Comparison of Collison and DeVilbiss 65 Nebulizers in the Generation of Aerosols for Respiratory Disease Studies

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ABSTRACT

An electronic particle counting instrument was used to compare aerosols of minimal essential medium and brain heart infusion broth containing 5% fetal bovine serum generated by Collison and DeVilbiss 65 nebulizers. The median diameter of Collison particles was approximately one half (0.8 μm) that of DeVilbiss particles (1.8 μm) at DeVilbiss settings of 3.5, 5.0, 7.0 or 10.0. The average DeVilbiss particle output per minute at these settings (5.0×10^6) was significantly greater ($p < 0.01$) than for the Collison (4.0×10^6). Settings below 3.5 produced erratic total output and particle size. More particles were produced by the DeVilbiss from minimal essential medium than from brain heart infusion broth containing 5% fetal bovine serum at a setting of 2.0, whereas median particle size and total output did not vary appreciably between media at settings of 3.5 or greater.

Because of these variations, it is suggested that the output characteristics of nebulizers be specified in reports of experimental respiratory disease studies using aerosols.

RÉSUMÉ

Cette expérience consistait à utiliser un instrument électronique, capable d'enregistrer le nombre de particules, pour comparer les aérosols engendrés par des pulvérisateurs Collison et DeVilbiss 65, à partir du milieu d'Eagle et d'une infusion de coeur et de cerveau, enrichie de 5% de sérum de foetus de veau. Le diamètre moyen des particules engendrées par les pulvérisateurs Collison atteignit 0.8 μm, i.e. environ la moitié de celui des particules engendrées par le pulvérisateur DeVilbiss, lequel atteignit 1,8 μm, quand on réglait le rhéostat aux points suivants: 3,5; 5,0; 7,0 et 10. Le débit moyen de particules engendrées par le pulvérisateur DeVilbiss, à ces points de réglage, atteignit $5,0 \times 10^6$ à la minute et s'avéra sensiblement plus élevé ($p < 0,01$) que celui des appareils Collison, lequel s'élevait à $4,0 \times 10^6$. Les points de réglage inférieurs à 3,5 produisirent un débit total erratique et des particules de dimensions irrégulières. Le pulvérisateur DeVilbiss produisit plus de particules à partir du milieu d'Eagle qu'à partir de l'infusion de coeur et de cerveau, au point de réglage 2,0; par ailleurs, les dimensions moyennes des particules et le débit total ne varièrent pas de façon appréciable, indépendamment du milieu, quand on réglait le rhéostat à 3,5 ou plus haut.

À cause de ces variations, les auteurs suggèrent de mentionner les caractéristiques du débit des pulvérisateurs, dans les rapports relatifs aux expériences sur les maladies respiratoires qui impliquent l'utilisation d'aérosols.

INTRODUCTION

Numerous methods and types of apparatus can be used to generate aerosols for experimental and therapeutic inhalation purposes (1). The choice of a particular instrument is often a function of availability and precedent in a particular laboratory or line of investigation. This creates difficulties in comparing and evaluating results. The purpose of this investigation was to determine and compare the particle size and total particle output per minute of two commonly used nebulizers.

MATERIALS AND METHODS

NEBULIZERS

Collison — This instrument, named after its inventor, has been described in detail (6). It is based on the principle that the expansion of a jet of compressed gas draws fluid from a glass reservoir, and disperses it into droplets. The smallest of these (less than 1% (9)) then escape in the spent compressed gas flow. Two collison nebulizers, manufactured locally,[1]

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were used in this study. Purified compressed nitrogen[2] at 26 psi was used as the gas source. This instrument does not have variable settings.

DeVilbiss 65 — This is an ultrasonic nebulizer manufactured for aerosol treatment of human respiratory conditions. The manufacturer[3] does not supply specific product information on particle size or rate of aerosol generation. Mechanical oscillations produced by an electrical current are transmitted through a water bath to a plastic membrane which comprises the base of a reservoir. Vibration of this membrane agitates the fluid medium inside the reservoir, creating an aerosol (9) which is then dispersed in room air drawn through by a fan. This nebulizer has a dial with settings of one to ten.

MEDIA USED FOR AEROSOL PRODUCTION

Eagle's minimal essential medium containing antibacterial agents (MEM) and brain heart infusion broth with 5% fetal bovine serum added (BHI), as used in standard microbiological procedures, were compared. A constant amount of an inert antifoaming agent[4] was added to both media.

