Research report: Charcoal type used for hookah smoking influences CO production

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ABSTRACT

A hookah smoker who was treated for severe carbon monoxide poisoning with hyperbaric oxygen reported using a different type of charcoal prior to hospital admission, i.e., quick-light charcoal. This finding led to a study aimed at determining whether CO production differs between charcoals commonly used for hookah smoking, natural and quick-light. Our hypothesis was that quick-light charcoal produces significantly more CO than natural charcoal. A medium-sized hookah, activated charcoal filter, calibrated syringe, CO gas analyzer and infrared thermometer were assembled in series. A single 9-10 g briquette of either natural or quick-light charcoal was placed atop the hookah bowl and ignited. CO output (ppm) and temperature (°C) were measured in three-minute intervals over 90 minutes. The mean CO levels produced by quick-light charcoal over 90 minutes was significantly higher (3728 ± 2028) compared to natural charcoal (1730 ± 501 ppm, $p = 0.016$). However, the temperature was significantly greater when burning natural charcoal (292 ± 87) compared to quick-light charcoal (247 ± 92 ºC, $p = 0.013$). The high levels of CO produced when using quick-light charcoals may be contributing to the increase in reported hospital admissions for severe CO poisoning.

INTRODUCTION

A 55-year-old white male with no significant medical history was admitted to the emergency department for severe CO poisoning. Prior to arrival, the patient reported chest tightness, dyspnea, severe weakness and presyncope without syncope following smoking using a hookah. Upon arrival to the emergency department approximately three hours after hookah use, his carboxyhemoglobin (HbCO) was 29%. He was transferred to Duke University Medical Center for hyperbaric oxygen (HBO_2) therapy.

Neurological deficits were identified prior to HBO_2, including mild dysmetria, Romberg sign, tandem gait unsteadiness, calculation difficulties, asymmetrical clock drawing and short-term memory impairment. Following two treatments of HBO_2 (seven hours following hookah and the next day), the patient's neurological symptoms resolved. The patient reported smoking hookah for years, but tried a different type of charcoal (quick-light) for the first time the day he was admitted to the hospital for severe CO poisoning.

The water pipe (hookah) has been a method of smoking tobacco for more than four centuries [1]. The number of hookah lounges and users has increased over the past decade, particularly in major cities and near universities [2,3]. One reason for increased hookah smoking is the perception that it is safer than cigarette smoking and/or other forms of tobacco [4,5]. However, users may not realize that they are being exposed to very high levels of polyaromatic hydrocarbons, nicotine and carbon monoxide (CO) [6,7].

During a hookah smoking session, charcoals are ignited to burn the tobacco. The charcoals can, by themselves, produce a significant amount of CO [8]. The amount of exhaled CO can range from 28.7 ppm to 38.5 ppm when hookah smoking [9-11], exceeding

KEYWORDS: hookah smoking, carbon monoxide poisoning, hypercapnia, hypoxia

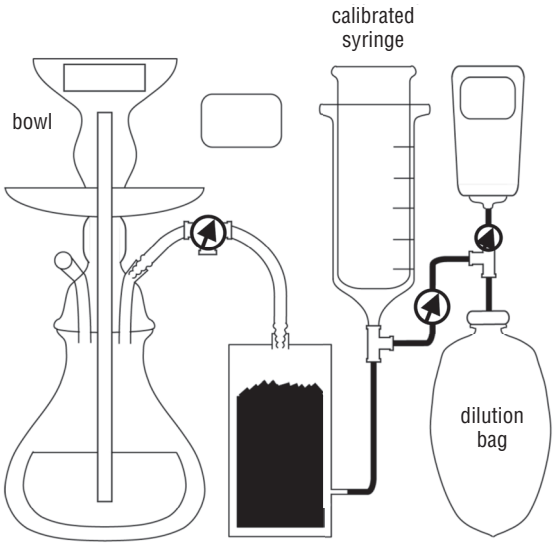

Figure 1. Medium-sized hookah assembly. A water pipe hose is attached to an activated charcoal filter, and a single charcoal briquette (natural or quick-light) is placed atop a bowl and ignited. The hookah smoke was collected with a 3-L calibrated syringe, diluted with air and equilibrated in a 3-L dilution bag, and analyzed using a carbon monoxide meter. During hookah smoking, tobacco would be placed on the bowl and covered with perforated aluminum foil. The charcoal briquette would then be placed on the aluminum foil and ignited. The individual would then smoke from the water pipe hose.

