May 10, 2026 115年機械通氣繼續教育課程

Inhalation Therapy for Critically Ill Patients During Mechanical Ventilation Weaning

陳韋成醫師

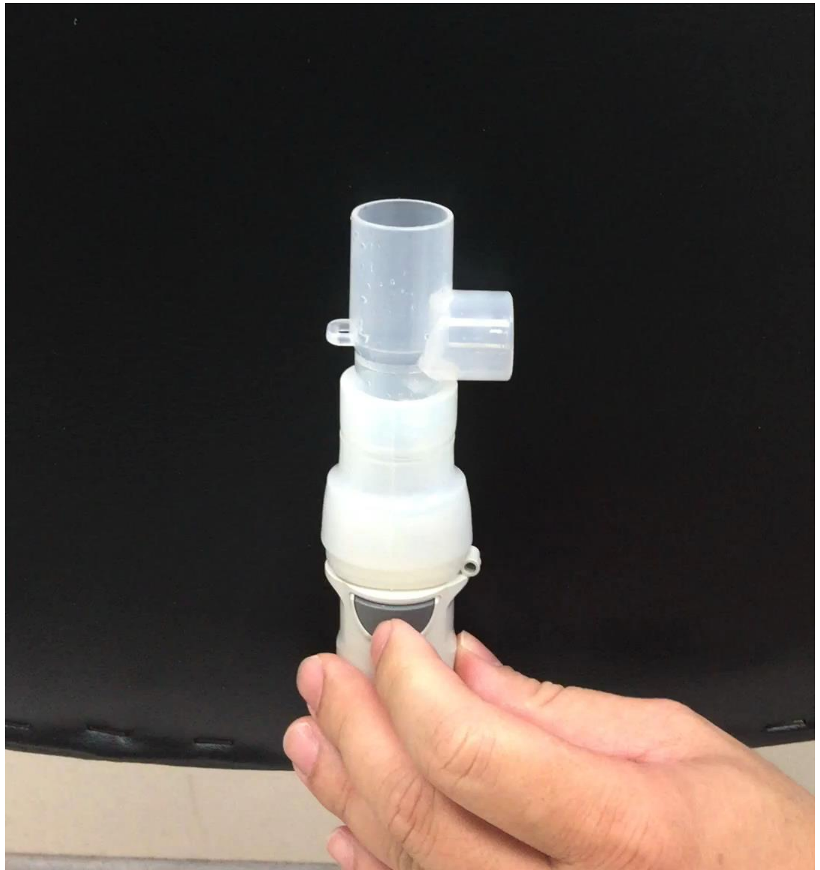
中國醫藥大學附設醫院 主任秘書
胸腔內科暨重症系 呼吸加護病房主任
中國醫藥大學醫學系 助理教授
重症醫學會 監事 暨青年創新委員會 主任委員

1. T connection
Air vents: open

2. T connection
Air vents: close

3. Y connection
Air vents: close

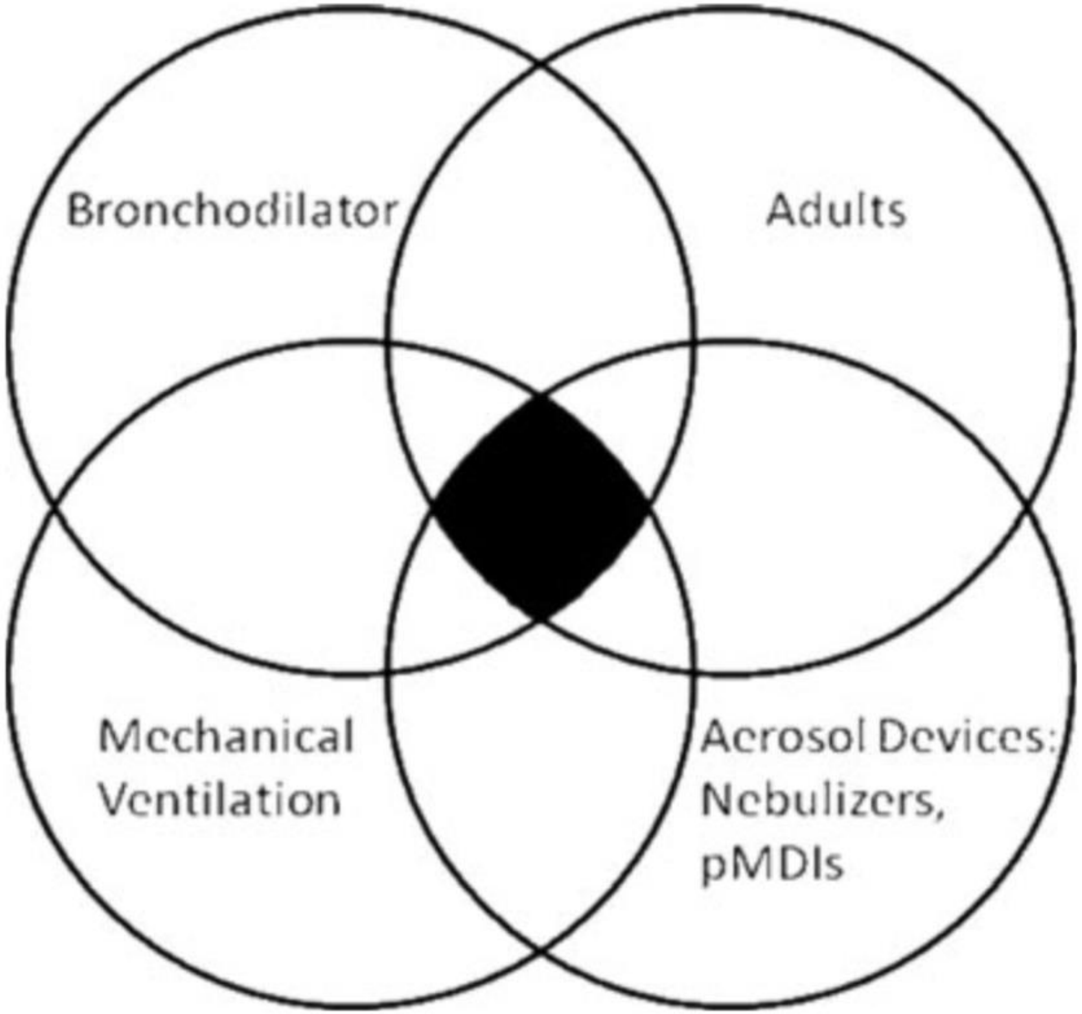
What do you think when **aerosol therapy** use in **ventilated patients** with **COVID-19 ?**



Aerosol Therapy During Mechanical Ventilation
From Drug Delivery to Ventilator Strategy

Drugs
Bronchodilators
Short- v.s. long-acting

Ventilator settings
Position, Vt, rate
Heated humidifier



Devices
Nebulizer, MDI, SMI

Outline

Arzu et al, Nurs Crit Care 2012; 15(4): 192-203

Prevalence

Aerosol therapy

ICU	Intubated
24%	22%

Ehrmann et al, ICM 2016; 42: 192-201

Prevalence

Drugs

	Aerosols ($n = 9714$)	Patients ($n = 678$)
Bronchodilators	7960 (82 %)	600 (89 %)
Short acting beta-2-adrenergic agonists	6780 (95 %)	463 (86 %)
Long acting beta-2-adrenergic agonists	88 (1 %)	24 (4 %)
Anticholinergic drugs	4958 (70 %)	198 (37 %)
Corticosteroids	1233 (13 %)	173 (26 %)
Beclomethasone dipropionate	269 (22 %)	31 (18 %)
Budesonide	897 (74 %)	130 (77 %)
Fluticasone	60 (5 %)	11 (6 %)
Other	5 (<1 %)	1 (<1 %)
Anti-infectious drugs	509 (5 %)	31 (5 %)
Amikacin	31 (6 %)	9 (30 %)
Amphotericin B	33 (6 %)	4 (13 %)
Colistin	400 (79 %)	19 (63 %)
Gentamicin	21 (4 %)	2 (7 %)
Ceftazidime	6 (1 %)	3 (10 %)
Tobramycin	14 (4%)	2 (<1 %)
Mucus modulating drugs	241 (3 %)	39 (6 %)
Acetylcysteine	136 (61 %)	22 (65 %)
Recombinant human deoxyribonuclease	12 (5 %)	7 (21 %)
2-Mercapto ethane sodium sulfonate (Mesna)	93 (42 %)	11 (32 %)
Electrolyte solutions	503 (5 %)	71 (9 %)
0.9 % sodium chloride[a]	440 (87 %)	65 (91 %)
Hypertonic sodium chloride	16 (3 %)	2 (3 %)
Sodium bicarbonate	47 (9 %)	4 (6 %)
Other	14 (<1 %)	5 (<1 %)

Bronchodilators
82% (SABA 95%)

Corticosteroid
13%

Antibiotics

Ehrmann et al, ICM 2016; 42: 192-201

Prevalence

Device

Jet nebulizer **56%**

MDI **23%**

Metered dose inhaler

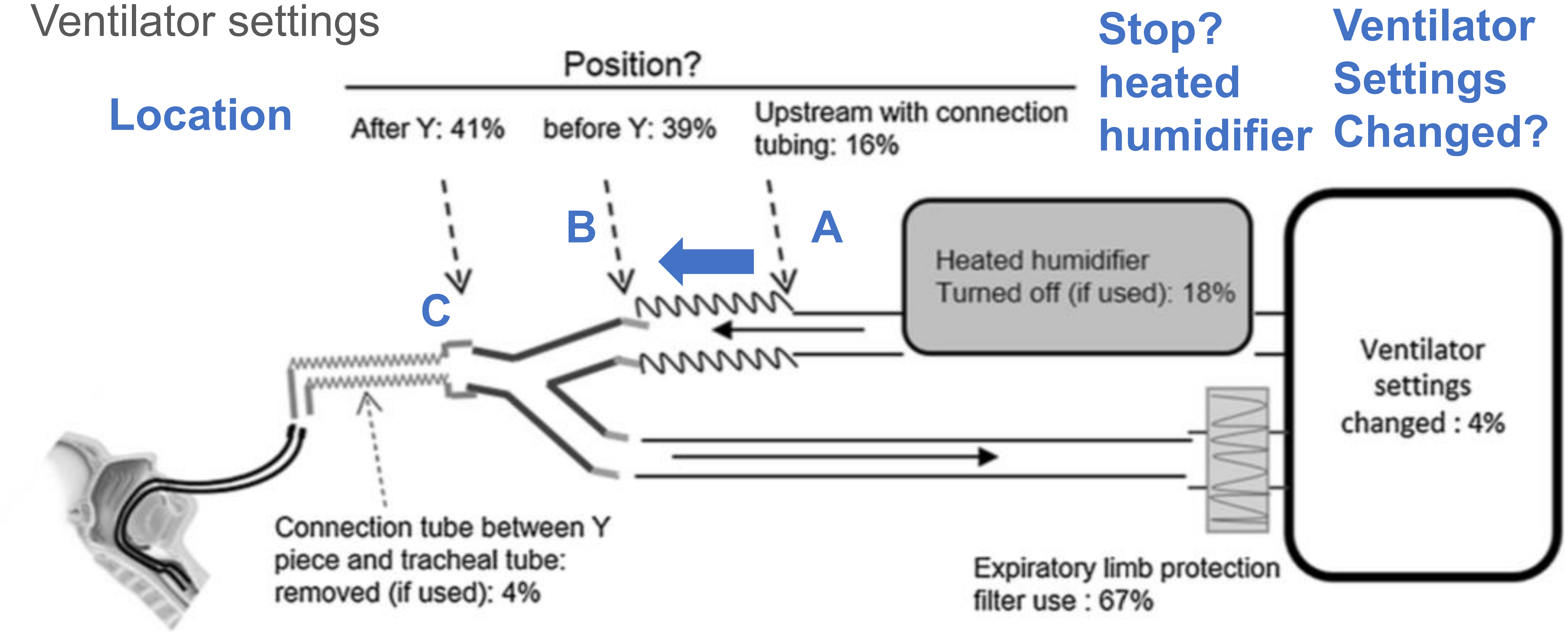
MDI

	$n = 9714$
Aerosol generation devices	
Jet nebulizer	5436 (56 %)
Ultrasonic nebulizer	940 (10 %)
Vibrating mesh nebulizer	999 (10 %)
Hand held devices[a]	2216 (23 %)
Instillation[b]	123 (1 %)
Ventilation during aerosol delivery	
Spontaneous breathing	4832 (50 %)
NIV[c]	350 (4 %)
Invasive ventilation	4532 (47 %)
Number of molecules within one aerosol[d]	
1	5583 (57%)
2	3657 (38 %)
≥3	474 (5 %)

Ehrmann et al, ICM 2016; 42: 192-201

Prevalence

Ventilator settings



Ehrmann et al, ICM 2016; 42: 192-201

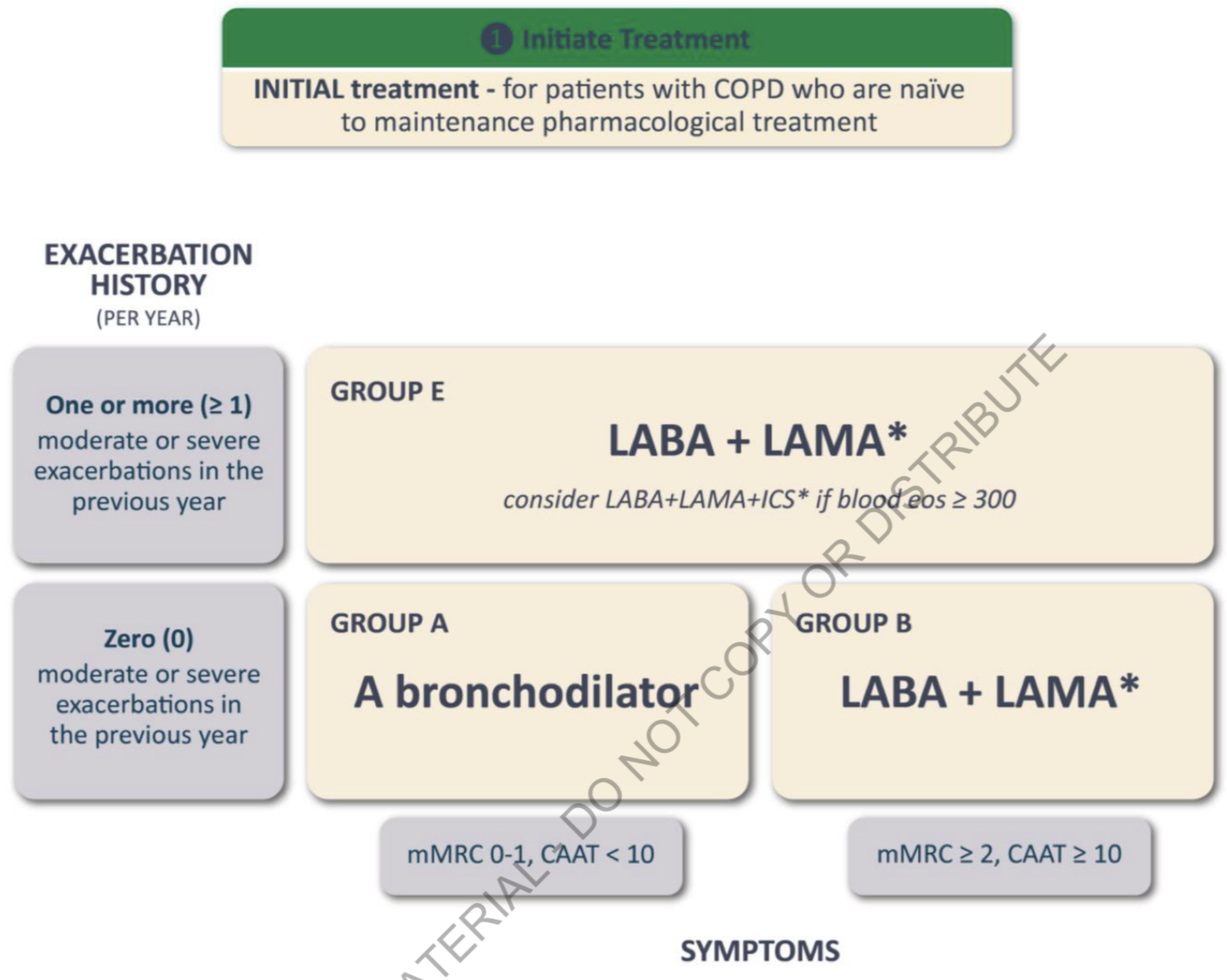
Global Initiative for
Chronic Obstructive
Lung Disease

2026 REPORT

Global Strategy for the Diagnosis, Management, and Prevention of Chronic Obstructive Pulmonary Disease

Initial Pharmacological Treatment

Figure 3.8



*Single inhaler therapy may be more convenient and effective than multiple inhalers; single inhalers improve adherence to treatment

Exacerbations refers to the number of exacerbations per year; eos: blood eosinophil count in cells per microliter; mMRC: modified Medical Research Council dyspnea questionnaire; CAAT™: Chronic Airways Assessment Test™.

