Performance of a New Polymer-Based Vibrating Mesh Nebulizer: A Comparison to Metal-Based Mesh Nebulizer

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Summary

It is important to understand the performance of vibrating mesh nebulizers, since it is related to the efficacy of inhalative drug delivery. The present study compared the distribution of droplet size, nebulization output rate, and vibration modal pattern during nebulization among the polymer-based mesh nebulizer from MicroBase Technology (MBTC), and metal-based mesh nebulizer from Aerogen® Solo, and PARI VELOX®. The results revealed that these nebulizers generated particle diameter distribution similarly. The volumetric-median-diameter of MBTC nebulizer, Aerogen® Solo, and PARI VELOX® were 5.11±0.44 μm, 5.02±0.67 μm, and 4.11±0.30 μm, respectively. The averaged output rate of the nebulizers from MBTC was 0.73±0.15 ml/min for normal saline (0.9%), which was at around 1.4 times greater than Aerogen® Solo (0.53±0.12 ml/min), and was similar to that of PARI VELOX® (0.76±0.18 ml/min). Moreover, these three nebulizers showed similar modal pattern during operations, and the resonant frequency was similar between MBTC and, Aerogen® Solo (125.9 kHz vs. 128.2 kHz, respectively) yet lower than the PARI VELOX® (160.0 kHz). Accordingly, further development and application of polymer-based mesh nebulizer could be implemented in different designs. Further studies will also be carried out to assess the delivery of other liquid medications from the MBTC nebulizer.

Key Message

In this study, a performance comparison was conducted on the new polymer-based vibrating mesh nebulizer from MBTC, and commercialized nebulizers from Aerogen (Aerogen® Solo) and PARI (PARI VELOX®). Through the measurements of droplet size distribution, output rate, vibrational modal pattern, it is demonstrated that the new polymer-based vibrating mesh nebulizer could present a comparable performance to current metal-based mesh nebulizer. A low-cost mesh nebulizer could be expected and achieved in the future.

Introduction

Inhaled medication plays a crucial role in treating patients with pulmonary and some systemic diseases. In order to improve the delivery efficacy, the liquid medication must be transformed into medical aerosol with specific droplet size distribution. Some researchers revealed that the droplet size of medical aerosol should be controlled within 1 to 6 μm because the droplets could deposit in the mouth and throat when the size is larger than 6 μm, and may be exhaled when the size is smaller than 2 μm [1-3]. For this reason, the nebulization device must generate aerosol that meet these demanding properties. In addition to droplet size, nebulization output rate is another factor which could affect the treating efficacy. The low output rate for aerosol delivery can extend therapeutic duration and reduce the treatment compliance for patients.

Polymeric material has the advantage in the cost of manufacturing than metal material, such as Pd-Ni, and Ni-Ti alloy. In addition, the polymeric material can be drilled easily through precisely laser processing. Yet, the performance of a polymer-based mesh nebulizer should be comparable to the metal-based mesh nebulizer on the current market, the cost to the users/patients could be reduced. In this study, a new polymer-based vibrating mesh nebulizer was fabricated through a specific process technique. Vibration modal pattern during nebulization, droplet size, and nebulization output rate of the nebulizer were determined and used to compare with those of commercially available vibrating mesh nebulizers, Aerogen® Solo and PARI VELOX®.

Experimental Materials & Methods

A 248 nm UV range excimer laser source (with output power 300 mJ and firing frequency of 200 Hz), optical path system, and laser dynamic control module were integrated to explore the relationship between different laser shots and the geometry of apertures. After that, the polymer-based meshes with specific aperture design were fabricated. The new polymer-based vibrating mesh module consists of a stainless steel plate in ring shape, vibrating mesh, and piezoelectric actuator (Figure 1).

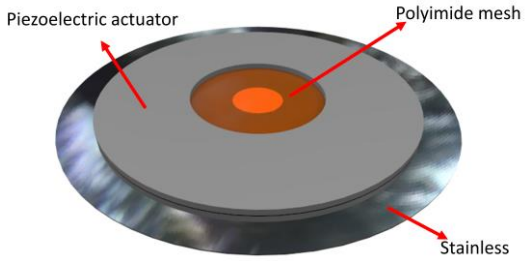

Figure 1 – Illustration of the new polymer-based vibrating mesh module

In order to compare the performances of nebulizers, the ability to aerosolize normal saline (0.9 %) of 4 new polymer-based vibrating mesh nebulizers from MBTC, 4 Aerogen® Solo and 4 PARI VELOX® were tested in this study. In addition to the output rate, the distribution of droplet size was assessed by Spraytec Analyzer (Malvern Panalytical Ltd., Malvern, UK) with 300 mm lens system using analysis ranging from 0.1 to 900 µm. The vibration modal pattern and resonance frequencies of each nebulizer during nebulization were determined by the Laser Doppler Scanning Vibrometer, Polytech PSV-500 (Polytec GmbH, Waldbronn, Germany).