the amount produced by cigarettes [12]. While natural charcoals have traditionally been used for hookah smoking, quick-light charcoals have increased in popularity over the past two decades [13]. Differences in CO production between natural and quick-light charcoals may explain the increase in reported cases of patients admitted to emergency departments for CO poisoning. Due to the paucity of data regarding charcoal type and CO production, we determined the amount of CO produced from natural and quick-light charcoals over 90 minutes, a typical hookah session. Our hypothesis was that quick-light charcoal produces more CO than natural charcoal.

MATERIALS AND METHODS

A semi-closed system consisting of a medium-sized hookah, an activated charcoal filter, a calibrated syringe (Hans-Rudolph 5530), a 3.0-L dilution bag and a CO gas analyzer (Bacharach Monoxor®II, New Kensington, Pennsylvania) was assembled within a fume cupboard (Figure 1). An airtight series of tubes and three-way valves connected all major components. Atop the hookah, a single 9-10 g briquette of commercially available natural or quick-light charcoal was placed onto an 18-hole perforated aluminum foil barrier and ignited.

Using a 3.0-L calibrated syringe, 600 mL of hookah smoke was withdrawn from the hookah, diluted with 2.4 L of air and equilibrated in a dilution bag. The puff topography consisted of a puff volume of 600 mL, puff duration of five seconds, and puff interval of 180 seconds, similar to that previously reported for human volunteers [22]. Dilution bag contents were analyzed by a calibrated CO gas analyzer every three minutes over a 90-minute period. Charcoal core temperatures were measured by an infrared thermometer (Cen-Tech™, Camarillo, California). Repeated measurements were conducted for both quick-light (n = 4) and natural (n = 3) charcoals. The coefficient of variation for the CO gas analyzer was 12% and 6% for the infrared thermometer.

Statistical analysis

Data were analyzed using SigmaStat version 3.5 (Systat Software, Inc., Point Richmond, California). A two-factor repeated measures ANOVA was used to compare mean differences between natural and quick-light charcoals over 90 minutes for CO and temperature. Statistical significance was set at $p < 0.05$.

RESULTS

CO production

CO production significantly changed within three minutes of ignition with both types of charcoals ($p<0.001$) (Figure 2A). The concentration of CO increased to 3469 ± 562 and 2418 ± 391 ppm, for quick-light and natural charcoal respectively. Quick-light CO concentration reached a maximum of 6424 ± 1042 ppm at 27 minutes, then declined over the remainder of the experiment. In contrast, natural charcoal CO output peaked at six minutes (2627 ± 422 ppm) and decreased thereafter. The overall mean CO concentration produced by quick-light was significantly greater than natural charcoal (3728 ± 2028 vs. 1730 ± 501 ppm) ($p = 0.016$), and over the first 63 min of the experiment ($p < 0.001$).