Bronchodilator Therapy in AE COPD
Key Conclusions

1. First-line Bronchodilator: **Inhaled SABA ± SAMA.** Avoid excessive dosing due to side effects

2. Delivery Method
   •pMDI and nebulizer show similar efficacy
   •**Nebulizer** may be easier for critically ill patients

3 Nebulization Strategy
   •Prefer **air-driven** nebulization
   •Avoid oxygen-driven nebulization to reduce risk of CO_2 retention

Bronchodilator Therapy in AE COPD
Key Conclusions

Although ***no clinical studies*** have evaluated the use of inhaled LABDs (either beta2agonists or anticholinergics or combinations) with or without ICS during an exacerbation, we recommend **continuing these treatments during the exacerbation or to start these medications as soon as possible before hospital discharge.**

4. LABA / LAMA / ICS
   - **Continue maintenance inhaled therapy during exacerbation**
   - **Restart before discharge if temporarily withheld Nebulized LABA**

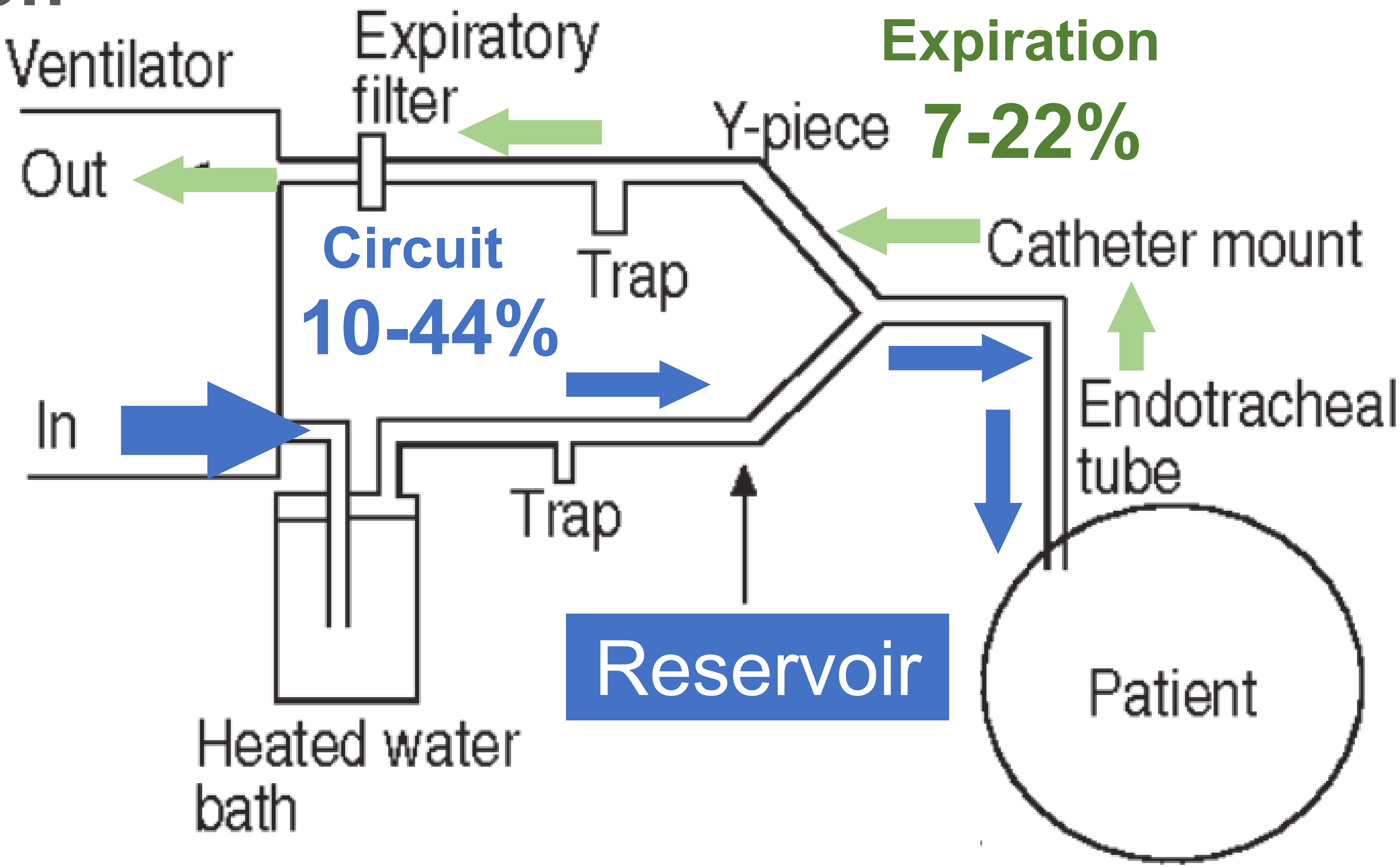
Current Evidence

- Limited direct comparative trials
- Retrospective data suggest possible *reduction in 30-day readmission* with nebulized LABA

Global Initiative for chronic obstructive lung disease, 2026

Deposition

Before
Enter the lung



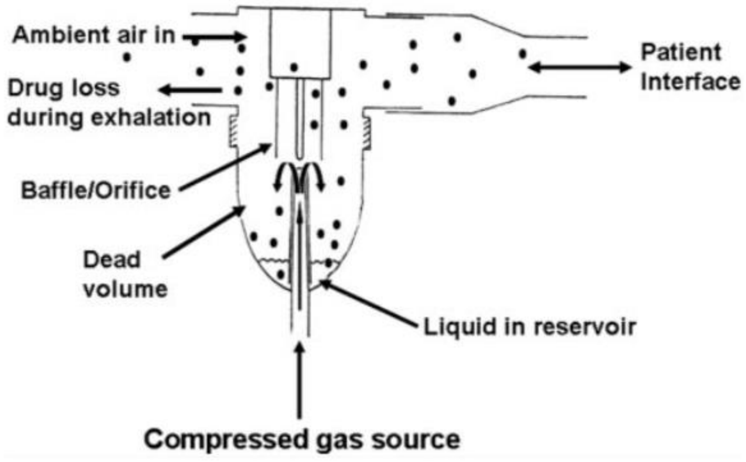
Dugernier et al. Critical Care (2017) 21:264

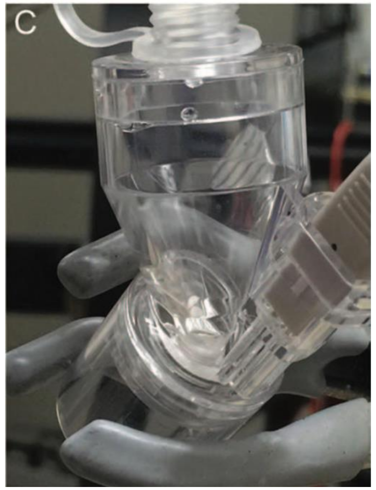
Deliver to **lung**

MDI+ chamber at Y-piece

38%

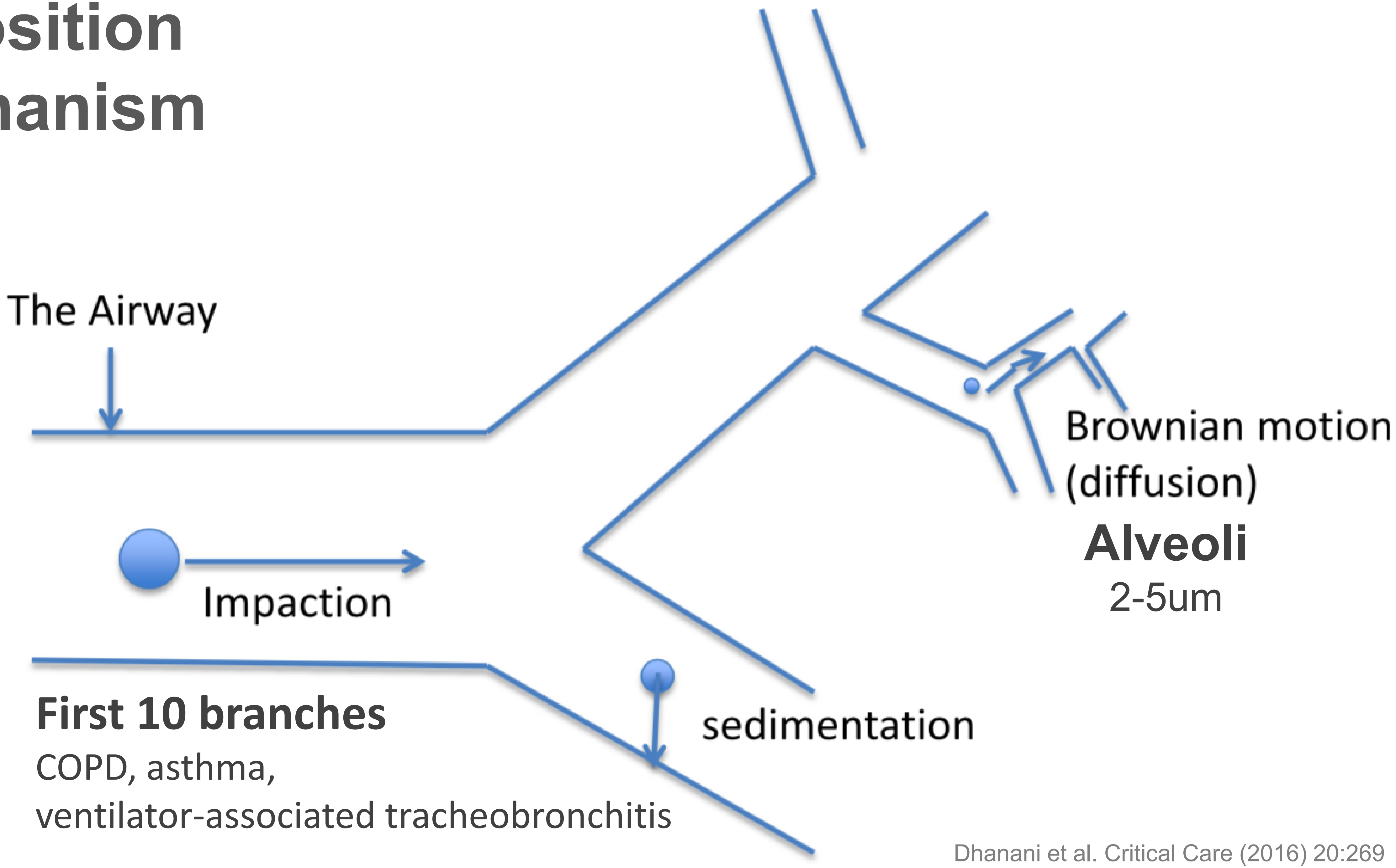
Jet Nebulizer	Ultrasonic Nebulizer	Vibrating mesh Nebulizer
3-7%	5%	10-15%





Mark et al. Chest. 1999;115(6):1653–7.

Deposition mechanism

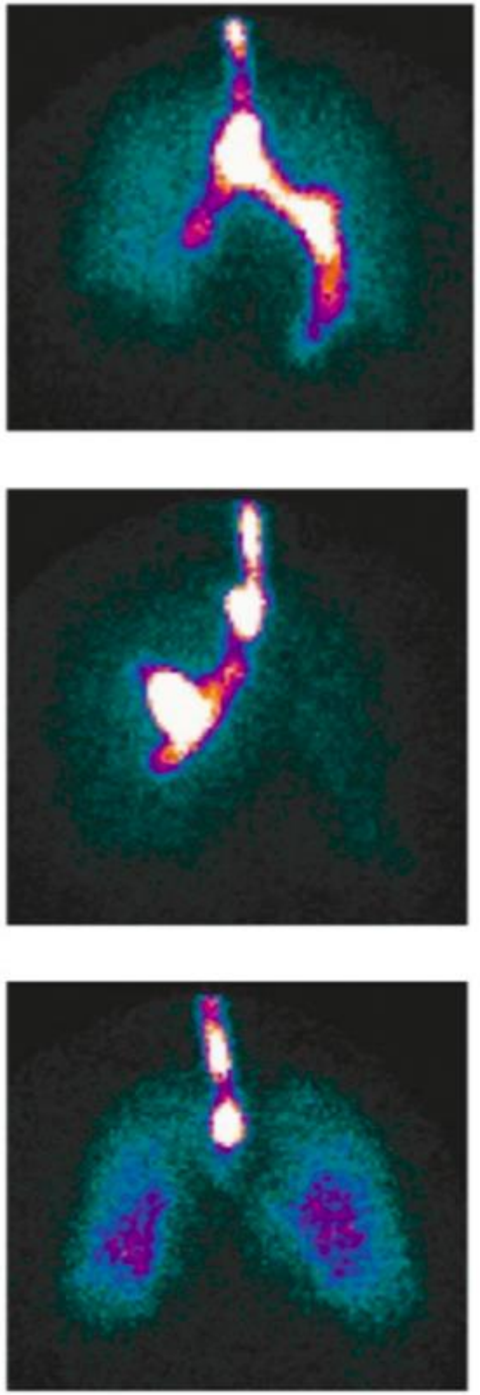


Dhanani et al. Critical Care (2016) 20:269

Deposition

Distribution in the lung

Achieving effective drug deposition at the target site remains ***a major challenge.***



Distal tip of the airway

Trachea Main bronchus	Whole lung
49%	51%

Distribution of both lungs

R't lung	L't lung
33%	17%

Klockare et al. J Clin Nurs. 2006;15(3):301–7.

