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"Crack Smoke" is a Respirable Aerosol of Cocaine Base[1]

CARROLL A. SNYDER, RONALD W. WOOD,[2] JOHN F. GRAEFE, ALAN BOWERS AND KENNETH MAGAR

Department of Environmental Medicine, New York University Medical Center, New York, NY 10016

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SNYDER, C. A., R. W. WOOD, J. F. GRAEFE, A. BOWERS AND K. MAGAR. *"Crack smoke" is a respirable aerosol of cocaine base.* PHARMACOL BIOCHEM BEHAV 29(1) 93–95, 1988.—The smoking of cocaine carbonate ("crack") has emerged as a significant substance abuse problem. A detailed characterization of cocaine smoke is a prerequisite for studies of its pharmacokinetics, abuse potential and toxicity. Model pipes were used to generate cocaine smoke analogous to that inhaled by human "crack" abusers. Using procedures to minimize pyrolysis, cocaine base smoke was determined to be 93.5% cocaine particles with the remainder being cocaine vapor. The average particle size generated from all model pipes was 2.3 μ which is small enough to ensure deposition into the alveolar region of the human lung. Although this particle size is eminently respirable by primates, a much smaller fraction will reach the alveolar region of rodents. Special generating procedures would therefore be required to expose rodents to meaningful doses of airborne cocaine that mimic the rapid absorption achieved by "crack" smokers.

Cocaine smoking "Crack" Aerosol inhalation

THE self-administration of cocaine ("crack") by smoking has recently emerged as a significant substance abuse problem. Cocaine carbonate is placed in a pipe and heated, releasing carbon dioxide and free cocaine base. Because this is a new method for the self-administration of cocaine, there have been very few studies concerning the characterization of cocaine smoke. Although there have been some reports of the pyrolysis products generated by excessive heating of cocaine [1,7], to our knowledge there have been no studies of the aerosol characteristics of cocaine smoke.

We have performed a number of experiments to characterize the effluent emanating from glass pipes similar to those employed by "crack" users. Using a variety of pipe configurations, air flow rates, and burning techniques, we have characterized the particle sizes of cocaine smoke and determined the relative amounts of particle and vapor therein.

METHOD

The generic apparatus used to characterize the particle sizes contained in cocaine smoke consisted of simulated glass pipes of varying configurations attached to a Casella cascade impactor (BGI Inc., Waltham, MA). A diaphragm pump attached to the impactor provided a constant, prescribed rate of air flow from a given glass pipe through the impactor. A 50 ml round bottom flask was used to examine the product when flame was not in direct contact with the drug. The flask was fitted with two glass tubes. A one-way valve was attached to one tube and the cascade impactor was attached to the other. Powdered cocaine base was placed in the flask and melted by heating the flask with a Bunsen burner. Airborne cocaine was generated by passing air over the surface of the molten cocaine.

In order to more closely reproduce the paraphernalia used by "crack" abusers, simulated glass pipes were constructed. These consisted of glass bowls with diameters of either 3.5 cm or 5.5 cm attached via right angled glass bends to glass stems. Two glass stems were used. One had an interior diameter of 20 mm and a length of 10 cm while the other had an interior diameter of 7 mm and a length of 12 cm. In one set of experiments, no stem was used; rather the effluent from the glass bowl was routed directly into the impactor. The combinations of bowl sizes and stem sizes used in the experiments are shown in Table 1. Two stainless steel wire mesh screens were placed in the bowls to provide a stationary support for the cocaine. Cocaine smoke was generated by heating cocaine base (in either powder or crystalline form) directly with a Bunsen burner or butane torch. Care was taken during heating to minimize charring. Pipes were charged with 25 mg to 50 mg of cocaine.

The Casella cascade impactor consists of a series of progressively narrower slits in close opposition to microscope slides. The slits are arranged such that air flows through a series of 90° bends. Particles in an airstream will not bend corners above a critical velocity that is a function of particle size. Particles that cannot follow the airstream impact on the microscope slide. Those that do not impact are drawn through the subsequent slits at progressively higher veloci-

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[2]Requests for reprints should be addressed to Ronald W. Wood, Department of Environmental Medicine, New York University Medical Center, 550 First Avenue, New York, NY 10016.

TABLE 1

MASS MEDIAN AERODYNAMIC DIAMETERS (MMAD) AND GEOMETRIC STANDARD DEVIATIONS (σ_g) OF COCAINE SMOKE AEROSOLS GENERATED WITH SIMULATED CRACK PIPES

Pipe Configuration	Flow Rate		Replications 1	2	3	4
50 ml round bottom flask	14 lpm	MMAD	2.30	2.32		
		σ_g	1.68	1.69		
3.5 cm bowl 10 cm stem	14 lpm	MMAD	2.35	2.16		
		σ_g	1.92	2.22		
3.5 cm bowl No stem	14 lpm	MMAD	2.58	2.87	2.13	2.34
		σ_g	1.94	1.87	2.23	1.97
5.5 cm bowl 12 cm stem	14 lpm	MMAD	2.05	2.32		
		σ_g	1.80	1.81		
3.5 cm bowl No stem	7 lpm	MMAD	3.61	3.80	3.16	3.20
		σ_g	1.95	1.86	1.95	2.09

ties and momentum (constant flow rate, narrower slits) and impact on subsequent slides. A final filter traps any extremely small particles. Cascade impactors are calibrated with aerosols containing latex beads of uniform size.