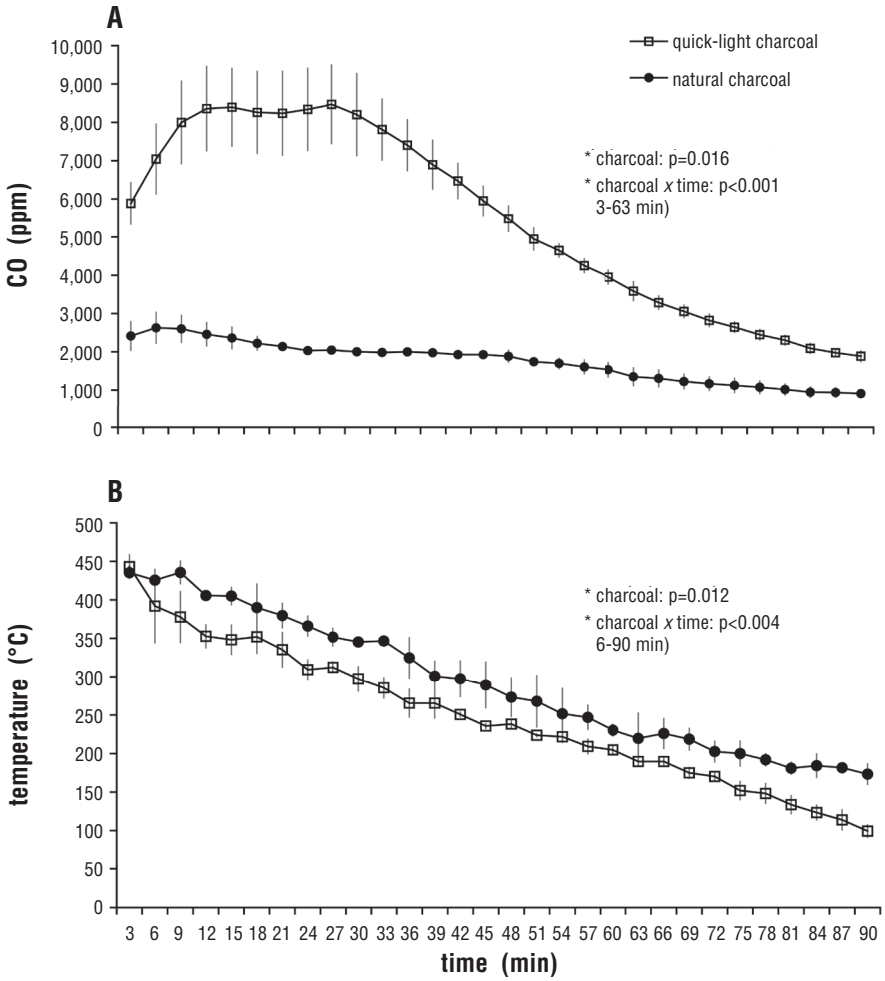

Figure 2A-2B. Carbon monoxide (CO) levels and temperature following ignition of natural and quick-light charcoals. Quick-light charcoal (open squares) produces significantly more CO than natural charcoal (filled circles) (p = 0.016) **(A)**. Natural charcoal generates significantly more heat than quick-light charcoal (p =0.012) **(B)**. Values are mean ± SD.

Temperature

Combustion temperature of the charcoals was highest immediately following ignition: quick-light (443 ± 16 ºC) and natural (435 ± 7 ºC), with both significantly declining thereafter ($p < 0.001$) (Figure 2B). The mean combustion temperature of natural charcoal was significantly greater than quick-light charcoal. This difference persisted from six minutes after ignition until the conclusion of the experiment (292 ± 87 vs. 247 ± 92 ºC, $p = 0.013$).

DISCUSSION

An estimated 100 million people worldwide smoke hookah [7], with the most harmful side effect (acute) being CO poisoning. Unfortunately, CO toxicity is seldom a concern of hookah users or health care providers. CO avidly binds to hemeproteins (e.g., hemoglobin, myoglobin and cytochrome a,a3), resulting in cellular dysfunction and death when levels are increased [14,15]. Severe CO poisoning produces symptoms of light-headedness, dyspnea, chest pain, confusion and loss of consciousness, with HBO_2 being the appropriate treatment.