Short-acting bronchodilators Mechanical ventilated patients

TABLE 3. INVESTIGATIONS OF BRONCHODILATOR THERAPY AND AIRWAY RESPONSE IN MECHANICALLY VENTILATED PATIENTS

Author, year (reference #)	Drug (dose, mg)	Aerosol device	Response
Gay, 1987[76]	Metaproterenol (1.8 mg)	Small-volume aerosol generator	Increase in expiratory flow at recoil pressure of 6 cm H_2O, and reduction in peak pressure and intrinsic PEEP
Wegener, 1987[77]	Ipratropium (0.2 mg)	pMDI and adapter	Decrease in inspiratory airway resistance and significant increase in paO_2
Fuller, 1990[21]	Fenoterol (0.8 mg) Fenoterol (1.75 mg)	pMDI-spacer Nebulizer	Decrease in peak airway pressure not significant with either device
	Albuterol (2.5, 5, 7.5 mg)	Nebulizer	
Yang, 1994[83]	Ipratropium (0.5 mg)	Nebulizer	Significant reduction in peak airway pressure, mean airway pressure and mean airway resistance
Fernandez, 1994[94]	Fenoterol (0.1 mg)+ Ipratropium (0.04 mg)	pMDI and short catheter	Significant decrease in airway resistance with combination
Dhand, 1995[26]	Albuterol (1.0 mg)	pMDI-spacer	Significant reduction of airway resistance for up to 60 min
Manthous, 1993[82]	Albuterol (0.5, 1.5, 3.0 mg cumulative dose)	pMDI-spacer	Significant reduction in airway resistance with 1.5 and 3.0 mg albuterol
Dhand, 1996[29]	Albuterol (0.4, 1.2, 2.8 mg cumulative dose)	pMDI-spacer	Significant reduction in airway resistance with 0.4, 1.2 and 2.8 mg of albuterol
Mouloudi, 1998[84]	Albuterol (0.6 mg) with or without end-inspiratory pause	pMDI-spacer	Significant reduction in airway resistance. No effect of end-inspiratory pause
Waugh, 1998[85]	Albuterol (0.4, 0.8 mg)	pMDI and chamber spacers	Reduction in airway resistance with 4 puffs and 8 puffs. No difference in response between 2 chamber spacers
Mouloudi, 1999[87]	Albuterol (0.6 mg)	pMDI-spacer	Significant reduction in airway resistance. No effect of tidal volume 8 mL/kg versus 12 mL/kg body weight
Guerin, 1999[86]	Fenoterol (0.2 mg)+ Ipratropium (0.4 mg) Fenoterol (1.25 mg)+ Ipratropium (0.5 mg)	pMDI-spacer Nebulizer	Significant reduction in airway resistance with both pMDI and nebulizer
Duarte, 2000[88]	Albuterol (0.4, 1.0 mg) Albuterol 2.5 mg	pMDI-spacer Nebulizer	Significant reduction in airway resistance with both pMDI and nebulizer for up to 2 h

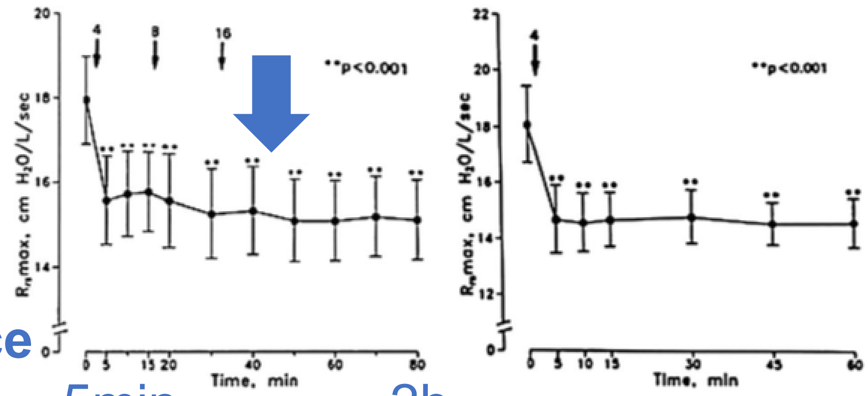
TABLE 3. (CONTINUED)

Author, year (reference #)	Drug (dose, mg)	Aerosol device	Response
Mouloudi, 2000[89]	Albuterol (0.2, 0.6 mg)	pMDI-spacer	Sign de sq
Mouloudi, 2001[111]	Albuterol (0.6 mg)	pMDI-spacer	Sign bu ur
Mouloudi, 2001[90]	Albuterol (0.4 mg)	pMDI-spacer	Sign in
			ventilation with similar tidal volumes
Malliotakis, 2008[93]	Salmeterol (0.1 mg)	pMDI-spacer	Significant reduction in airway resistance for up to 8 h, but the duration of effect was variable and unpredictable in individual patients.
Kondili, 2011[109]	Albuterol (0.4 mg)	pMDI-spacer	Expiratory resistance of the respiratory system (expiratory Rrs) was several-fold higher than inspiratory resistance. After albuterol, there was significant reduction in expiratory Rrs with increase in the rate of lung emptying toward the end of expiration. Changes in expiratory Rrs did not correlate with changes in end-inspiratory inspiratory resistance after albuterol

Salbutamol, fenoterol, ipratropium **nebulizer** & **MDI**

Significant **decreased airway pressure and resistance.**

Airway resistance



5min 2h

Ari et al. J Aerosol Med Pulm Drug Deliv 2012; 25(6): 319-32.

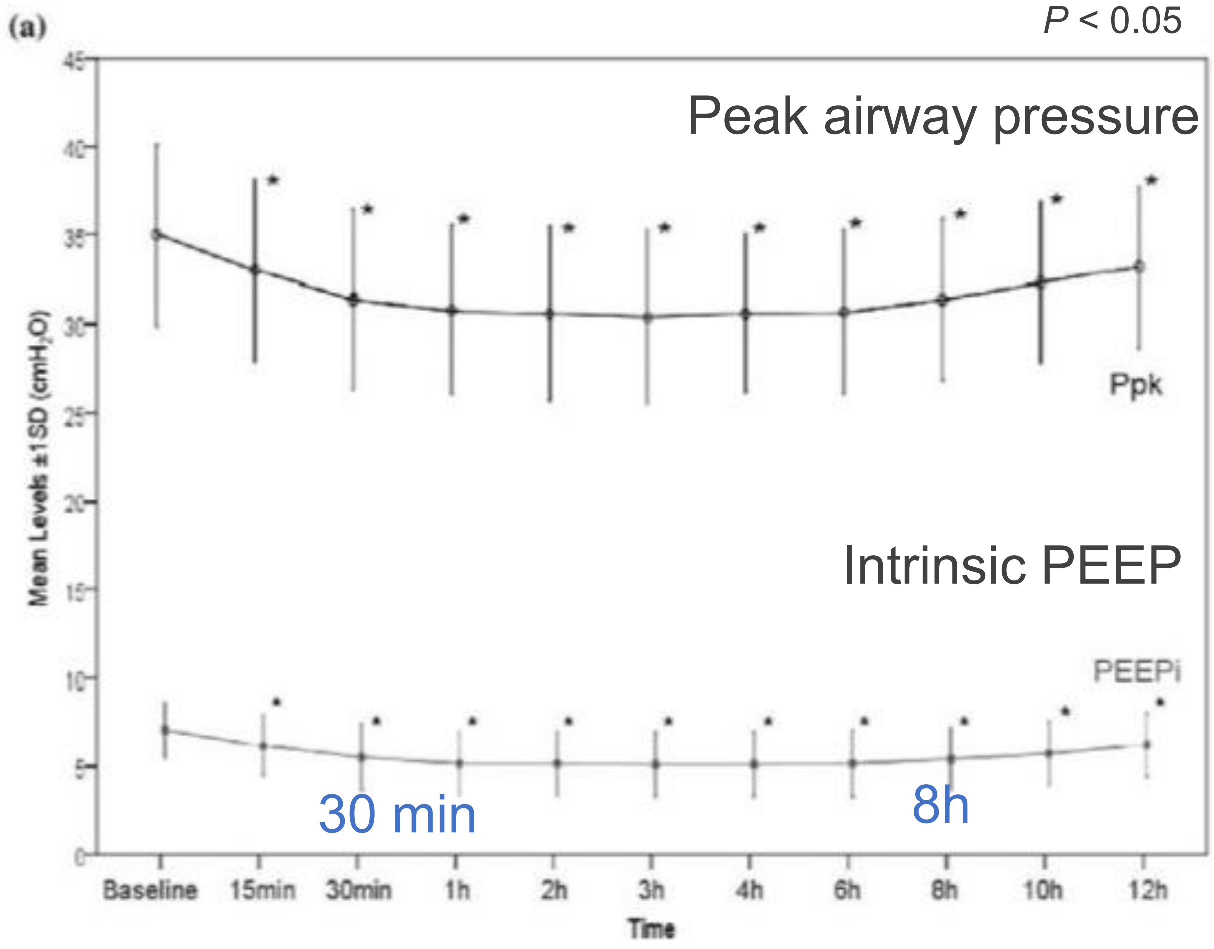
Long-acting β2-agonists

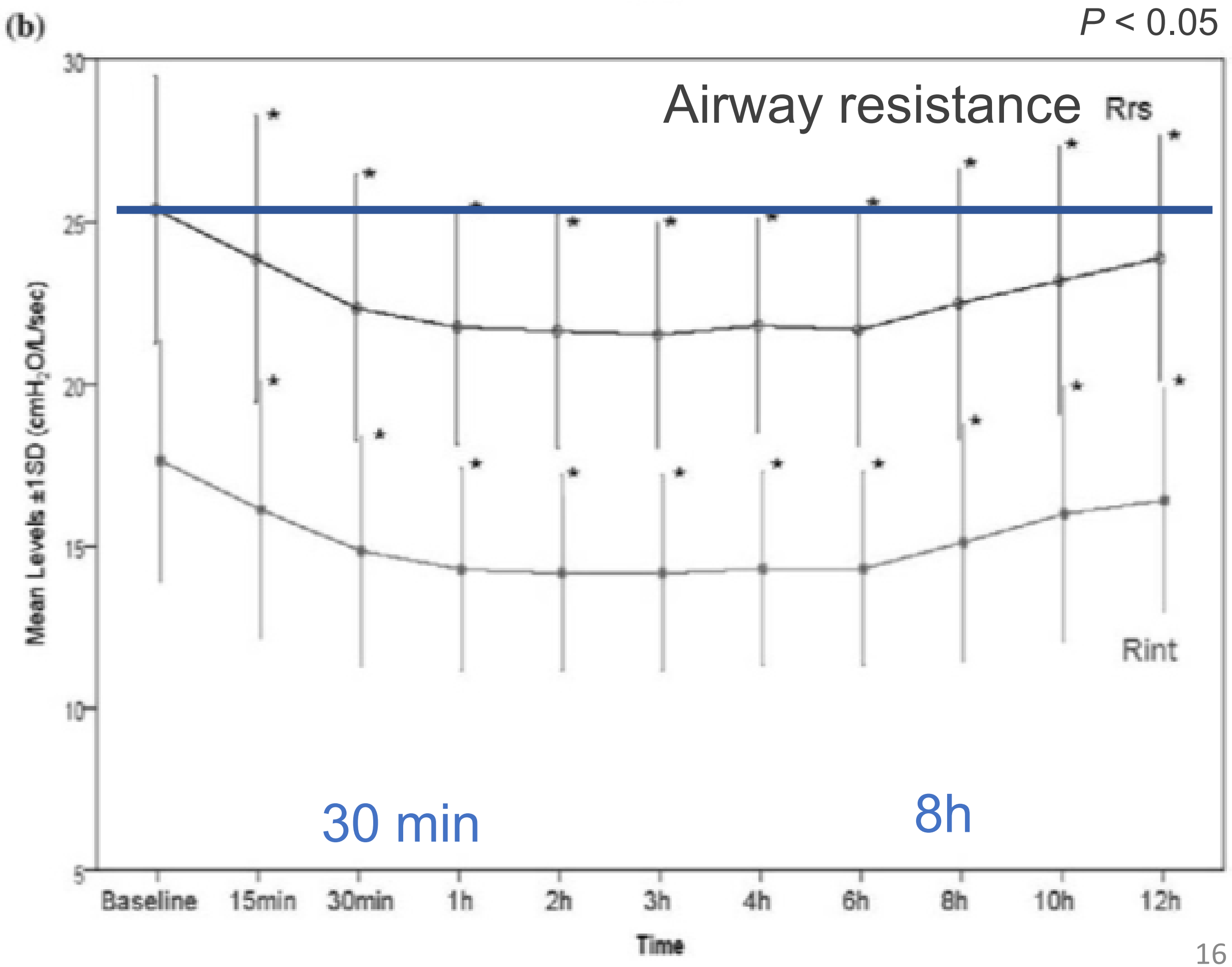
Malliotakis et al. Critical care 2008; 12(6): R140.