Flow rates through the impactor were selected at 14 liters per min (lpm) and 7 lpm. Seven lpm corresponds to the resting minute ventilation rate for men [2], while 14 lpm was used to simulate the somewhat higher flow rates that occur during "crack" self-administration. Airborne cocaine samples were drawn through the impactor for two min.

The amount of cocaine deposited on the various stages of the cascade impactor was determined by dissolving the collected cocaine samples in ethanol and determining the absorbances of the resulting solutions in an ultraviolet spectrophotometer at a wavelength of 230 nm. These absorbances were compared to those of a previously prepared calibration curve. Aerodynamic mass median diameters of the particle samples were calculated from these measurements [4,6].

Ratios of cocaine vapor to cocaine particulate were determined by first passing the effluent smoke through a Whatman #1 filter and then through two tandem midget impingers charged with 10 ml of ethanol. Corrections for the efficiencies of collection by the impingers were made for each determination. The filter collected the particulates while the impingers collected vapor passing through the filter. The amounts of cocaine collected by the filter and the impingers were analyzed by u.v. spectroscopy as described above. Flow rates for these determinations were 7 lpm. Under these conditions the efficiency of collection of the Whatman #1 filter is better than 95% for particles of size $\geq 0.3\ \mu$ [5].

RESULTS

The generating conditions and resultant particle sizes are presented in detail in Table 1. At 14 lpm, regardless of pipe configuration, the mass median aerodynamic diameters (MMAD) of cocaine particles ranged only from 2.05 μ to 2.87 μ, while the geometric standard deviation of these particles ranged only from 1.68 μm to 2.22 μm. At 7 lpm the particle sizes were larger (3.16 μm to 3.8 μm).

Four determinations were made of the distribution of cocaine particulate and cocaine vapor in effluent smoke. The mean percentage of cocaine (±SD) retained by the filters in these experiments was 93.5±3.5%, indicating that most of the cocaine smoke generated in the pipes was particulate rather than vapor.

DISCUSSION

These studies demonstrate that the particulate size of cocaine generated by "crack" pipes is eminently respirable by humans. Particles with the determined distributions in aerodynamic size will deposit mainly in the alveolar region of the human respiratory tract during oral breathing [11]. Moreover, it appears that the particle size is a function of the flow rate of air through the pipe, but is not a function of its size or configuration. Although reducing the flow rate increased particle size, particles with the larger determined aerodynamic size will still deposit mainly in the alveolar region of the human respiratory tract during oral breathing. This is particularly noteworthy because in our determinations we observed that 93.5% of the cocaine effluent from a "crack" pipe was particulate, while only 6.5% was cocaine vapor.

Cocaine smoking has emerged as a significant substance abuse problem. The major obstacle which has limited the growth of an experimental literature on this substance abuse practice is the challenge offered by the development of technologies for generating defined and reproducible test atmospheres upon demand and appropriate for the test species. The particle size distributions obtained in the present study are suitable for inhalation studies with primates. Because the rat is an obligate nose breather with extremely efficient nasal filtration [9,11], particles representing 90% of the mass in our distribution are too large to pass beyond the upper respiratory tract of the rat and achieve alveolar deposition. When cocaine hydrochloride is applied to human nasal mucosa, peak blood levels are obtained 15 to 60 minutes after application [3,12], and maximum heart rate changes are observed in 15 to 25 minutes [3,10]. Following a single smoking episode, the rapid changes in plasma levels resemble those following intravenous administration [1]. Intravenous administration produces peak levels in approximately 5 minutes [1]; a 20% increase in heart rate accompanies the peak "high" that occurs 6–8 minutes after injection or smoking, with peak heart rate occurring at 12 minutes [8]. A comparison of the acute intravenous and intranasal effects of cocaine in man indicates that the intranasal route is associated with a shift to the right of the dose-effect function, and a more prolonged onset of acute effects [3]. Thus, because most of the particles comprising typical cocaine smoke are likely to deposit in the nose of rodents, rodent studies will probably require small particle or vapor generation systems tailored to achieve biologically effective test atmospheres that achieve more efficient dosing of the deep lung and that produce a time course of blood concentrations mimicking the rapid absorption achieved by human "crack" smokers. Any test atmosphere generator will have to produce atmospheres upon demand that have both constant particle size distributions and constant concentration; systems for primate experiments will have to do so on a larger scale. When test atmosphere technologies appropriate to the selected species are implemented and characterized, it will be possible to identify characteristic actions of cocaine which are unique to the inhalation route, and to identify aspects of cocaine self-administration which can be generalized across routes of administration.

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