While hookah has been used worldwide for several centuries, there has been an increase in the reported cases of hookah smokers admitted to the emergency department for severe CO poisoning (Table 1). This disturbing trend has led to several hypotheses for the cause:

Table 1

Reported cases of patients presenting to the hospital for hookah related carbon monoxide poisoning

Reference	Age (yrs)	Gender	COHb (%)	LOC	HBO_2	Country
Al-Moamary et al., 2000 (22)	n/a	n/a	30.0	n/a	n/a	Saudi Arabia
Levant et al., 2006 (23)	n/a	n/a	20.8	n/a	n/a	France
Lim et al., 2009 (24)	19	M	27.8	no	no	Singapore
Uyanik et al., 2009 (25)	25	M	28.7	no	no	Turkey
Cavus et al., 2010 (26)	25	M	31.1	yes	no	Turkey
La Fauci et al., 2012 (27)	16	F	24.0	yes	yes	Israel
Turkmen et al., 2011 (28)	21	M	26.0	no	no	Turkey
	20	F	27.5	yes	no	Turkey
Höjer et al., 2011 (29)	15	F	21.0	yes	no	Sweden
	28	M	32.0	yes	yes	Sweden
	16	M	23.7	no	no	Sweden
Clarke et al., 2012 (30)	30	M	15.0	no	no	UK
	34	M	21.0	no	no	UK
	38	M	18.0	no	no	UK
	26	M	20.0	no	no	UK
	21	F	18.0	no	no	UK
	21	F	7.3	no	no	UK
	31	M	23.0	no	no	UK
	19	F	2.0	no	no	UK
	22	F	14.0	no	no	UK
	17	F	12.0	no	no	UK
	18	M	25.0	no	no	UK
	22	F	15.0	no	no	UK
Ashurst et al., 2012 (31)	21	M	15.3	yes	no	USA
Karaca et al., 2013 (32)	20	F	31.1	yes	no	Turkey
Ozkan et al., 2013 (33)	19	M	32.7	yes	no	Turkey
Misek et al., 2014 (34)	24	M	33.8	yes	yes	USA
Case reported herein	55	M	29.0	no	yes	USA

Of the 27 reported hookah related carbon monoxide (CO) poisoning cases requiring hospital care, only four were treated with hyperbaric oxygen (HBO_2) therapy. The mean age of the patients was 23.7 ± 10.3 years, and the mean HbCO was 21.4 ± 8.2%. LOC, loss of consciousness; n/a, data not available.

1. a higher CO concentration compared to cigarettes due to incomplete combustion of tobacco and embers [9,16];
2. a larger puff volume due to a lower, more comfortable smoke temperature [16]; or
3. differences in puff topography among young adults in the Western world compared to traditional users in the Middle East [17].

Interestingly, charcoal type has not been considered as a potential cause of increased CO production.

The results from this study show that quick-light charcoal produces more than twice as much CO as natural charcoal. In the present investigation, the CO produced by natural charcoal peaked within six minutes of ignition, followed by a linear decrease, whereas CO produced by quick-light charcoal was sustained for 20-30 minutes prior to decreasing at a similar rate. Since the objective was to specifically determine the CO produced from combustion of the two types of commonly used charcoals, tobacco was not used. During hookah smoking, a charcoal briquette is ignited on top of perforated aluminum that covers the tobacco. If tobacco was used, the concentration of CO would likely have been substantially higher [7]. Although we are unaware of any hookah-related fatalities, if the CO produced from the quick-light charcoals used in this study were sustained, the exposure would have been considered lethal [18].

The combustion core temperature was higher with natural charcoal compared to quick-light charcoal. An increased temperature may facilitate complete combustion and thus produce significantly less CO. While temperature cannot be excluded as contributing to the increased levels of CO when burning quick-light charcoal, it is unlikely that this was the sole reason, as the rate of decline was similar between the two charcoal types. A more plausible explanation is the charcoal material. Charcoal manufacturers are not required to provide product information regarding composition or safety [19,20]; thus the material of both charcoals used in this study are unknown. In general, quick-light charcoals contain powdered coal, various metal oxides and organic matter dry-pressed into a briquette that is easier to ignite than natural charcoals, which are lump pieces of wood or coconut prepared by burning hard wood under oxygen-deficient conditions [21]. While these two commercial charcoals are the most commonly used, we acknowledge that other types of charcoals exist and may also produce different CO levels than those determined for natural and quick-light charcoals.

