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ORIGINAL ARTICLE

Pulse carboxyhemoglobin-oximetry and cigarette smoking

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Summary

Purpose: *We used a pulse carbon monoxide (CO)-oximeter to measure the levels of carboxyhemoglobin (COHb) in smokers and non-smokers. Our goal was to determine if this device could not only define smoking status, but also to increase accuracy of self-reported data at various surveys on smoking.*

Methods: *Thirty-four healthy volunteers participated in this study. Twenty-two of them were current daily smokers; 12 participants were non-smokers who lived alone or with a non-smoker, and who worked in non-smoking environment. Nicotine dependency level was determined by the modified Fagerstrom questionnaire. Blood COHb levels were measured with a pulse CO-oximeter (Masimo, Radical 7).*

Results: *The COHb levels in both moderate/heavy smokers and light smokers increased significantly after they smoked a single cigarette. This increase persisted for more than 6 h in the moderate/heavy smokers, while in the light smokers COHb levels returned to the baseline level after one hour. The pulse rate of all smokers increased significantly 20 min after smoking.*

Conclusion: *We conclude that the CO-oximeter can detect smoking by moderate/heavy smokers and light smokers if they smoked 6 h or 20 min earlier, respectively. We concluded that it could be used as a validation test for smoking at the time of admission to the surgical facility and to increase smoking abstinence during preoperative and postoperative periods. This noninvasive, simple and inexpensive test may also be used at various surveys to increase accuracy of self-reports on smoking.*

Key words: biochemical validation, cigarette smoking, CO-oximetry, Fagerstrom Questionnaire, preoperative smoking cessation, self-reported smoking

Introduction

Tobacco smoking continues to be the largest single preventable cause of premature morbidity and mortality, especially in many developing countries. Smoking also may cause difficulties of anesthetic management due to increase of pulmonary and cardiovascular complications, higher occurrence of airway and respiratory events (reintubation, laryngospasm, bronchospasm, hypoventilation), and it impairs healing of bones and surgical wounds [1-3]. Because even a brief preoperative abstinence from tobacco is beneficial to smokers undergoing surgery, anesthesiologists and surgeons should strongly recommend to their patients to abstain from smoking prior to elective surgery, and during the perioperative period [4]. Evaluations of smoking cessation programs to date have been mainly based on self-reported quit rates, but parallel biochemical validation indicates that self-reports are often biased [5,6].

The methods that have been used for smoking validation [7,8] are based on measurements of cotinine in saliva, serum or urine (half-life of 15 to 40 h); CO in exhaled air (half-life of 4 to 5 h); and COHb in the blood (half-life of 1 to 4 h). However, biochemical validation is not a gold standard in assessing a smoker. CO can be elevated in those who do not use tobacco. To increase accuracy of self-reports, a bogus pipeline procedure when the subjects are informed that their reports can or will be objectively verified by the researchers may increase accuracy of such reports on smoking.

Exposure to high concentration of CO causes toxicity that could be clinically stratified into three levels:

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mild (10-20% COHb), severe (20-40% COHb), and lethal (>40% COHb). In the heavy smokers that have the COHb level about 10%, minor clinical signs and symptoms of CO poisoning may develop, such as headache, lethargy or fatigue [9]. However, there are rare cases of heavy smokers who can tolerate levels of COHb of up to 15% [10]; such individuals are without clinical symptoms of CO poisoning.

The pulse CO-oximeter, Radical 7, can measure oxygen saturation, two dyshemoglobins (COHb and methemoglobin), and pulse rate. In addition to diagnosing acute CO poisoning, the pulse CO-oximetry has the potential of diagnosing chronic exposure to CO that peaks during the winter months when it is associated with increased indoor smoking and unsafe heating, and reduced external ventilation. The highest risk from low-level CO poisoning is to individuals with coronary heart disease, vascular disease, anemia, pregnant women and their fetus, infants, and the elderly with existing co-morbidities [11].

This device was mainly developed for non-invasive, real time measurements to be used at the emergency departments and other clinical settings, especially during surgical operations when the anesthesiologist may suspect carboxyhemoglobinemia [12]. We would like to see if it could be used for biochemical validation of smoking. Therefore, we determined the blood levels of COHb in healthy volunteers, daily cigarette smokers and non-smokers.

Methods

Following Institutional review and approval, we recruited 36 healthy individuals for the study. All subjects (28 male, 8 female) gave informed consent. They ranged in age between 24 and 73 years. Twenty-two of these volunteers were current daily smokers; 15 in this group were male. Fourteen healthy non-smoking volunteers formed the control group. Twelve of them reported that they never smoked, they either lived alone or with a non-smoker, and they worked in non-smoking environments. Two of non-smokers were excluded because they worked in smoking environments. The study was done in the springtime when indoor heating was not used.

Among the smoking group, nicotine dependency was established with a modified Fagerstrom questionnaire [13]. The smokers were then classified according to the nicotine dependency score as either "light smokers" (a score of 3 points or less) or "moderate/heavy smokers" (a score of 4 points or more). Eleven were classified as light smokers and 11 as moderate/heavy smokers. The health status of the participants and the average number of cigarettes used per day were self-reported. The light smokers smoked from 3 to 7 cigarettes a day (median 4), while the moderate/heavy smokers smoked from 10 to 25 cigarettes a day (median 14). Blood COHb levels were measured with a pulse CO-oximeter (Radical-7, Masimo, Irvine, California). Smokers were asked not to smoke over the night (for 10 to 12 h). Then blood levels of COHb were determined before (baseline level) and at various times after they smoked a single cigarette of their chosen brand. Measurements were made at 20 min, 1 h, 3 h and 6 h after finishing the cigarette. The level of COHb in non-smokers was also measured over time.

