is clear evidence that self-reporting of smoking habits may underestimate the smoking status, both qualitatively (i.e. whether smoking or not) and quantitatively (i.e. number of cigarettes smoked daily).[4]

In recent times, biochemical markers of smoking status have attracted increased scientific interest. Since cigarette smoking is known to be associated with increased blood levels of carboxy haemoglobin (COHb), exhaled breath carbon monoxide (CO) levels have received considerable attention. Studies have already shown that breath CO levels can accurately predict smoking status in a number of populations.[5]

In order for CO levels to be a useful qualitative as well as quantitative indicator of smoking status, CO levels among non-smoking controls must also be determined for the population under question. This is important in order to exclude the effect that other variables (such as air pollution or gas heaters) may have on CO levels.

In Pakistan, a developing country that is the sixth most populous in the world, the epidemiology of baseline breath CO levels among non-smoking adults is not known. Moreover, in heavily populated urban centers with unchecked air pollution levels and absence of environment-protective traffic laws and green belts, it remains to be established whether or not there is a distinct difference in CO levels between smokers and non-smokers.

In this initial survey, we aimed to estimate baseline exhaled breath CO levels and its predictors in a sample from the resident population of Karachi, Pakistan's most populous urban center.

Subjects and Methods

This cross sectional study was conducted on patients and attendants visiting a Pulmonology clinic at the Aga

Khan University Hospital (AKUH), Karachi. The inclusion criteria were as follows: all subjects were at least 18 years old, and had been residents of Karachi for the greater part of the past two years. Subjects with any chronic or recurrent pulmonary disease were excluded from the study. Since the study was performed in fall season, which is characterized by very warm temperatures in Karachi, domestic heating systems were assumed to play no role whatsoever in the study findings.

Two hundred and eighteen subjects were recruited through convenience sampling and a structured questionnaire-based interview was carried out by a doctor in the local language (Urdu). The questionnaire was initially drafted on the basis of literature review, after which two clinical pulmonologists were separately asked to review it. The preliminary questionnaire was pre-tested on 25 patients and attendants and modified to address the identified deficiencies.

The questionnaire's first section recorded demographic characteristics as well as years of residence in Karachi, nature of occupation (if any) and perception of exposure to air pollutants at workplace. Questions concerning smoking status, including passive smoking at home or workplace, ex-smoker status, number of cigarettes smoked daily and time (in hours) since the last smoke were included in the second section of the questionnaire. According to National Health Interview Survey, 1992 definition, any smoker who claimed to be not smoking "at all" currently was considered as an ex-smoker.[6] Subjects were also asked about alternative forms of tobacco consumption, including hookah and sheesha (variants of piped smoke) and were also asked to quantify their duration of exposure to vehicular traffic on a usual day.

Next, exhaled breath CO levels were measured in parts per million (ppm) using a CO breath analyzer (Smokerlyzer™). Patients were asked to hold their breath for as close to 10 seconds as possible, then expire fully into the breath analyzer via a disposable mouth-piece. A doctor made a demonstration before supervising the exercise, and those subjects who failed to conduct the test properly had to repeat it.

The study was conducted in compliance with "Ethical principles for medical research involving human subjects" as per the Helsinki Declaration. Participants' identity was not sought or recorded. Verbal informed consent was obtained from all participants.

Data was entered and analyzed in Statistical Package for Social Sciences 13.0 (SPSS 13.0). One-way analysis of variance (ANOVA), Student's t-test and linear regression were employed to test for putative associations between CO levels and each of various factors. For all purposes, a p-value of <0.05 was considered as the criterion of significance.

Results

There were 218 participants in total, of which 161 were males and 55 females. Mean period of residence in Karachi was 31 years. Table 1 illustrates the other socio-demographic characteristics.

Median duration spent in the traffic per day was 2 hours. Thirty-seven percent of subjects drove in air-conditioned vehicles daily, 41% in vehicles with open windows and 22% did not drive on a daily basis. Twenty percent stated that they were exposed to inhaled pollutants at their workplace. Sixteen percent were self-reported smokers, another 11% being ex-smokers. Twenty-five percent and 16% said they were exposed to passive smoking at work place and at home, respectively.

The mean exhaled breath carbon monoxide (CO) level in the overall population was 2.92 parts per million (ppm). The mean exhaled breath CO levels in various demographic groups of our sample are shown in Table 1. Male smokers had a higher mean CO level (3.26 vs. 1.98 ppm; $p<0.05$). However, males who had never smoked had results 1.81 vs. 1.98 ppm. The difference in mean exhaled CO levels in different age groups was not statistically significant (one-way ANOVA $F=8.49$, $df=36$, $p=0.3$). In a linear regression model, age, number of years of residence in Karachi or number of hours per day in traffic were not associated with CO levels. Traveling in an air-conditioned

Table 1. Socio-demographic features of a Karachi population.

Variable	Number (%)	Mean exhaled CO ± SD (ppm)
Overall	218	2.92±0.3
Age (in years)		
<25	51 (23)	2.14±0.3
26-40	69 (32)	3.16±0.5
>40	98 (45)	3.15±0.5
Gender*		
Male	161 (75)	3.26±0.4
Female	55 (25)	1.98±0.3
Education (in years)		
<5	13 (6)	3.08±0.7
6-10	58 (27)	2.38±0.4
11-14	109 (50)	2.93±0.4
>14	38 (17)	3.66±0.9
Smoking status*		
Current smokers	35 (16)	8.54±1.2
Ex-smokers	23 (11)	1.83±0.2
Never-been-smokers	160 (73)	1.86±0.1

[*Statistically significant association with CO levels]

Table 2. Number of cigarettes per day and mean exhaled CO level (ppm) among smokers of a Karachi population.