PARTICLE MEASUREMENT

The diameter and total numbers of particles were determined with a photoelectric measuring device[5] positioned so that the aerosol was sampled approximately 1.7 m from the nebulizer under study. This instrument counts the numbers of particles in various size ranges over a given time interval. The particles under study cause scattering of a light beam which is measured by a photometer, the amount of scatter being proportional to the particle diameter. The percentage of particles within each size range, total particle count and median particle size were calculated.

EXPERIMENTAL DESIGN AND DATA ANALYSIS

Three replicates using each of the two Collison nebulizers and five arbitrarily selected DeVilbiss settings (2.0, 3.5, 5.0, 7.0 10.0) with the two media were carried out. Each observation was repeated three times on one occasion (replicate 1). On a second occasion replicates 2 and 3 were done; three observations per replicate were again done in each category except as noted in Table I.

Analyses of variance (7) were carried out on data for the aforementioned variables with the statistical model including effects due to replication, nebulizer-setting treatments, media and the interaction of treatments with media.

RESULTS

Summaries and graphs of the data for total particles released per minute and their median diameters are given in Table I and Figs. 1 and 2.

Analyses of variance indicated significant ($p < 0.01$) effects of nebulizer-setting and significant interactions among the nebulizer-setting and medium factors for: total particles per minute, median diameter, and the percentage of total particles less than 1 μm in diameter. When data for the Collisons were omitted from the analyses, a significant ($p < 0.01$) nebulizer-setting and medium interaction was evident only for total particles per minute.

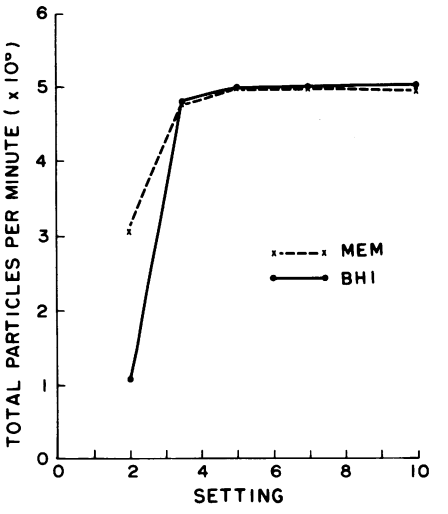

Fig. 1. Effect of DeVilbiss setting on total particles generated per minute from MEM and BHI media.

Total Particles Produced Per Minute — At the lowest setting used (2.0) the DeVilbiss nebulizer generated the fewest particles and the output using BHI was significantly ($p < 0.01$) less than for MEM (Table I, Fig. 1). The number of particles increased sharply and levelled off, averaging approximately 5.0×10^6/min, at settings higher than 2.0. Signifi-

TABLE I. Comparison of Performance Characteristics for Collison and DeVilbiss Nebulizers Using Two Media

Nebulizer and Setting	Total Particles ($\times 10^6$/min)		Median Diameter (μm)		% Less Than 1 μm	
	BHI[a]	MEM[b]	BHI	MEM	BHI	MEM
Collison #1	4.385	3.916	0.996	0.675	53.2	76.7
Collison #2	4.125[c]	3.421	0.808[c]	0.646	61.7[c]	77.6
DeVilbiss, 2.0	1.179[c]	3.117[c]	0.862[c]	0.946[c]	59.6[c]	55.6[c]
DeVilbiss, 3.5	4.931[c]	4.903	1.507[c]	1.594	33.6[c]	28.0
DeVilbiss, 5.0	4.996	4.996	1.680	1.793	25.4	20.4
DeVilbiss, 7.0	5.042	5.009	1.785	1.881	20.7	17.0
DeVilbiss, 10.0	5.038	4.989	1.795	1.767	20.3	21.9
SE (22 d.f.)	0.082		0.061		2.6	

[a]Brain heart infusion broth with 5% fetal bovine serum
[b]Eagle's minimal essential medium with antibiotics
[c]Means based on two replicates; all others on three replicates

[2]Super Nitrogen, Canadian Liquid Air, Calgary, Alberta.
[3]DeVilbiss Corp., Somerset, Pennsylvania.
[4]Dow Corning Y-30 Emulsion, Dow Corning Silicones Inter-America Ltd., Toronto, Ontario.
[5]Model 208A Particle Analyzer and Model 209 Counter Printer, Climet Instrument Co., Redlands, California.