Mechanical ventilated patients

Salmeterol (25mcg/puff) 4 puff
MDI + spacer; inspiratory limb

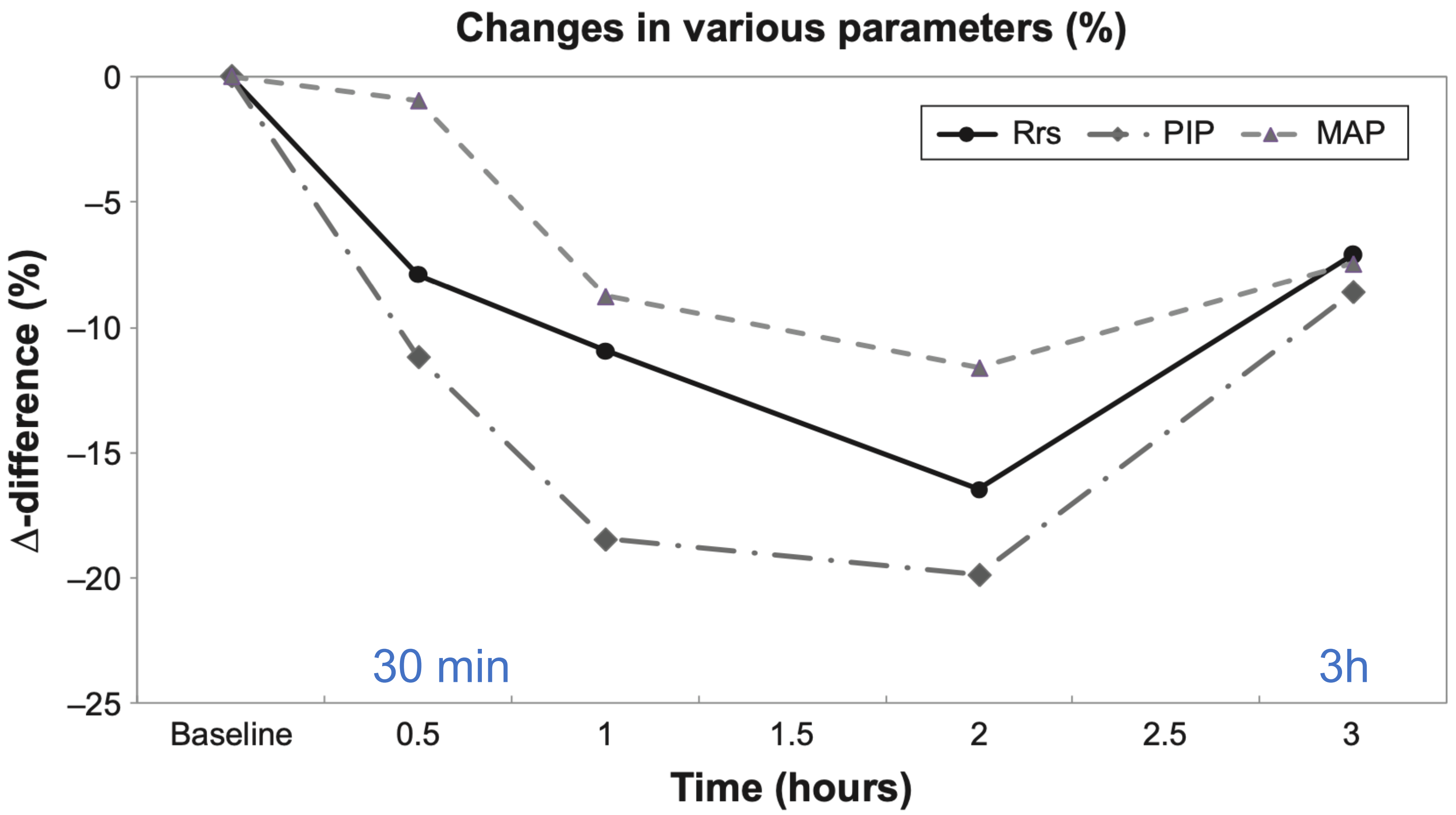
Significant **decreased airway pressure and resistance**.
Evident at 30min; remained **8 hours** (6-10h)





4 puffs of salmeterol 25 μg/fluticasone 125 μg combination therapy

ICS + LABA for AE COPD **decrease resistance and peak inspiratory pressure (30mins- 2 h - 3 h)**



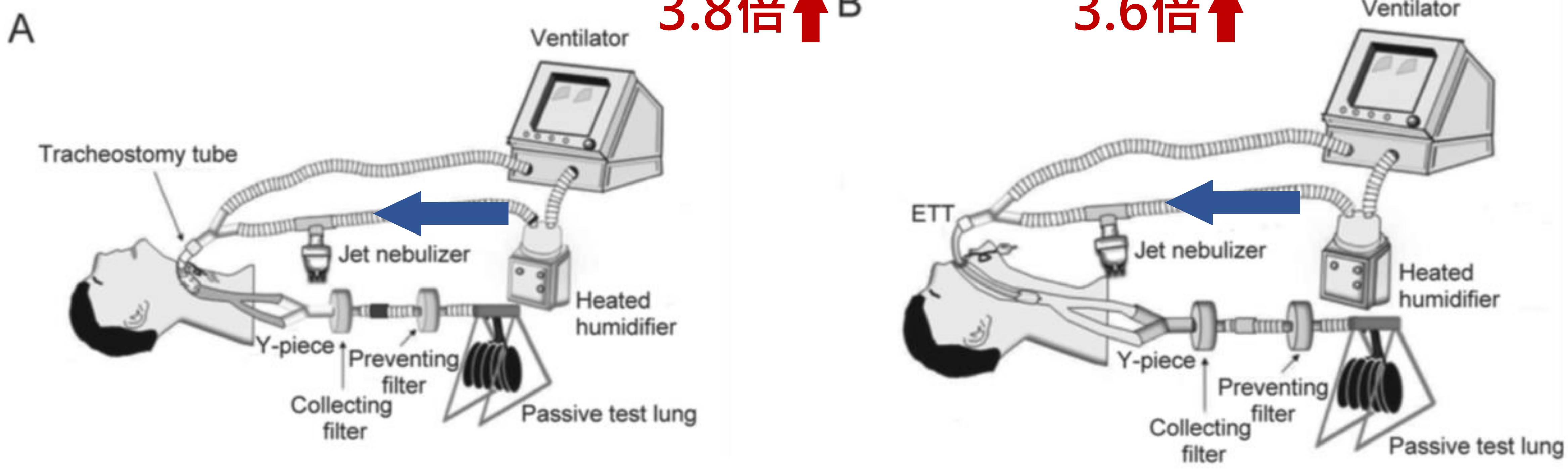
Chen WC, et al. Int J Chron Obstruct Pulmon Dis. 2016 Jan 27;11:167-74.

MDI: greater delivery efficiency than jet nebulizer

Table 1. Mean Inhaled Mass and Lung Dose as Percent of Nominal Dose Delivered Distal to the Trachea With Each Aerosol Device

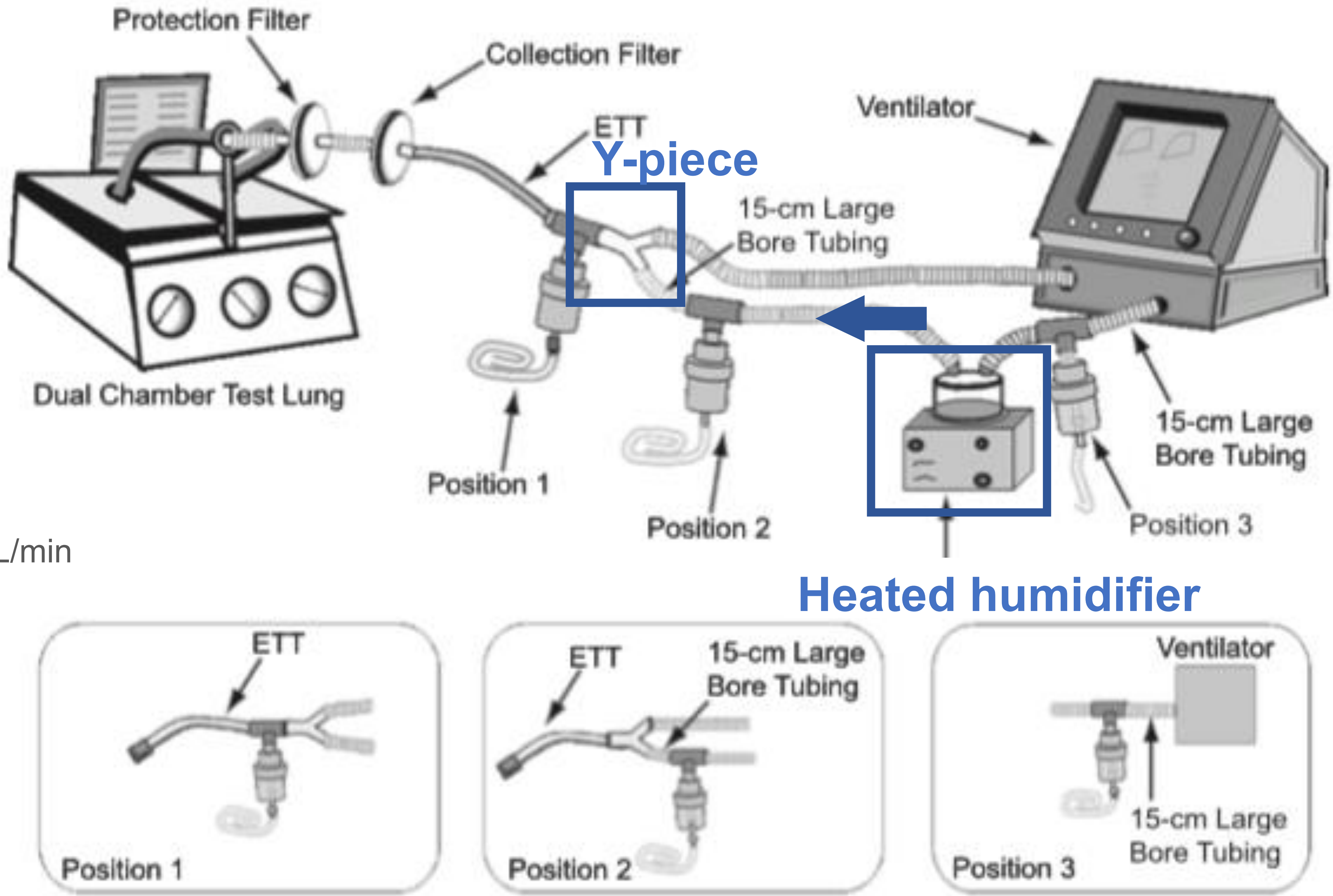
Salbutamol (SABA)	TT (2.5mg/3ml)	(0.1mg x 4 puff)		ETT (1/6的劑量)		
	Jet Nebulizer	pMDI	*P*	Jet Nebulizer	pMDI	*P*
Inhaled mass, mean ± SD μg	97.3 ± 14.0*	63.6 ± 0.4†	.01	79.6 ± 3.8	50.1 ± 8.2	.005
Lung dose, mean ± SD %	3.9 ± 0.5‡	14.7 ± 0.1§	.001	3.2 ± 0.1	11.6 ± 1.9	.002

3.8倍 ↑ 3.6倍 ↑



Arzu et al. Respir Care. 2015;60(11):1570–1574.

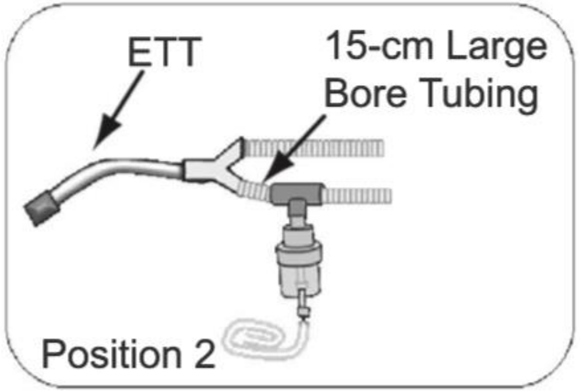
Position & Humidifier of aerosol devices



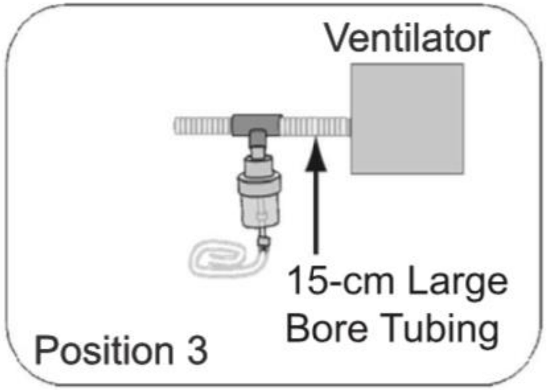
Tidal volume 500 mL
Ramp flow pattern
15 breaths/min
Peak inspiratory flow 60 L/min
PEEP 5 cm H_2O

Arzu et al. Respir Care. 2010;55(7):837–844.

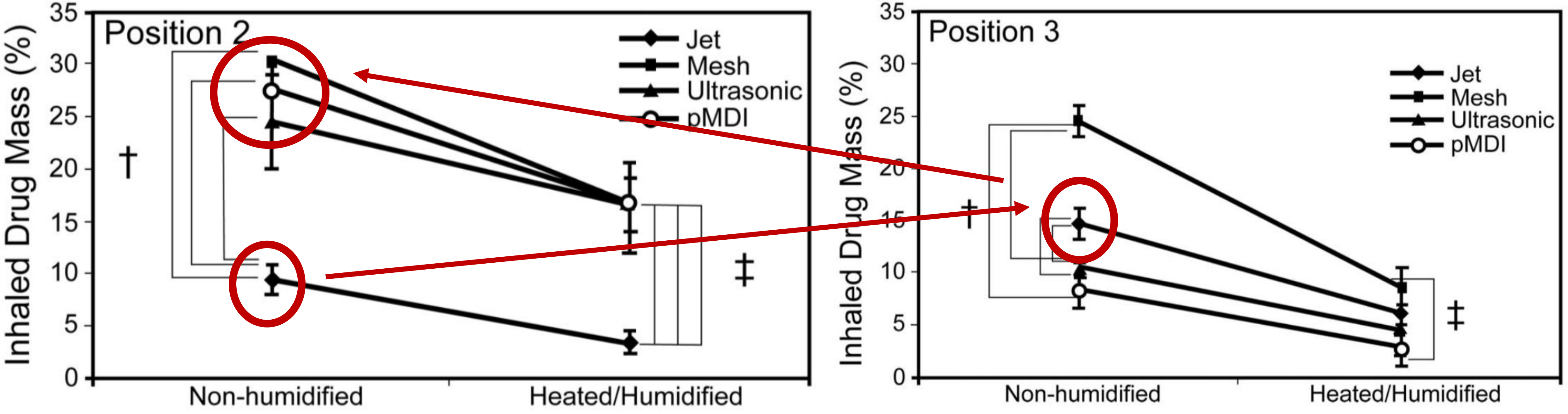
Position Inhaled drug mass (%)



pMDI
US Nebulizer
VM Nebulizer
15cm before Y-piece



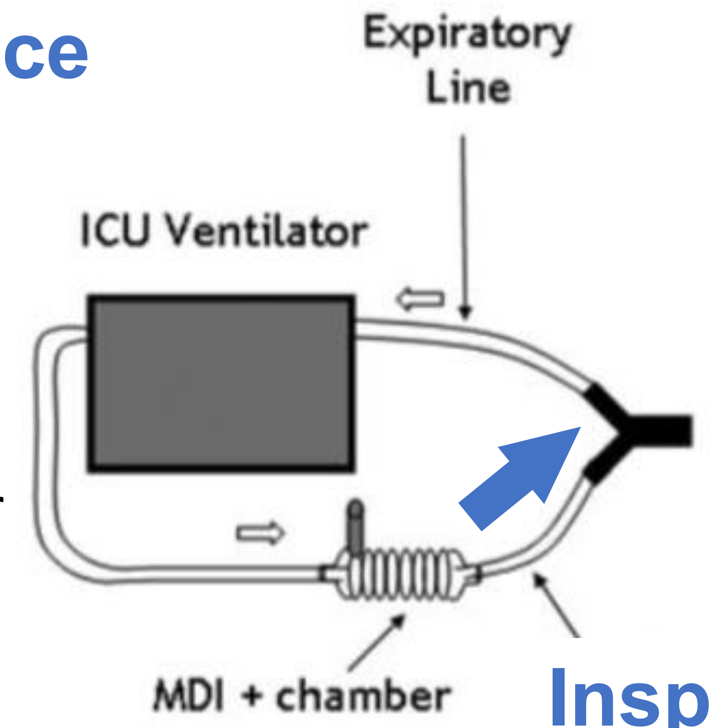
Jet Nebulizer
15cm from ventilator



Arzu et al. Respir Care. 2010;55(7):837–844.