Results and Discussion

The volume droplet size distribution of the new polymer-based vibrating mesh nebulizers from MBTC, and commercialized nebulizers from Aerogen and PARI are shown in Figure 2. Three nebulizers present a similar distribution of particle diameter pattern that approximately 75% of droplets were smaller than 6 µm. The output rate and volumetric-median-diameter of each nebulizer are shown in Figure 3. The output rate from MBTC ranges from 0.53 to 0.92 ml/min, while that of Aerogen® Solo and PARI VELOX® ranges from 0.33 to 0.66 ml/min and 0.60 to 1.07 ml/min, respectively. The volumetric-median-diameter of the nebulizers from MBTC ranges from 4.62 to 5.81 µm, while that of Aerogen® Solo ranges from 3.99 to 5.85 µm and PARI VELOX® ranges from 3.60 to 4.39 µm.

The volumetric-median-diameter of the droplet, output rate, and resonant frequency of the nebulizer from MBTC, Aerogen® Solo and PARI VELOX® are summarized in Table 1. In addition to output rate, all the nebulizers present a similar result in distribution of particle size. The output rate 0.73±0.15 ml/min of MBTC's nebulizer is similar to PARI VELOX® at 0.76±0.18 ml/min , in which both are greater than the output rate 0.53 ml/min of Aerogen® Solo. It is believed that a nebulizer having a high output rate as well as fine particle size of aerosol can shorten the treatment time for treatment and increase the treatment compliance of patients.

The Figure 4 shows the vibration modal pattern among three nebulizers during operations. The vibration modal pattern of the MBTC nebulizer features with a concentric circle pattern, same as the Aerogen® Solo and PARI VELOX®. That might be a possible reason to explain the similarity in droplet size distribution between these nebulizes.

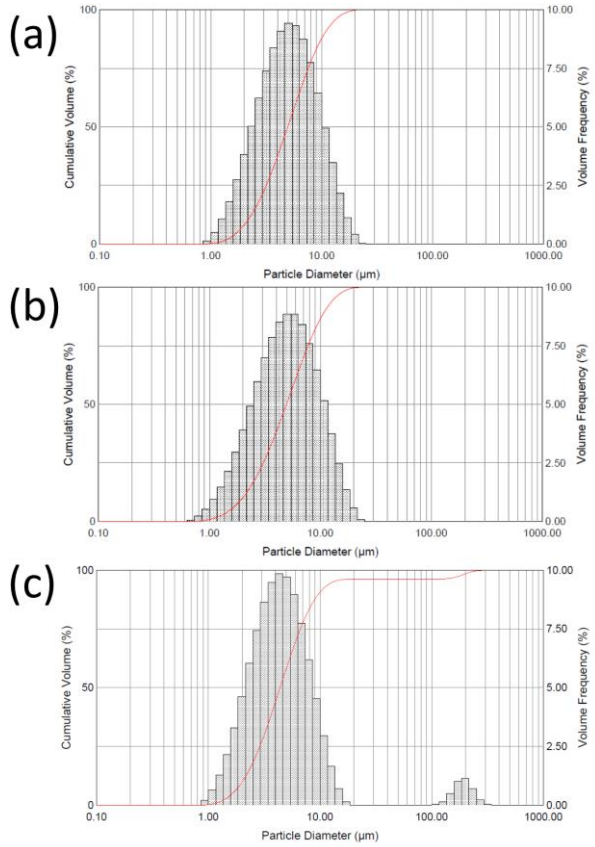

Figure 2 – The droplet size distribution of the new polymer-based vibrating mesh nebulizers from MBTC (a), Aerogen® Solo (b) and PARI VELOX® (c)

