

A Performance and Cost Comparison of Four Valved Holding Chambers During Simulated Uncoordinated Breathing

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Introduction

Valved holding chambers (VHCs) are widely prescribed to patients for whom coordinated breathing is difficult. For such patients, there may be a brief time lapse between metered-dose inhaler (MDI) actuation into the VHC and inhalation, during which time drug can deposit and be lost inside the VHC chamber. To simulate such uncoordinated breathing, our study compared the drug mass delivered per MDI actuation after a two-second delay by four VHCs: one collapsible device made from paperboard (LiteAire[®], Thayer Medical), and three devices made from rigid polymer (AeroChamber Max[®] and AeroChamber Plus[®], Monaghan Medical Corp.; and OptiChamber Advantage[®], Respironics). Using these results and the unit cost of each VHC, a cost-to-performance ratio was calculated for each device.

Materials and Methods

Five of each of the four VHCs (n=5) were evaluated using a USP throat model attached via 22 mm tubing to a Harvard Apparatus large animal ventilator simulating tidal breathing of 750 mL at 12 breaths/minute and 1:1 I:E. Eight actuations of albuterol sulfate were delivered to each VHC from a pre-primed and shaken MDI canister. After each MDI actuation there was a two-second pause prior to inhalation.

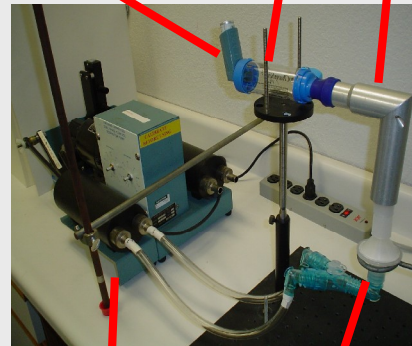


Figure 1. Optichamber Advantage, AeroChamber Max, LiteAire, AeroChamber Plus

Materials and Methods (continued)

Drug delivered through each VHC was captured on a filter connected just downstream of the throat model, eluted by rinsing twice with an 18 mL aliquot of 1 M KCl buffer, and quantified via ultraviolet spectroscopy at 276 nm. Drug mass delivered per MDI actuation was calculated as the mean of five unit results for each VHC tested. Device performances were compared via two-tailed T-tests with $p < 0.05$ indicating a significant difference between VHCs.

Metered Dose Inhaler Holding Chamber USP throat model



Breathing simulator Drug collection filter

Figure 2. Drug output testing apparatus

Results

The results are summarized in Table 1. The drug mass per MDI dose delivered by the AeroChamber Max (67 $\mu\text{g}/\text{dose}$) was significantly larger than the LiteAire (55 $\mu\text{g}/\text{dose}$), the OptiChamber Advantage (52 $\mu\text{g}/\text{dose}$), and the AeroChamber Plus (48 $\mu\text{g}/\text{dose}$), which were not significantly different from each other. When device cost was factored in, the LiteAire was significantly more efficient than the other three VHCs, costing \$0.05 per μg of drug delivered, compared to \$0.16 for the AeroChamber Max, \$0.20 for the OptiChamber Advantage, and \$0.21 for the AeroChamber Plus.

Results (continued)

Holding Chamber Comparisons	AeroChamber		OptiChamber	AeroChamber
	Max	LiteAire	Advantage	Plus
Cost (US\$)	\$10.95 ¹	\$2.95	\$10.30 ¹	\$10.30 ¹
Chamber volume (mL)	198	160	218	150
Mass Median Aerodynamic Diameter (MMAD) (μm)	2.7	2.6	2.7	2.6
% of drug mass in respirable range (MMAD < 4.7 μm)	94%	93%	93%	95%
Drug mass delivered per actuation (μg)	67 \pm 4 [*]	55 \pm 3	52 \pm 6	48 \pm 8
Cost-To-Performance Ratio ²	\$0.16 [*]	\$0.05 [#]	\$0.20	\$0.21

¹Tri-Anim unit price

^{*}Significantly higher than the other three VHCs tested

²VHC Unit Cost/drug mass delivered per actuation; higher value = higher VHC cost/drug mass delivered (\$/ μg)

[#]Significantly lower than the other three VHCs tested

^{*}Significantly lower than OptiChamber Advantage and AeroChamber Plus, significantly higher than LiteAire

Table 1. Results Summary

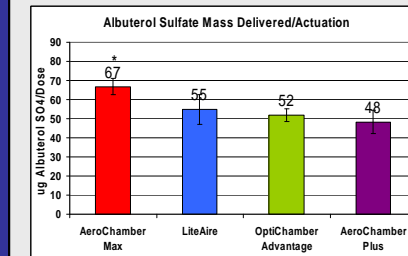


Figure 3. Mass of albuterol sulfate delivered by VHCs per MDI actuation (mass delivered by MDI mouthpiece alone = 108 μg)

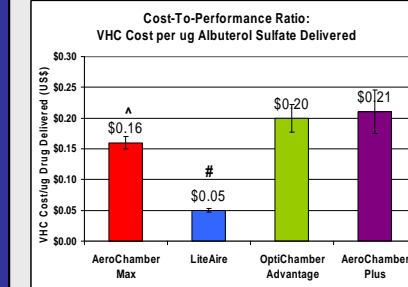


Figure 4. Cost-to-performance ratio: VHC cost per μg albuterol sulfate delivered

Conclusions

Under the conditions tested, the AeroChamber Max offered drug mass delivery performance that was significantly higher than the other VHCs. When device cost was considered, the LiteAire yielded significantly lower device cost per drug mass delivered than the three plastic VHCs. This metric may be of importance for short-term VHC applications in which both device cost and performance are of interest.