Procedure	*Metered-dose inhaler*	*Nebulizer*
Choose the device	MDI plus a cylinder chamber	Small volume nebulizer
Locate the device	In the inspiratory line between 10 to 30 cm from the Y piece	
	Bottom-up in the chamber	Horizontal

1. Locate the device



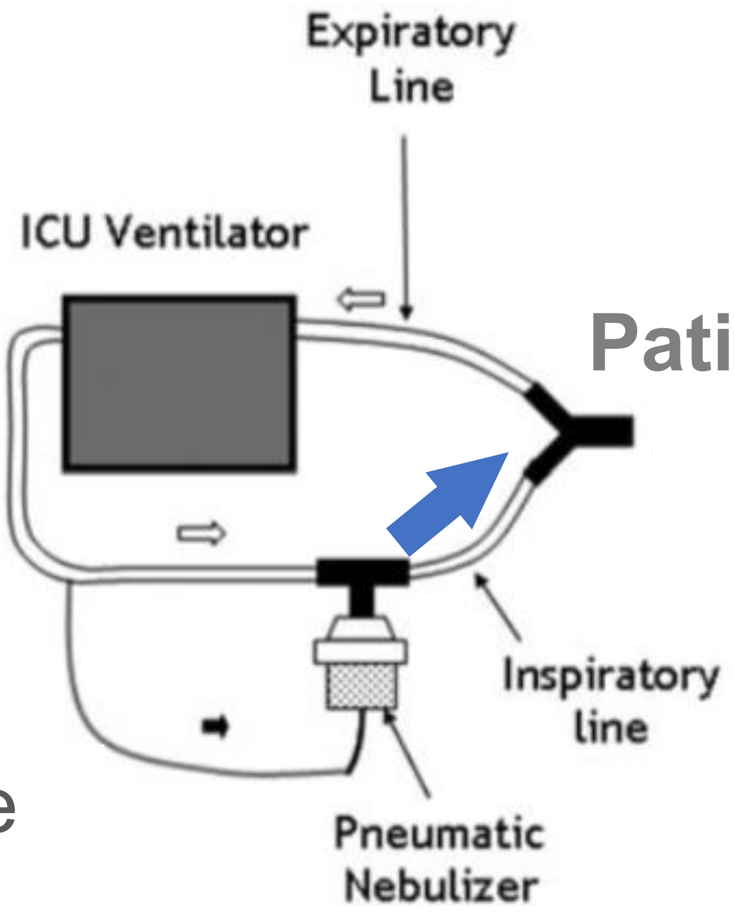
Metered dose inhaler

MDI

Inspiratory limb

15cm from Y piece

MDI+ **Spacer**



Guerin. J Aerosol Med Pulm Drug Deliv. 2008 Mar;21(1):85-96

Procedure	*Metered-dose inhaler*	*Nebulizer*
Minimize humidity of the air	**2. STOP** Heater-humidifier	
Clear the airways	**3. Sputum suction**	

Please wait

until the end of the talk **!**

Procedure	*Metered-dose inhaler*	*Nebulizer*
Adjust ventilator settings	a. V_T 500 mL: make sure that plateau pressure if measurable ≤32 cm H_2O b. Duty cycle ≥0.30 and/or inspiratory flow 30–50 L/min: make sure that intrinsic PEEP does not rise c. No change in applied PEEP and F_IO_2	

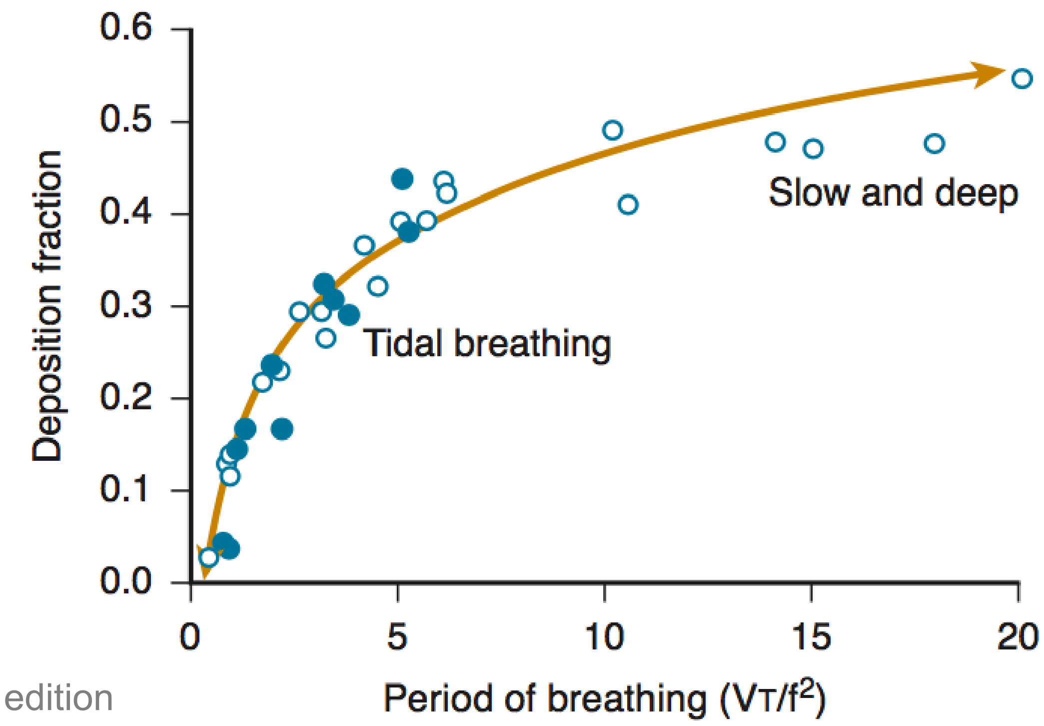
4. Ventilator settings

Deep Vt 500ml

Slow

↑Vt/f^2

1. ↑Vt 越深
2. ↓f 越慢



Murray & Nadels et al, Textbook of Respiratory Medicine, 6th edition

Guerin. J Aerosol Med Pulm Drug Deliv. 2008 Mar;21(1):85-96

Increased inspiratory flow reduces the inhaled dose.

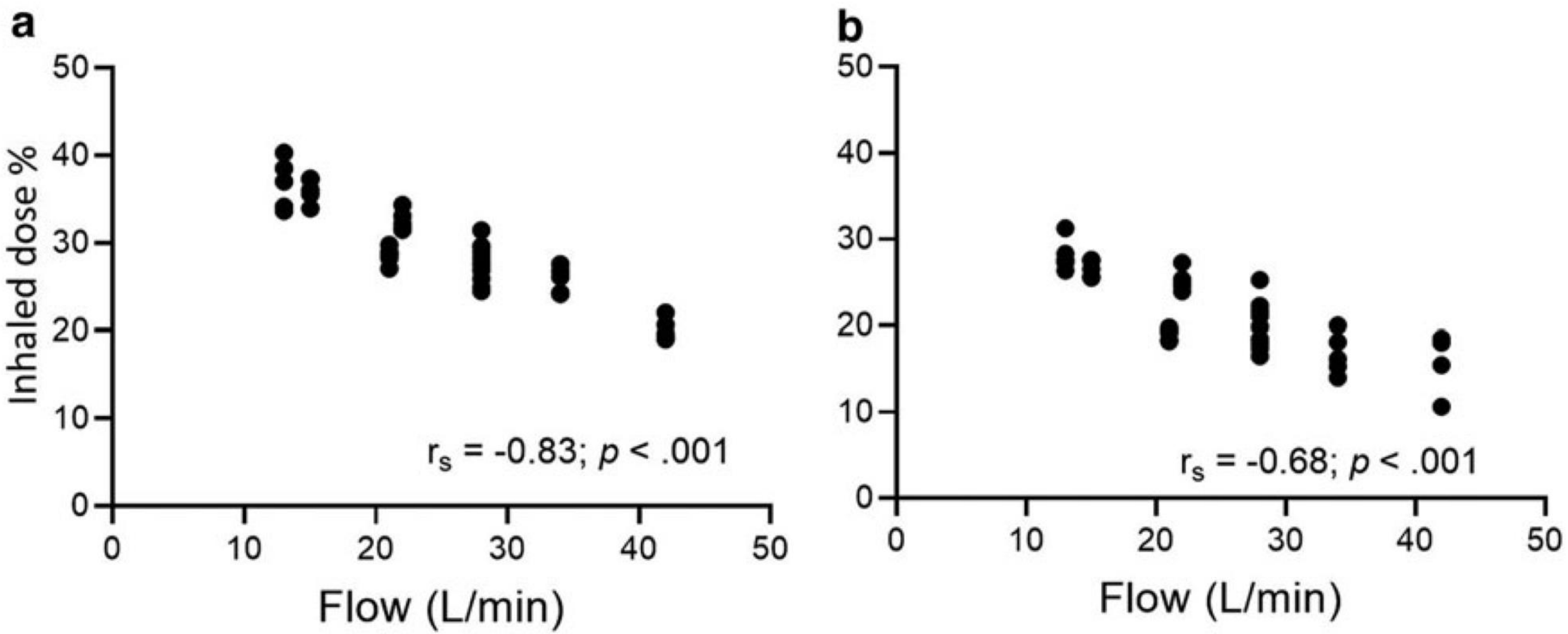


FIG. 4. Correlations between the inhaled dose with inspiratory flow. Nebulizers were placed at inlet of heated humidifier **(a)** and 15 cm away from the Y-piece **(b)**.

An inspiratory pause reduces the inhaled dose.

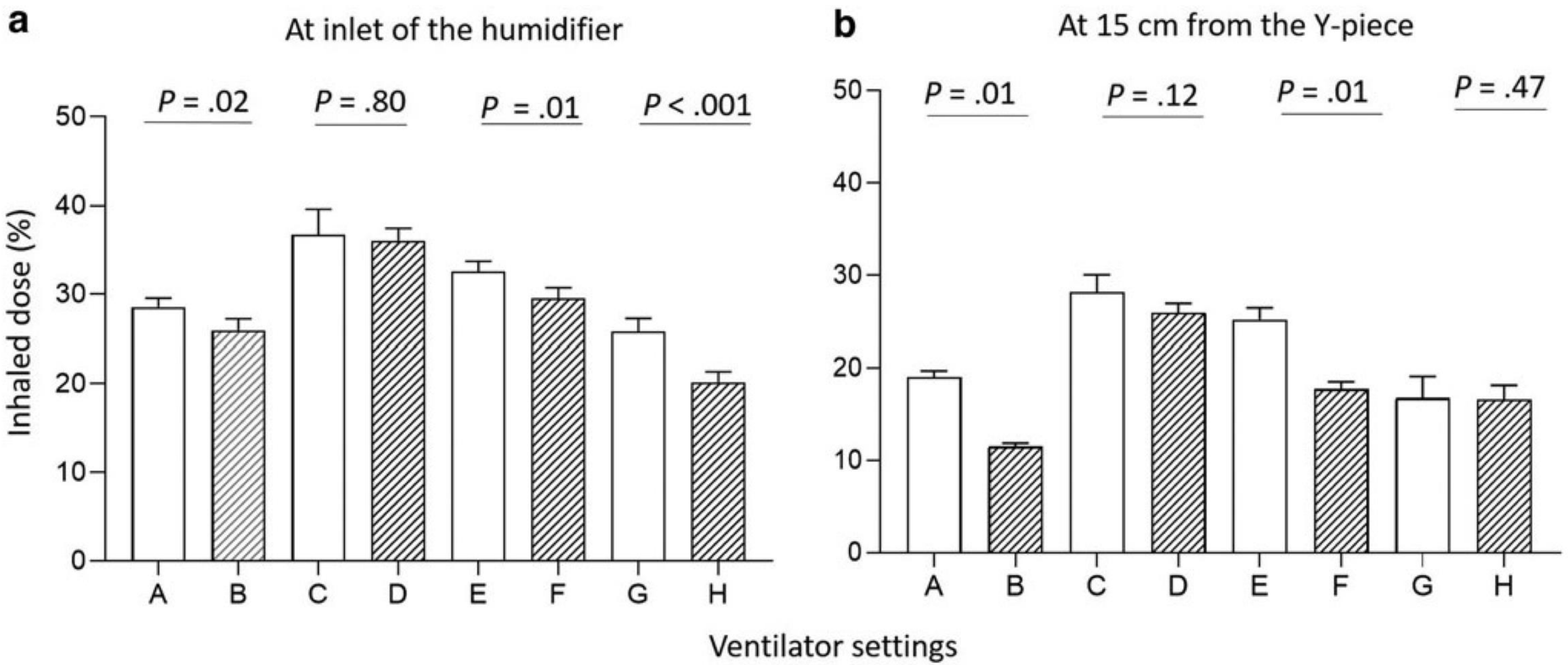


FIG. 2. Comparisons of the inhaled dose with and without an inspiratory pause across different ventilator settings. Inhaled doses (mean ± SD) without an inspiratory pause (clear bars) versus with an inspiratory pause (bars with slash lines). Nebulizer was placed at the inlet of humidifier **(a)** and 15 cm away from the Y-piece in the inspiratory limb **(b)**. SD, standard deviation.