To our knowledge this is the first study that has considered whether the two most commonly used commercially available charcoals (natural and quick-light) produce different levels of CO upon ignition. The results from this study reveal that quick-light charcoals produce significantly more CO than the traditional natural charcoal type over 90 minutes; however, we acknowledge that only one brand of quick-light charcoal was used herein and may not reflect CO production by all quick-light charcoals. Given the dramatic increase in the reported cases of severe hookah-related CO poisoning in the past five years, the use of quick-light charcoal may be a contributing factor. Hookah smokers who use quick-light charcoals are exposed to dangerously high CO levels that may result in severe CO poisoning requiring urgent medical care and HBO_2 treatment, as reported herein. Healthcare providers should, therefore, be aware of the potential harmful consequences of hookah smoking.

Conflict of interest

The authors report no conflict of interest with this submission. ■

REFERENCES

1. World Health Organization Study Group on Tobacco Product Regulation. Waterpipe tobacco smoking: health effects, research needs and recommended actions by regulators. Geneva, CH: WHO, 2005.

2. Sutfin EL, McCoy TP, Reboussin BA, Wagoner KG, Spangler J, Wolfson M. Prevalence and correlates of waterpipe tobacco smoking by college students in North Carolina. Drug Alcohol Depend 2011;115(1-2): 131-136.

3. Primack BA, Shensa A, Kim KH, et al. Waterpipe smoking among U.S. university students. Nicotine Tob Res 2013;15(1): 29-35.

4. Martinasek MP, McDermott RJ, Martini L. Waterpipe (hookah) tobacco smoking among youth. Curr Probl Pediatr Adolesc Health Care 2011;41(2): 34-57.

5. Akl EA, Gaddam S, Gunukula SK, Honeine R, Jaoude PA, Irani J. The effects of waterpipe tobacco smoking on health outcomes: a systematic review. Int J Epidemiol 2010;39(3): 834-857.

6. Shihadeh A, Saleh R. Polycyclic aromatic hydrocarbons, carbon monoxide, "tar", and nicotine in the mainstream smoke aerosol of the narghile water pipe. Food Chem Toxicol 2005;43(5): 655-661.

7. Jacob P 3rd, Abu Raddaha AH, Dempsey D, et al. Comparison of nicotine and carcinogen exposure with water pipe and cigarette smoking. Cancer Epidemiol Biomarkers Prev 2013;22(5): 765-772.

8. Monzer B, Sepetdjian E, Saliba N, Shihadeh A. Charcoal emissions as a source of CO and carcinogenic PAH in mainstream narghile waterpipe smoke. Food Chem Toxicol 2008;46(9): 2991-2995.

9. Eissenberg T, Shihadeh A. Waterpipe tobacco and cigarette smoking: direct comparison of toxicant exposure. Am J Prev Med 2009;37(6): 518-523.

10. Bacha ZA, Salameh P, Waked M. Saliva cotinine and exhaled carbon monoxide levels in natural environment waterpipe smokers. Inhal Toxicol 2007;19(9): 771-777.

11. Barnett TE, Curbow BA, Soule EK, Jr., Tomar SL, Thombs DL. Carbon monoxide levels among patrons of hookah cafes. Am J Prev Med 2011;40(3): 324-328.

12. Daher N, Saleh R, Jaroudi E, et al. Comparison of carcinogen, carbon monoxide, and ultrafine particle emissions from narghile waterpipe and cigarette smoking: Sidestream smoke measurements and assessment of second-hand smoke emission factors. Atmospheric Environment 2010;44(1): 8-14.

13. Chaouachi K. The medical consequences of narghile (hookah, shisha) use in the world. Revue d'Epidemiologie et de Sante Publique 2007;55(3): 165-170.