No. of Cigarettes / day	No. of Smokers	Mean exhaled CO (ppm)	One way ANOVA
<1	2	1.00	
1-5	12	3.42	F-value 8.49
6-10	9	7.33	df = 36
11-20	5	8.40	p<0.001
>20	9	16.67	

versus openly ventilated vehicle did not have any impact on CO levels. Perception of being occupationally exposed to inhaled pollutants was not associated with higher CO levels (3.93 vs. 2.66 ppm; (p<0.07).

Current smokers had a higher mean CO level than never-been-smokers (8.54 vs. 1.86 ppm) (p=0.01) or ex-smokers (8.54 ppm vs. 1.83 ppm) (p=0.01). Moreover, as depicted in Table 2, CO levels increased with increasing numbers of cigarettes smoked per day (p=0.01). In a linear regression model, time since the last smoke (in hours) was inversely related to CO level (p=0.01). Every additional hour lapsed reduced the CO level by 0.42 ppm (regression coefficient) and this factor alone explained 33.8% of the variability (R2) in the CO levels among smokers.

Out of the 35 current smokers, 32 had levels higher than 7 ppm (91% sensitivity), while 153 out of 179 current non-smokers had levels below 7 ppm (85% specificity). This was found to be the optimal cut-off for predicting smoking status. Reduction of the cut-off to 3 ppm was needed in order to take the negative predictive value to 100%.

Ten subjects said they consumed alternative forms of tobacco. Of these, only one respondent claimed a minimum consumption frequency of once every week.

Among non-smokers, there was no statistically significant difference in the mean CO levels of ex-smokers and never-been-smokers (1.83 vs. 1.86 ppm, respectively). Similarly, exposure to passive smoking at work place or home did not have any association with CO levels.

Discussion

We chose as our study population the residents of Karachi, which is the largest urban center as well as the economic capital of Pakistan. Vehicular traffic on the main roads of Karachi is one of the busiest in the country, and infrequent monitoring by the law-enforcement agencies contributes to a substantial proportion of vehicles emitting large amounts of pollutants in defiance of existing traffic laws. There is heavy traffic congestion on most roads during a large port of the day, which increases duration of exposure to traffic pollutants. To make matters worse, there are few roads with any plantation on either side, and few parts of the city have any provision for green belts. A recent study carried out by the Pakistan Space and Upper Atmosphere Research Commission (SUPARCO) confirmed the high levels of air pollution in Karachi, although a few urban centers had even higher levels.[7]

The prevalence of self-reported smoking as estimated from our sample was 16%, which is similar to the figure of 15.2% reported in Ahmad K et al's analysis of data from the National Health Survey of Pakistan (NHSP) 1990-1994.[8] The mean CO level among never-been-smokers was 1.86, compared to 8.54 among current smokers. The optimal cut-off value for predicting smoking status was found to be 7 ppm. This is somewhat lower than the values reported by most Western studies, but closer to the cut-off of 6.5 ppm recently reported from Turkey.[5] On the other hand, a dramatic reduction in the cut-off value was required in order to take the negative predictive value to maximum, an observation supported by various studies.[9] Thus, if it is important to screen out every case of a violation of smoking cessation, a cut-off around 3 ppm would be more appropriate. However, given the small size of this sample, it is advised to be when generalizing these results. It is suggested that more extensive studies be carried out to establish the optimal cut-offs for this population and setting.

In a developing country with limited resources like Pakistan, the preferred diagnostic tool or therapeutic intervention is all the more dictated by factors other than diagnostic validity and clinical efficacy. Cost, degree of expertise involved and indeed local availability are usually the over-riding issues. In this context, measurement of the exhaled breath CO level stands quite favourably as a useful tool. The equipment is easy to use and read off, the test is quick to administer, and the patient need not be additionally charged for using a couple of disposable mouth-pieces.

An additional advantage over the conventional self-reported assessment tools in this setting would be the fact that in Pakistan's multi-lingual society (with over five languages commonly spoken, Urdu not understood by a significant minority and translators regularly needed in hospitals), measuring the CO level circumvents the need (to an extent) for interviewing the patient on current smoking habits.

While perception of occupational exposure to pollutants was not found to be associated with CO levels, authors note with interest the relevant p-value of 0.07. It is plausible that there may well be an association which was not covered due to the limited sample size of this study. In any case, we do suggest that this finding mandates more extensive research into this relationship in our setting.

The sample was derived from visitors attending a

Pulmonology clinic at the Aga Khan University Hospital (AKUH). AKUH is a privately owned, 500-bed tertiary level hospital, offering some of the most state-of-the-art diagnostic and therapeutic facilities in the country. It is conceivable that a relatively higher proportion of people visiting these clinics would belong to affluent and educated families. This is significant in the sense that according to the NHSP 1990-1994, illiteracy was associated with a higher prevalence of cigarette smoking.[8] This is, however, unlikely to make a bearing on our findings vis-à-vis the relationship of CO levels to various putative factors including smoking status.

Moreover, our comparison of various groups among smokers on the basis of number of cigarettes smoked per day (Table-2) might lack an ideal validity due to a relatively limited number of smokers in the overall study sample. It follows that more extensive studies are needed to further examine this relationship.

We conclude that in spite of high air pollution levels, the exhaled breath CO level continues to provide a valid and real-time assessment of a subject's current smoking status. Larger studies are required in order to definitively establish the optimal cut-off values for predicting smoking status as well as for detecting violation of smoking cessation.

We also recommend additional studies to explore the relationship between occupational exposure and CO levels in this setting.

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