Inline suction catheter reduces the inhaled dose

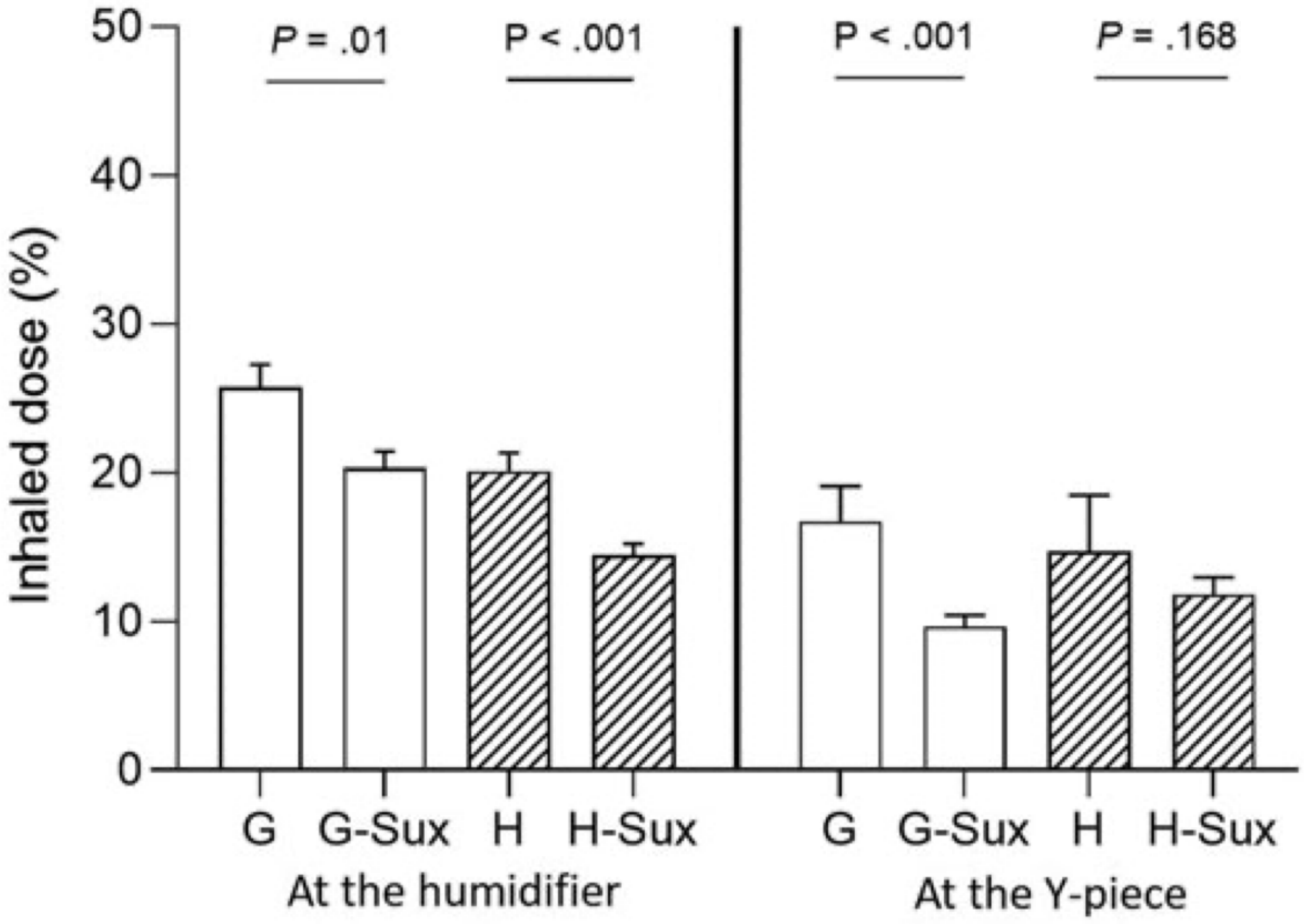


FIG. 5. Comparisons of inhaled dose with versus without an inline suction catheter with two nebulizer placements. Ventilator settings were V_T 560 mL, RR 20 breaths/min, Ti 1.0 seconds, and I:E of 1:2 and without Ti_{pause} (G) and with 0.3 seconds Ti_{pause} (H), with nebulizer placed at two nebulizer placements. Sux: with an inline suction catheter; bars with slash lines: setting with a Ti_{pause}.

J Aerosol Med Pulm Drug Deliv. 2024 Jun;37(3):125-131

Procedure	*Metered-dose inhaler*	*Nebulizer*
Proceed inhalation	a. Shake the canister. b. Actuate at the beginning of mechanical inspiration. c. Allows at least 30 sec between two actuations.	a. Fill the nebulizer with optimal volume. If unknown fill with 4–6 mL. b. Select optimal flow to power the nebulizer. If unknown, choose 6–8 L/min. c. Adjust minute ventilation if required to keep V_T constant. d. Set the optimal duration of nebulization. If unknown, choose 30 min.

5. Inhalation timing

Synchronization with the respiratory cycle: during **inspiration**

30- 60 sec interval between serial actuation

Dose-escalation protocol

Procedure	*Metered-dose inhaler*	*Nebulizer*
Observe inhalation	Observe emitted aerosol cloud for adequate aerosol generation	Observe nebulizer volume for adequate aerosol generation until sputtering
Monitor patient	a. Heart rate, SpO_2, blood pressure	a. Heart rate, SpO_2, blood pressure b. Patient–ventilator synchronization
Return to baseline after inhalation	a. Disconnect MDI plus chamber or nebulizer b. Reset previous ventilatory settings c. Heater-humidifier or heat and moisture exchanger ON	

6. Observe & monitor

7. Return to baseline

RESPIRATORY CARE 2020 VOL 65 NO 7

In Vitro Evaluation of Aerosol Performance and Delivery Efficiency During Mechanical Ventilation Between Soft Mist Inhaler and Pressurized Metered-Dose Inhaler

Wei-Ren Ke, Wei-Jhen Wang, Tzu-Hsuan Lin, Chao-Ling Wu, Sheng-Hsiu Huang, Huey-Dong Wu, and Chih-Chieh Chen

Respimate

Soft moisture inhaler

SMI

2 puffs of tiotropium (2.5 μ g/puff) with T-adaptor connection

LAMA for stable COPD **decrease resistance and peak inspiratory pressure (1h - 6h – 12 h)**

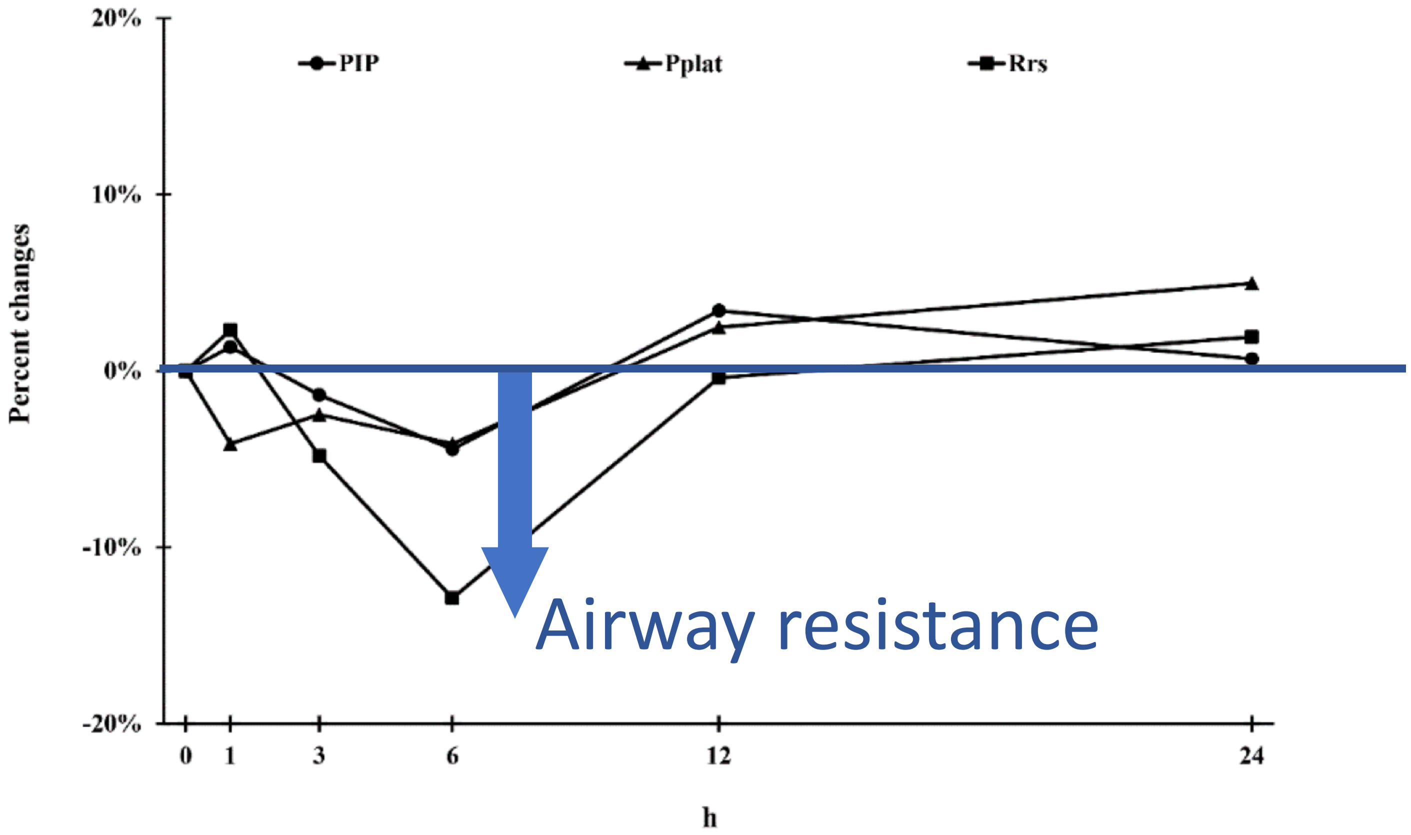
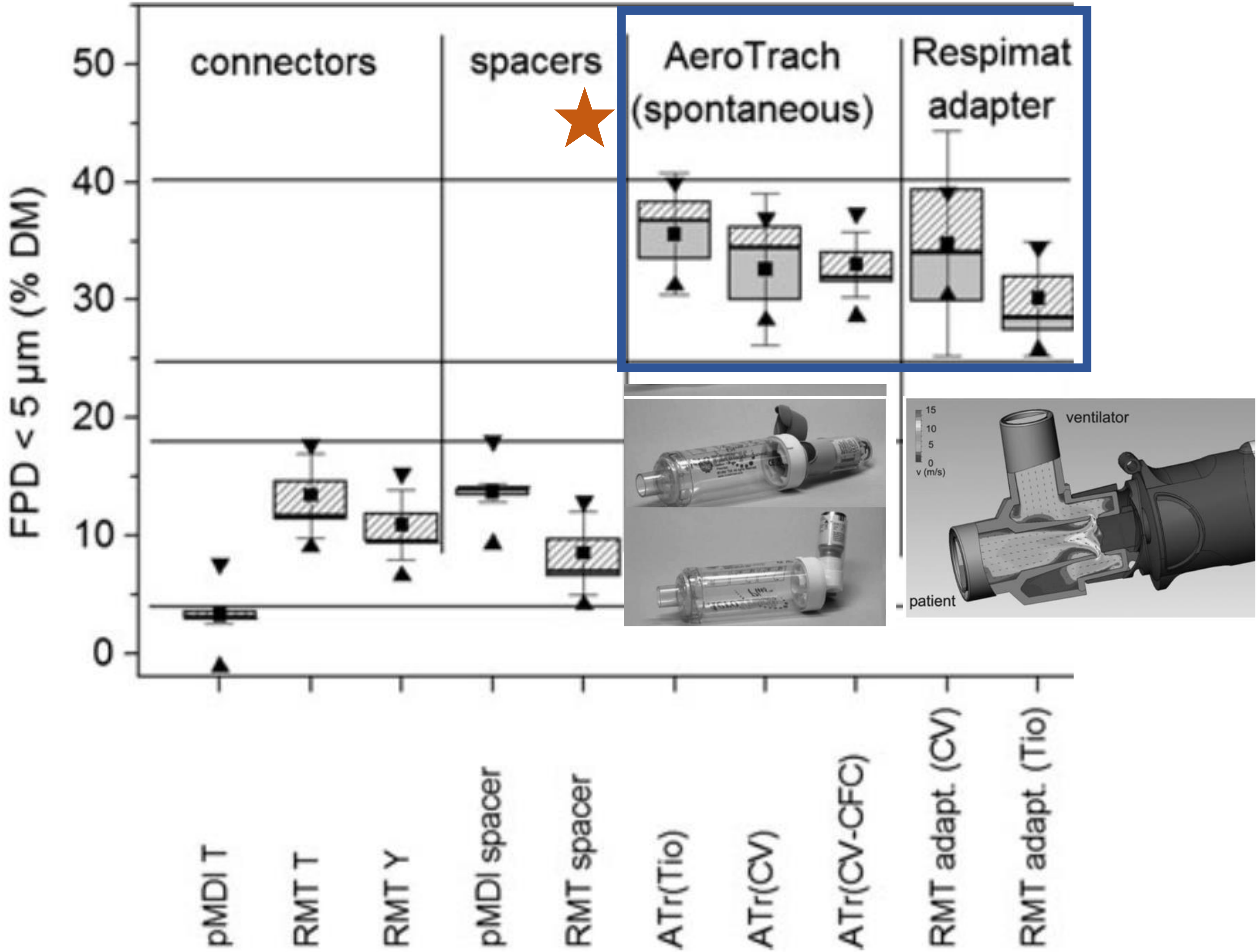
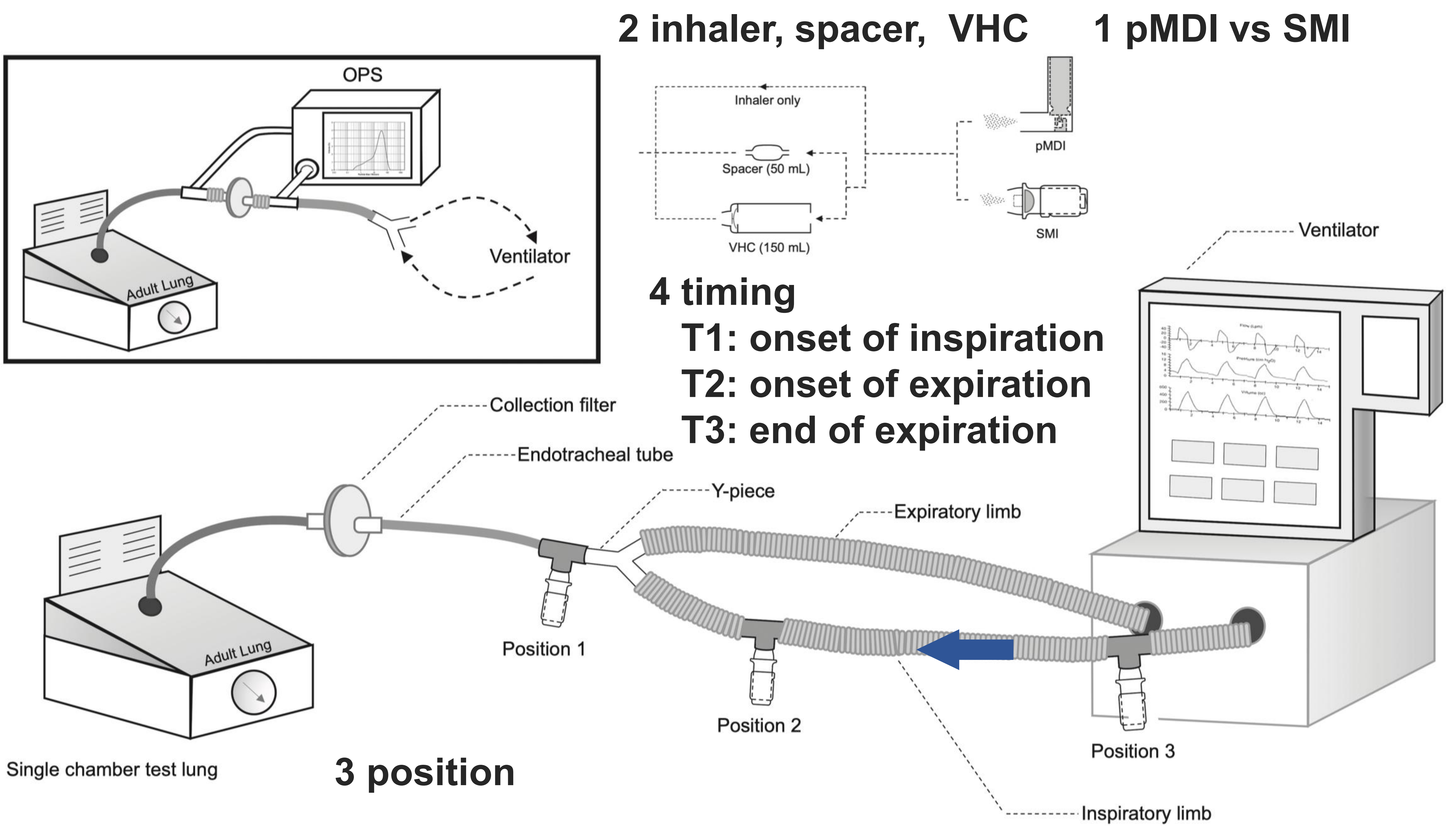


Figure 1. Percent changes (△-difference %) in Peak inspiratory pressure (PIP), mean airway pressure (Pmean), plateau pressure (Pplat), and maximum resistance of the respiratory system (Rrs).