14. Hampson NB, Piantadosi CA, Thom SR, Weaver LK. Practice recommendations in the diagnosis, management, and prevention of carbon monoxide poisoning. Am J Respir Crit Care Med 2012;186: 1095-101.

15. Weaver LK. Hyperbaric oxygen therapy for carbon monoxide poisoning. Undersea Hyperb Med 2014;41: 339-354.

16. Theron A, Schultz C, Ker JA, Falzone N. Carboxyhaemoglobin levels in water-pipe and cigarette smokers. S Afr Med J 2010;100(2): 122-124.

17. Smith-Simone S, Maziak W, Ward KD, Eissenberg T. Waterpipe tobacco smoking: knowledge, attitudes, beliefs, and behavior in two U.S. samples. Nicotine Tob Res 2008; 10(2): 393-398.

18. The National Institute for Occupational Safety. Carbon monoxide. Immediately Dangerous to Life or Health Concentrations. Available at: http://www.cdc.gov/niosh/idh/630080.html. Accessed Mar 15, 2014.

19. U.S. Food and Drug Administration. Product requirements, marketing and labeling. Available at: http://www.fda.gov/TobaccoProducts/Labeling/default.htm. Accessed Mar 1, 2014.

20. McCarthy M. FDA moves to regulate e-cigarettes and pipe and hookah tobacco. BMJ 2014;348: g2952.

21. Sajid KM, Akhter M, Malik GQ. Carbon monoxide fractions in cigarette and hookah (hubble bubble) smoke. J Pak Med Assoc 1993;43(9): 179-182.

22. Al-Moamary MS, Al-Shammary AS, Al-Shimemeri AA, Ali MM, Al-Jahdali HH, Awada AA. Complications of carbon monoxide poisoning. Saudi Med J 2000;21(4): 361-363.

23. Levant ACC, Genestal M. Acute CO poisoning after smoking narghile. In: Journee de Tabacologie 2006: 22e.

24. Lim BL, Lim GH, Seow E. Case of carbon monoxide poisoning after smoking shisha. Int J Emerg Med 2009;2(2): 121-122..

25. Uyanik B, Arslan ED, Akay H, Ercelik E, Tez M. Narghile (hookah) smoking and carboxyhemoglobin levels. J Emerg Med 2011;40(6): 679.

26. Cavus UY, Rehber ZH, Ozeke O, Ilkay E. Carbon monoxide poisoning associated with narghile use. EMJ 2010;27(5): 406.

27. La Fauci G, Weiser G, Steiner IP, Shavit I. Carbon monoxide poisoning in narghile (water pipe) tobacco smokers. CJEM 2012;14(1): 57-59.

28. Turkmen S, Eryigit U, Sahin A, Yeniocak S, Turedi S. Carbon monoxide poisoning associated with water pipe smoking. Clin Toxicol (Phila) 2011;49(7): 697-698.

29. Hojer J, Enghag M. Carbon monoxide poisoning caused by water pipe smoking. Clinical Toxicol (Phila) 2011;49: 702-703.

30. Clarke SF, Stephens C, Farhan M, et al. Multiple patients with carbon monoxide toxicity from water-pipe smoking. Prehosp Disaster Med 2012;27(6): 612-614.

31. Ashurst JV, Urquhart M, Cook MD. Carbon monoxide poisoning secondary to hookah smoking. J Am Osteopath Assoc 2012;112(10): 686-688.

32. Karaca Y, Eryigit U, Aksut N, Turkmen S. Syncope associated with water pipe smoking. BMJ Case Rep 2013: pii: bcr2013009526.

33. Ozkan S, Ozturk T, Ozmen Y, Durukan P. Syncope associated with carbon monoxide poisoning due to narghile smoking. Case Rep Emerg Med 2013: 796857.

34. Misek R, Patte C. Carbon monoxide toxicity after lighting coals at a hookah bar. World Health Organization Study Group on Tobacco Product Regulation. Waterpipe tobacco smoking: health effects, research needs and recommended actions by regulators. Geneva, CH: WHO, 2005.

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