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Aerosol Evaluations of the DeVilbiss No. 40 and Vaponefrin Nebulizers

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DeVilbiss no. 40 and Vaponefrin standard nebulizers produced aerosols of small particles suitable for deep pulmonary vaccination and therapy of respiratory infections in man and animals.

A comprehensive review by Hatch and Gross (2) has indicated that aerosol particles in the aerodynamic size range of about 0.5 to 3.0 μm in diameter will in large part be deposited in lung alveoli of man and various species of animals. Particles larger than about 5 μm will impinge on the mucous membranes of the upper airways. The current interest in aerosol vaccination against (7, 9), and therapy (R. F. Berendt, G. G. Long, and J. S. Walker, Prog. Abstr. Intersci. Conf. Antimicrob. Agents Chemother., 14th, San Francisco, Abstr. 176, 1974; 8) of, respiratory infections prompted us to evaluate four inexpensive nebulizers on the basis of aerosol particle size and total output.

In a first experiment a glass DeVilbiss no. 40 (DeVilbiss Corp., Somerset, Pa.) and a glass Vaponefrin standard nebulizer were tested. When it was determined that the glass Vaponefrin device was no longer marketed, a second experiment was conducted to evaluate two plastic Vaponefrin standard nebulizers (Fison's Corp., Bedford, Mass.) of design similar to the glass unit.

The aerosol trials were performed in a Henderson apparatus (3), modified by the incorporation of an animal exposure box (6). The DeVilbiss was operated at 20 lb/in² (gauge) with laboratory compressed air; the Vaponefrin devices were operated at 10 lb/in². Total flow in the aerosol system was 28 liters/min, including both the air flowing through the nebulizer and supplementary laboratory air. Operating pressures were selected on the basis of available literature (5) and visual performance when disseminating water. The nebulizers were charged with 5.0 ml of liquid and were operated for 8 min in each trial.

Heart infusion broth and undiluted allantoic fluid, harvested from uninfected 10-day-old embryonated chicken eggs, were aerosolized. Sodium fluorescein dye (Fisher Scientific Co., Uranine) at a concentration of 0.2% (wt/vol) was added as a mass physical tracer. Aerosol particle size distributions were determined with single-stage impactors (4); total aerosol concentrations were measured by using all-glass impinger samplers (1). Dye concentrations were measured with a fluorophotometer (Photovolt, model 54, Photovolt Corp., N.Y.). Among 32 trials consisting of 4 replicates with each nebulizer and fluid combination, the relative humidity levels within the aerosol system ranged from 30 to 60%; dry-bulb temperatures were from 24 to 27 C.

Mass median diameters (MMD) and geometric standard deviations were computed from the single-stage impactor results with the all-glass impinger results providing measures of total airborne material. The MMD represents the particle diameter associated with 50% of the airborne mass; one-half of the mass was in particles of smaller size, one-half was in particles of larger size. The geometric standard deviation provides a measure of distributional spread with 68% of the aerosol mass, from the 16th through the 84th percentiles of the distribution, contained in particle sizes bounded by the diameters given by the quotient and product, respectively, of the MMD and geometric standard deviation. In addition, the percentages of the total airborne mass contained in particles less than 5 μm in diameter were computed.

The total aerosol concentrations obtained with the DeVilbiss were slightly more than threefold those obtained with the glass Vaponefrin device (Table 1). The DeVilbiss nebulizer used 16.2 liters of compressed air/min compared to 5.6 liters/min with the glass Vaponefrin. The average liquid use rate, including evaporative losses and conversion of liquid to aerosol, was 0.33 ml/min by the DeVilbiss nebulizer, only slightly less than three times that of 0.12 ml/min by the Vaponefirn. The glass Vaponefrin produced aerosols of consistently lower MMD than the DeVilbiss. By analysis of

TABLE 1. *Particle sizes and aerosol concentrations with DeVilbiss no. 40 and Vaponefrin standard nebulizers disseminating fluorescein dye in HIB and AF*[a]

Test fluid	Nebulizer	Evaluation parameters			
		Aerosol concn (μg of dye/liter of aerosol)	MMD (μm)	GSD	% Mass <5 μm
		Expt 1			
HIB	DeVilbiss no. 40	20.08	2.30	2.22	84
	Vaponefrin (glass)	6.97	1.79	1.85	95
AF	DeVilbiss no. 40	21.68	2.11	2.12	87
	Vaponefrin (glass)	6.04	1.59	2.12	94
		Expt 2			
HIB	Vaponefrin no. 1 (plastic)	13.86	2.36	1.92	87
	Vaponefrin no. 2 (plastic)	13.35	2.40	1.99	86
AF	Vaponefrin no. 1 (plastic)	13.36	2.04	1.77	94
	Vaponefrin no. 2 (plastic)	13.94	2.21	1.89	90

[a] HIB, Heart infusion broth; AF, allantoic fluid; MMD, mass median diameter; GSD, geometric standard deviation.

variance the difference was significant at $P < 0.05$.

The plastic Vaponefrin devices yielded very similar results when compared to each other. The total aerosol concentrations were intermediate between the low of the glass Vaponefrin and the high of the DeVilbiss. MMD values were similar to those measured with the DeVilbiss and higher than those with the glass Vaponefrin. These observations were consistent with a liquid use rate of 0.28 ml/min and compressed air-flow rates of 6.6 to 6.9 liters/min.

Similar results were obtained with heart infusion broth and allantoic fluid regardless of the nebulizer employed. A mean geometric standard deviation of 2.0 with both test fluids and all nebulizers indicated that the aerosols were relatively heterogeneous with 68% of the aerosol mass contained in particles in the range from approximately 1.0 to 4.2 μm in diameter. Among all of the experimental treatments, between 84 and 95% of the airborne mass was contained in particles <5 μm in diameter.

In summary, we have measured the aerosol performance characertistics of a series of inexpensive, and with one exception, readily available liquid nebulizers under laboratory test conditions. Whereas the nebulizers produced aerosols which were relatively heterogeneous, the particle sizes were within a range that would be expected to deposit with reasonable efficiencies in the lung alveoli of man and experimental animals.

Any of the nebulizers could be used in respiratory disease investigations when alveolar exposures are required but when the circumstances do not demand exclusive deposition in the lungs. It would not be unreasonable, also, for the clinician concerned with presenting aerosols to patients to adapt these devices for continuous aerosol administration of antimicrobial or chemotherapeutic agents.

Glass nebulizers which can be autoclaved and reused would appear to have the advantage of eliminating the potential for device-to-device variability. Plastic devices have a disadvantage in this respect unless the application does not require sterilization or nondestructive sterilizing procedures can be employed. Under critical circumstances requiring precise estimates of performance, it would be advisable to calibrate the nebulizer of choice using a test fluid that is physically similar to the fluid of interest. Although our studies showed no differences between heart infusion broth and allantoic fluid, one can expect dissemination performance to depend to some extent upon fluid properties such as solute and total solids concentrations, surface tension, and viscosity.

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