Fu et al. Pharmaceutics 2021, 13, 51.

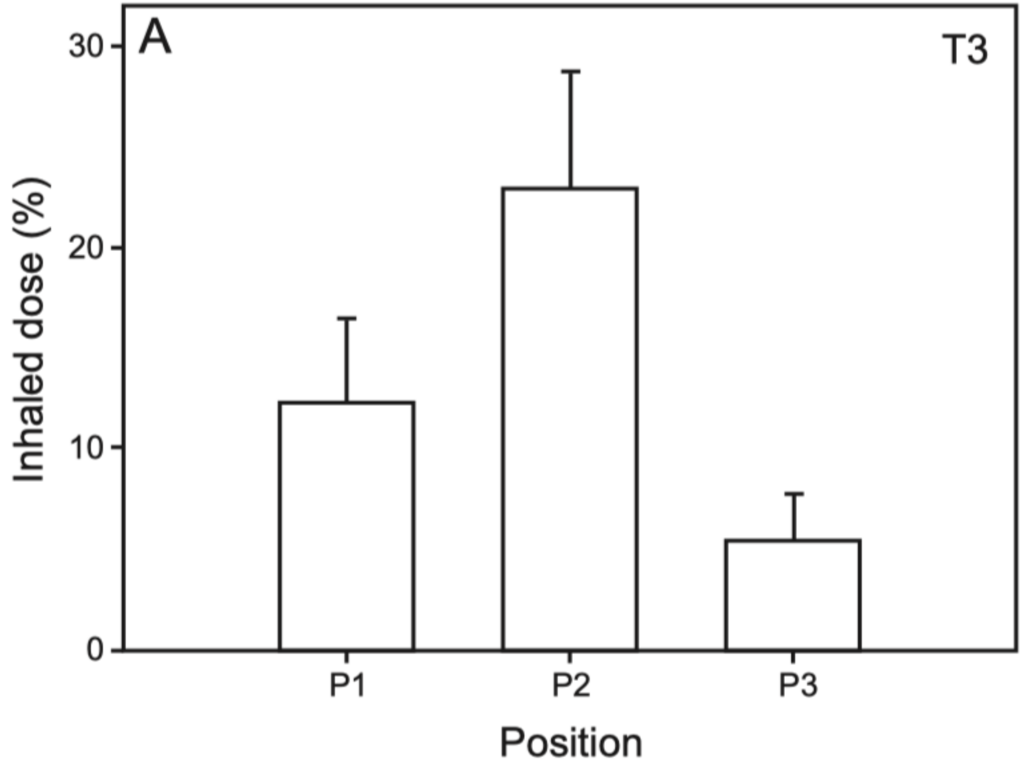


Dellweg. J Aerosol Med Pulm Drug Deliv. 2011 Dec;24(6):285-92

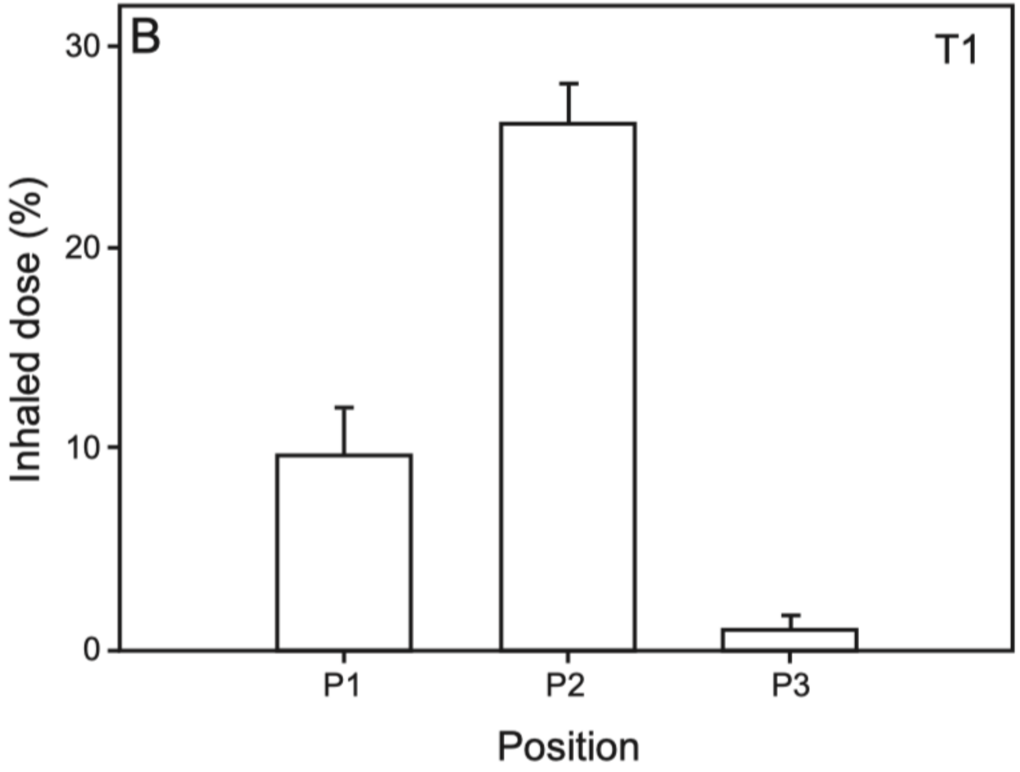

2 inhaler, spacer, VHC
1 pMDI vs SMI
OPS
Adult Lung
Ventilator
Inhaler only
Spacer (50 mL)
VHC (150 mL)
pMDI
SMI
4 timing
T1: onset of inspiration
T2: onset of expiration
T3: end of expiration
Ventilator
Collection filter
Endotracheal tube
Y-piece
Expiratory limb
Adult Lung
Position 1
Position 2
Position 3
Single chamber test lung
3 position
Inspiratory limb

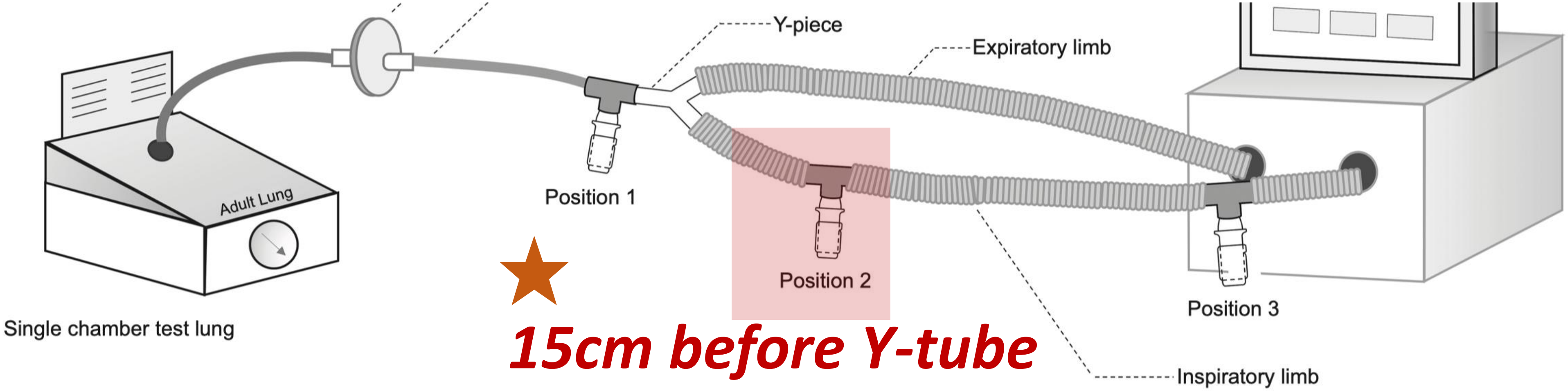
Position

SMI



MDI



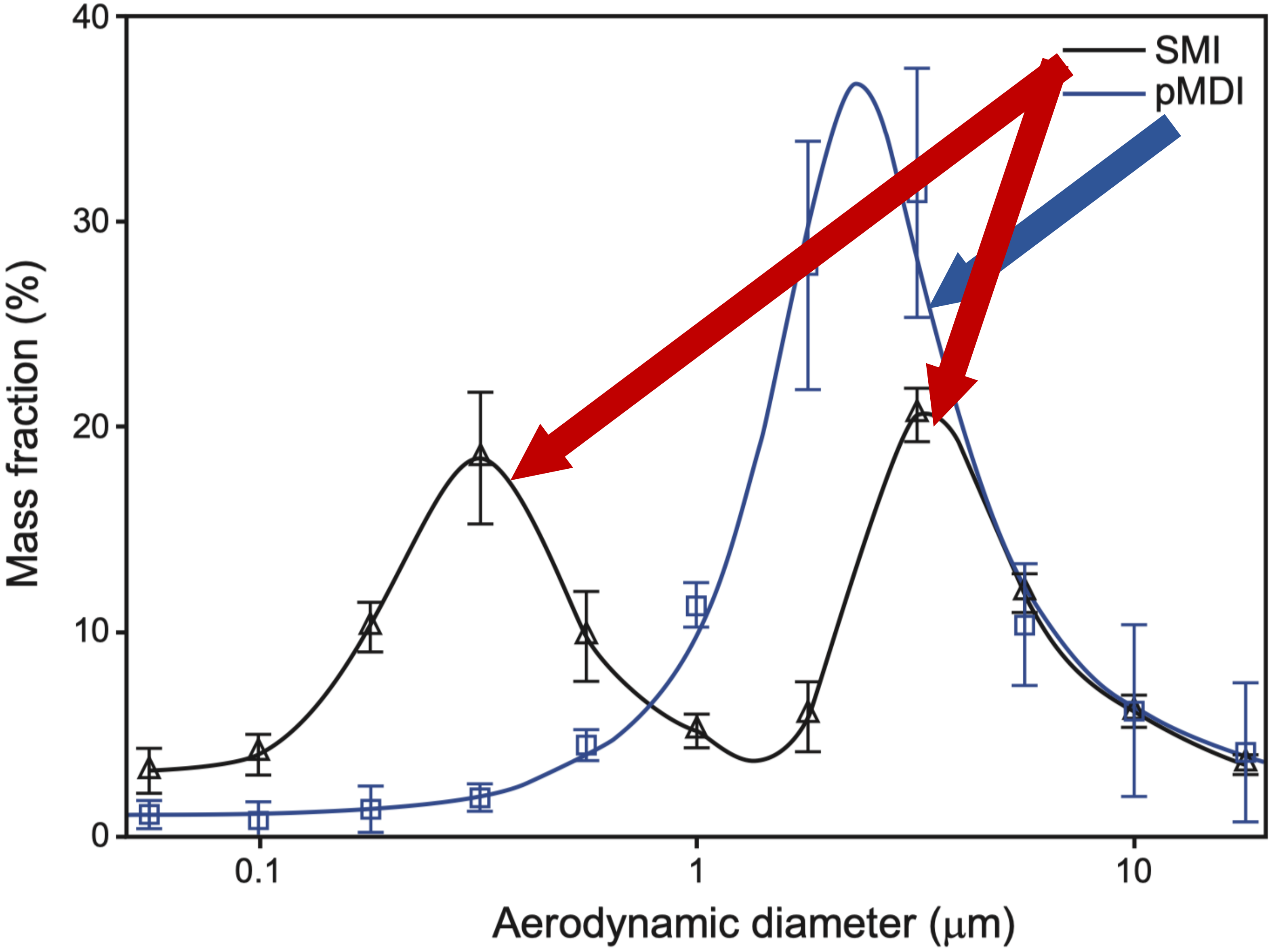


SMI generated **smaller** MMAD (mass median aerodynamic diameter) than the pMDI
the PSD(particle size distribution) of the SMI showed **bimodal** distribution