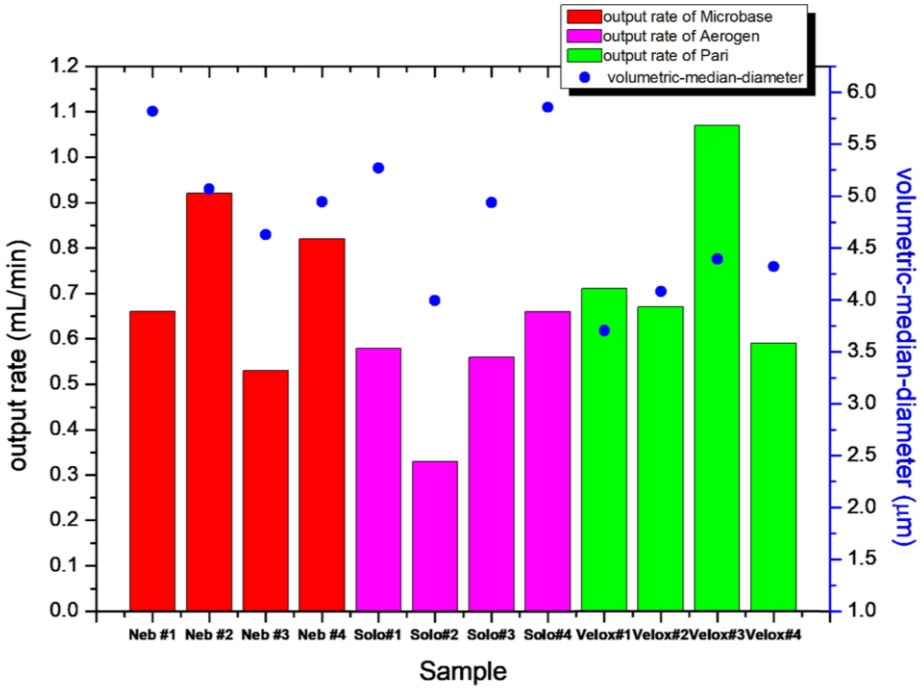

Figure 3 – The experimental results of volumetric-median-diameter and output rate among different Nebulizers

Table 1 – Comparison in volumetric-median-diameter of the droplet, output rate and resonant frequency of each nebulizer

	Dv(10) (µm)	Dv(50) (µm)	Dv(90) (µm)	output rate (ml/min)	Resonant frequency (kHz)
MBTC nebulizer	2.24±0.12	5.11±0.44	11±1.08	0.73±0.15	125.9
Aerogen® Solo	2.08±0.19	5.02±0.67	10.84±1.6	0.53±0.12	128.2
PARI VELOX	1.97±0.12	4.11±0.30	8.53±1.15	0.76±0.18	160.0

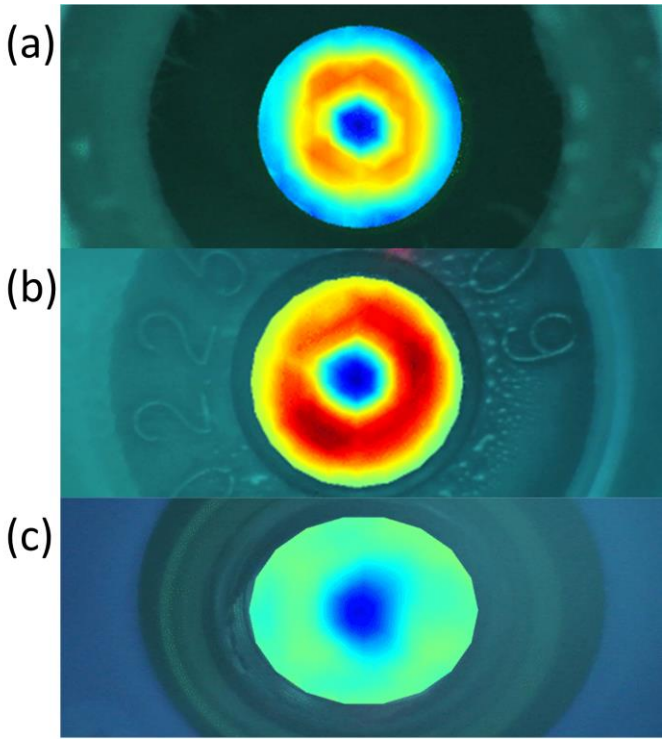

Figure 4 – Vibration modal pattern of the new polymer-based vibrating mesh module from MBTC (a), Aerogen® Solo (b) and PARI VELOX® (c)

Conclusion

In this study, nebulizer performance comparisons were conducted on the new polymer-based vibrating mesh nebulizer from MBTC, and commercialized nebulizers of Aerogen (Aerogen® Solo) and PARI (PARI VELOX®). The MBTC nebulizer presents a similar aerosol distribution to Aerogen® Solo and PARI VELOX®. The output rate of MBTC nebulizer was comparable to that of PARI VELOX®, but 40% greater than that of Aerogen® Solo. In addition, these three nebulizers showed similar modal pattern (concentric circle pattern) during operations. As a result, the new polymer-based vibrating mesh nebulizer illustrated a comparable performance to current metal-based mesh nebulizers. A low-cost mesh nebulizer could be achieved in the future. Microbase will further study in assessing the delivery of other liquid medications from the MBTC nebulizer.

Reference

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