Statistical analysis

The continuous variables were assessed for normality of their distribution [14] and for normally distributed data (pulse rate). Student's t test was applied to assess statistical significance. We found that levels of COHb were non-normally distributed, and we could not assess the statistical significance of a quantitative change. Accordingly, we used the nonparametric Mann-Whitney test to assess qualitative changes [15]. All statistical operations were done with statistical software (GraphPad Instat). The data are given as mean and SD along with the range. A value of $p<0.05$ was judged significant.

Results

Carboxyhemoglobin levels in smokers and non-smokers

The COHb levels in smokers increased significantly after the subjects smoked a single cigarette. This increase persisted for more than 6 h in the moderate/heavy smokers, while for the light smokers, COHb returned to baseline levels within 60 min after smoking (Table 1). In addition, baseline levels of COHb were 0.6% and 0.7% higher in moderate/heavy smokers than in light smokers or non-smokers, respectively.

Oxygen saturation, methemoglobin, and pulse rate in smokers

Oxygen saturation (Spo2, range 96-100%) and methemoglobin levels (MetHb, range 1.0-1.7%) did not change significantly in any group of participants during the experiment. All smokers experienced an increased pulse rate, but this increase was significant only 20 min after smoking (72 [SD=10.6] vs. 85 [SD=12.6] bpm; $p < 0.005$).

Table 1. Pulse oximetry measurements of carboxyhemoglobin levels in healthy cigarette smokers and non-smokers

Group	*n*	*Levels of carboxyhemoglobin (%)*		*p-value**
		Range	*Mean (SD)*	
Non smokers	12	0-2	0.7 (0.8)	–
Moderate/heavy smokers	11			
12 h abstinence		0-2	1.4 (0.8)	NS
Post smoking**				
20 min		3-13	6.1 (2.9)	< 0.001
60 min		2-8	4.8 (2.0)	< 0.001
3 h		2-4	3.2 (0.9)	< 0.001
6 h		2-4	2.9 (0.8)	< 0.001
Light smokers	11			
12 h abstinence		0-1	0.8 (0.6)	NS
Post smoking**				
20 min		1-4	2.1 (1.1)	< 0.005
60 min		0-2	1.2 (0.6)	NS
3 h		0-1	0.6 (0.7)	NS
6 h		0-1	0.7 (0.5)	NS

The smokers were classified into two groups according to the nicotine dependency score: "light smokers" (a score of 3 points or less) and "moderately/heavy smokers" (a score of 4 points or more). *smokers vs. non-smokers; **the time after one cigarette was smoked; NS: not significant; n: number of subjects.

Discussion

The results presented show a significant elevation of COHb in both light and moderate/heavy smokers after they smoke a single cigarette. Elevated COHb persists in heavy smokers longer than in the light smokers. For the majority of moderate/heavy smokers, it takes more than 6 h to return to baseline values of COHb, while in light smokers this occurs much faster (less than 60 min). It is possible that this big difference in COHb elevation and its persistence between the two groups of smokers is caused by various depth and duration of inhalation. Perhaps the moderate/heavy smokers inhale deeper and longer after abstinence for 12 h.

The variations of the data obtained from all smokers result in part from an uncertainty of ±2% within the range of 0-15% for COHb measurement with the pulse CO-oximeter [12]. High uncertainty is probably why pulse CO-oximeter is not successful for detecting COHb levels in nonsmokers exposed to second hand smoke [16]. Nicotine dependence, body size and duration of the smoke inhalation, brand of cigarettes, age, exposure to atmospheric pollution, and environmental tobacco smoke exposure are all additional factors that may cause variation of the COHb levels in smokers. Our results indicate that the degree of nicotine dependence is important factor that contributes to these variations.

Biochemical assessment of cigarette by-products in the body is often more accurate than self-reports. Thus, cotinine in plasma, saliva or urine, along with CO in expired air are most commonly used means of establishing smoking status. Smokers who participate in such studies are either told in advance that these measurements will be made or asked to provide consent and specimens "on the spot." Sometimes subjects are informed that their self-reports will be confirmed by a biochemical test, even though the researchers do not intend any biochemical verification. The specimens are collected and left unanalyzed [17] simply as a means of enhancing the cooperation of subjects to adhere to the experimental protocol.

Because preoperative abstinence from tobacco is clearly beneficial to smokers who must undergo surgery, these individuals should be encouraged to abstain during the preoperative period, with an additional goal of quitting permanently [18]. A surgical event presents the potential for a 'teachable moment.' It is an excellent opportunity to motivate the smoker to change a behavior that imposes a health risk [19]. A pulse CO-oximeter is a very convenient tool for the busy anesthesiologist and his team not only to monitor patient status during surgery but also to implement smoking-cessation behavior in the perioperative period. Smokers could be told in advance that they will be monitored for smoking abstinence from the time of admission to the surgical facility until they are released from the hospital. Testing could also confirm smoking abstinence beyond the postoperative period to follow-up visits.

Our study indicates that the pulse oximetry would be useful for monitoring smoking within the time frame of most surgical procedures and used to increase smoking abstinence during preoperative and postoperative periods. The results presented permit one to validate the use of the pulse CO-oximeter, but additional studies are needed to make conclusions on the clinical impact of

these results. The pulse Co-oximeter might also be used for validation of self-reported smoking during various surveys [20], especially under conditions expected to influence the participants' willingness to admit smoking.

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