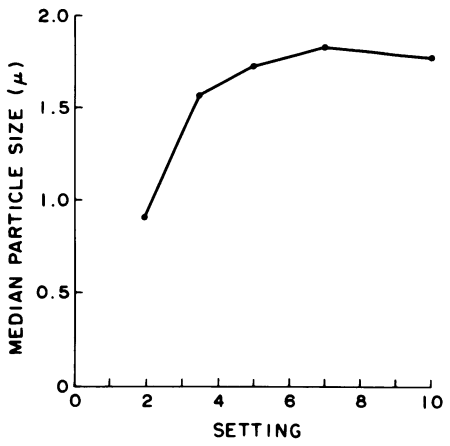

Fig. 2. Effect of DeVilbiss setting on median particle size. The points are means of BHI and MEM data.

cantly ($p < 0.01$) fewer particles were produced by the Collisons (approximately 4.0×10^6/min) compared to the higher DeVilbiss settings.

Particle Size — The median diameter particle size for both media from the DeVilbiss nebulizer was smallest at the 2.0 setting but increased rapidly and then leveled off as the setting was increased (Table I, Fig. 2). Correspondingly, the percentage of particles smaller than 1 μm in diameter was greatest at 2.0 and then decreased rapidly followed by a more gradual decline as the setting was increased (Table I).

Particles produced by the Collisons were smaller and the percentages less than 1 μm in diameter were higher than those produced by the DeVilbiss at settings above 2.0 ($p < 0.01$).

In general, the two Collisons gave very similar outputs. However, Collison 1 produced smaller particles and a correspondingly higher proportion less than 1 μm diameter with MEM than with BHI. Collison 2 data varied similarly, but this difference in median diameter was not statistically significant.

Replicate 1 gave lower total particles per minute ($p < 0.01$), smaller median diameter ($p < 0.01$) and higher percentage particles smaller than 1 μm ($p < 0.01$) than did replicates 2 and 3.

DISCUSSION

The data indicated that there are substantial differences in performance between Collison and DeVilbiss 65 nebulizers. In particular, particles generated by the Collison averaged approximately one half the median diameter of those produced by the DeVilbiss at settings of 3.5 or greater. Both the Collison and DeVilbiss particles could readily penetrate to the alveolar level of the lung in most species (3, 8). In fact, the smaller Collison droplets could conceivably be exhaled more easily prior to deposition on the respiratory membrane. Particles between 1 and 2 μm or those less than 0.2 μm are said to have the highest probability of deposition in the human lung (2), and the size of inhaled particles has been shown in several biological systems to have substantial effects on the severity of disease processes [reviewed by Hatch (4)]. Many factors in addition to size determine the deposition and retention of inhaled particles (1, 2), but the median diameter must be considered essential information in any experimental system (9).

It was not possible to use infectious organisms in this measurement system. However, the data are considered to be of relevance to aerosols of organisms suspended in MEM or BHI, since viruses or bacteria are usually suspended in droplets larger than 0.4 μm (4, 8). The measurement system employed in this study counted particles to a lower limit of 0.3 μm diameter.

The distance of 1.7 m between the location of the nebulizers and the site of sampling was adequate to ensure that the aerosol particles would have dried to their final size by the time they were measured. If the samples had been taken too near their source, they may not have had time to dry sufficiently and the analysis would have indicated larger diameters than would be delivered to animals under actual conditions.

In terms of total output per minute, the DeVilbiss nebulizer at its higher settings generated more particles than the Collisons. This may be of relevance where maximum exposure in the shortest possible time is desirable.

The settings on the DeVilbiss did not correlate well with output for the two media studied here. Below a setting of 2.0 no aerosol could be detected, whereas at 5.0 and beyond the output was constant in terms of particle size and number. This might not be a drawback in most practical situations, but the presence of a rheostat control with settings ranging from zero to ten, does suggest more flexibility than the machine actually delivers; there was certainly no linear relationship between dial setting and output from this nebulizer.

Replicates 2 and 3 were performed on the same day and produced similar particle counts, whereas in replicate 1, which was conducted on another date, the counts were significantly lower. The reasons for significant differences in total particle numbers and median diameters among the replicates may relate to ambient temperature and relative humidity (5). However, other unidentified factors, such as variation between batches of media, could have had an effect.

It is probable that various nebulizers or other instruments used to generate aerosols are adequate for a given experimental purpose. However, these findings indicate that complete definition of the system being employed in a given experimental respiratory disease study should include measurement of the size of particle being generated.

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