Respimate

Soft moisture inhaler

SMI



Timing

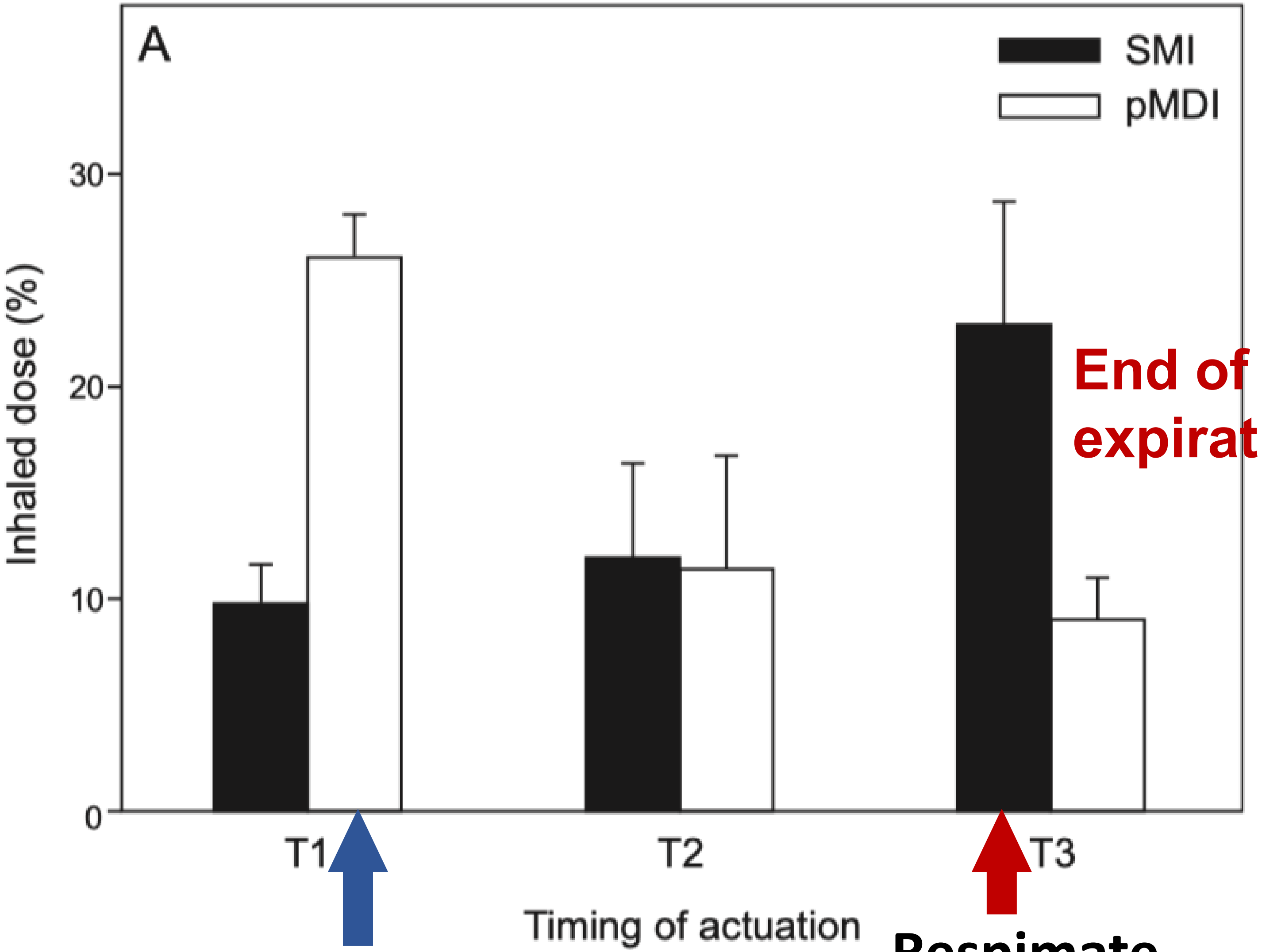
T1: onset of inspiration
T2: onset of expiration
T3: end of expiration

SMI: end of expiration
pMDI: onset of inspiration

The spray duration
SMI : **1.43** ± 0.12 s
pMDI: **0.17** ± 0.03 s

Ti: 0.9 s

★



Metered dose inhaler

MDI

Respimate

Soft moisture inhaler

SMI

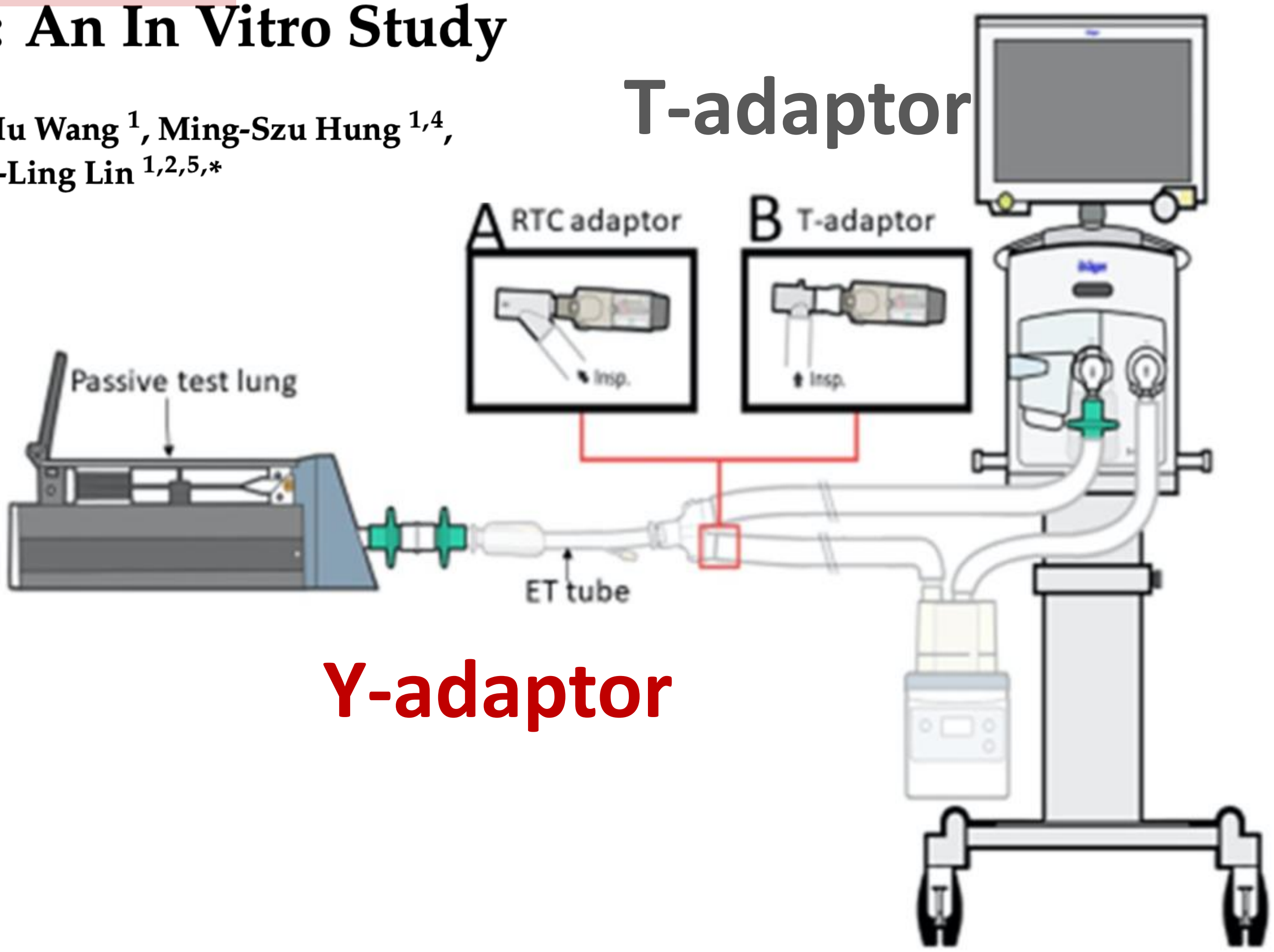
pharmaceutics

MDPI

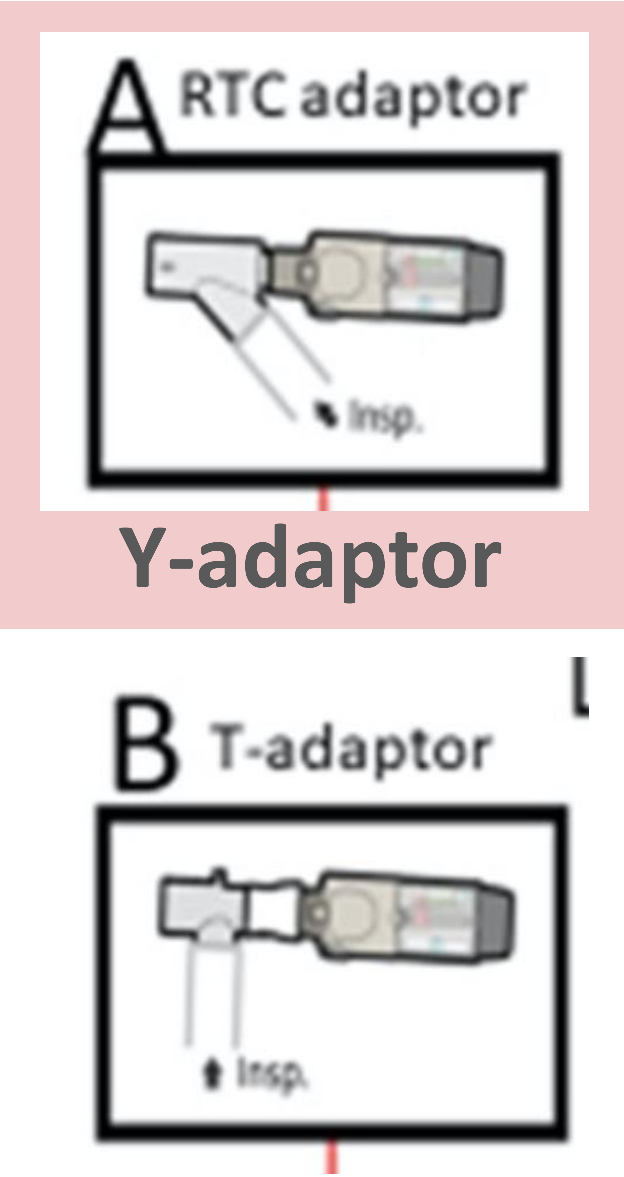
Article

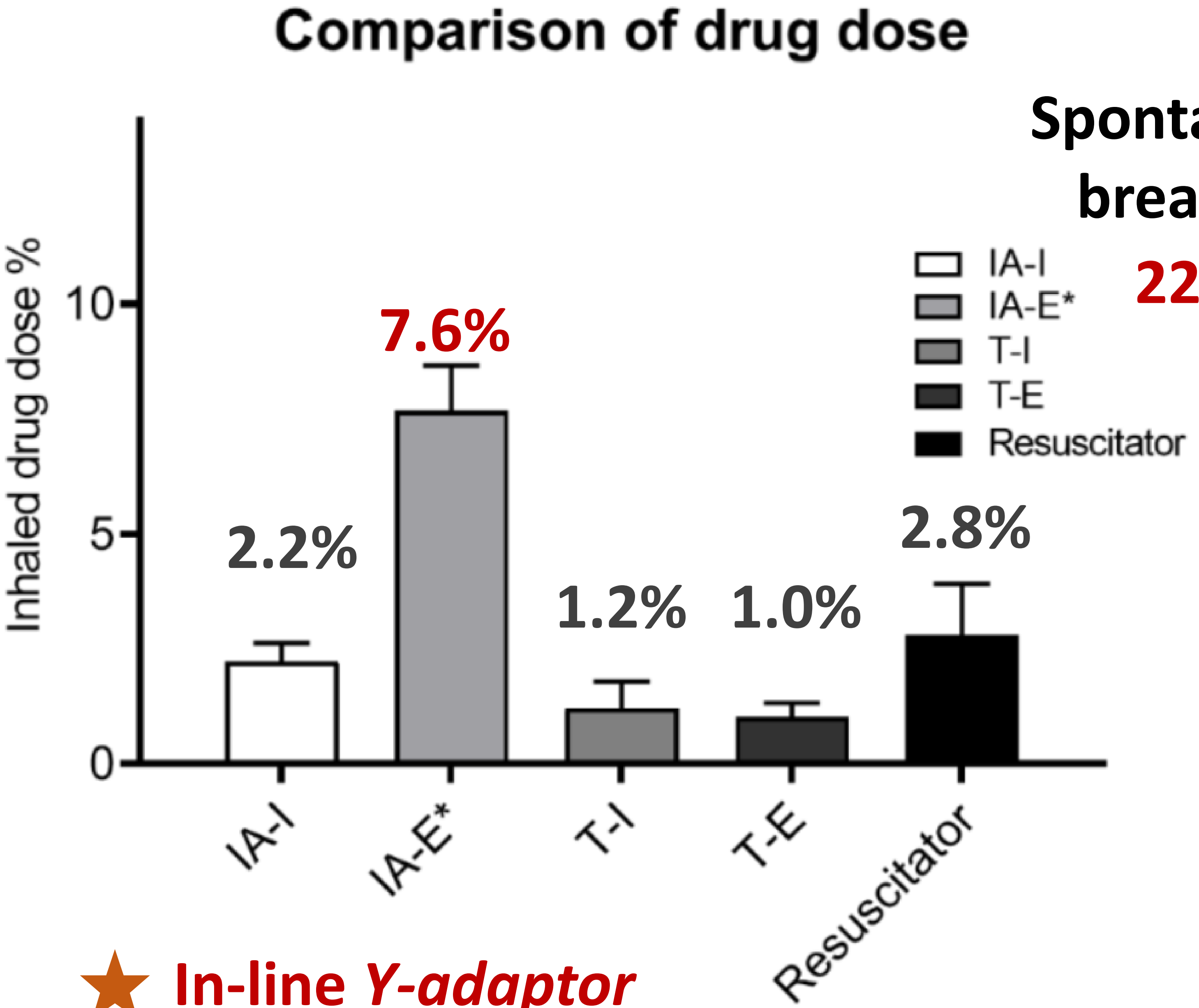
Optimal Connection for Tiotropium SMI Delivery through Mechanical Ventilation: An In Vitro Study

Tien-Pei Fang [1,2], Yu-Ju Chen [3], Tsung-Ming Yang [4], Szu-Hu Wang [1], Ming-Szu Hung [1,4], Shu-Hua Chiu [1], Hsin-Hsien Li [5], James B. Fink [6] and Hui-Ling Lin [1,2,5,*]



Pharmaceutics 2020, 12, 291





Spontaneous breathing

22.8%

★ **In-line *Y-adaptor***
Actuation during *Expiration*


1. T connection
Air vents: open

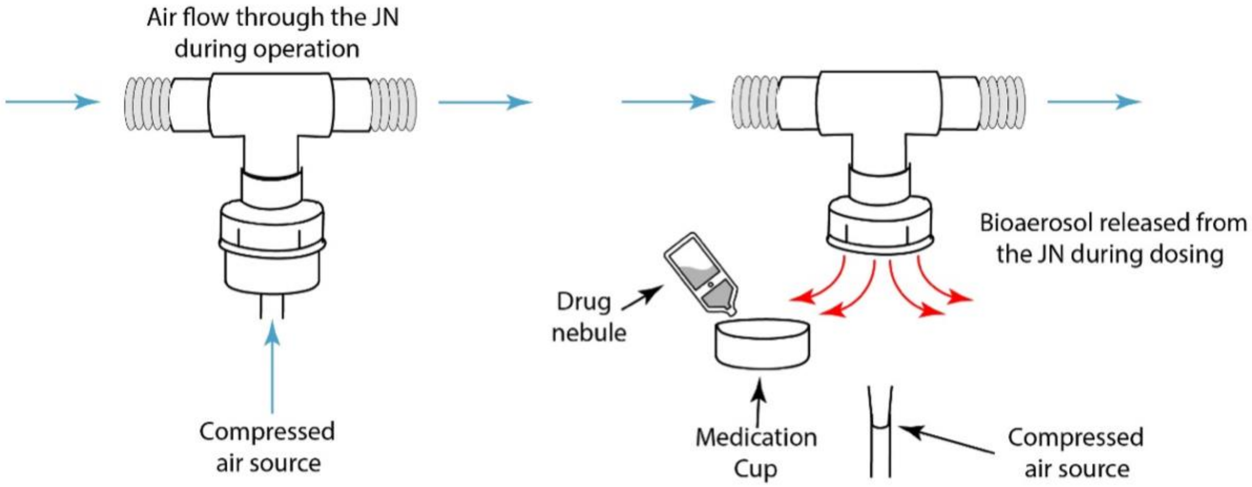

2. T connection
Air vents: close

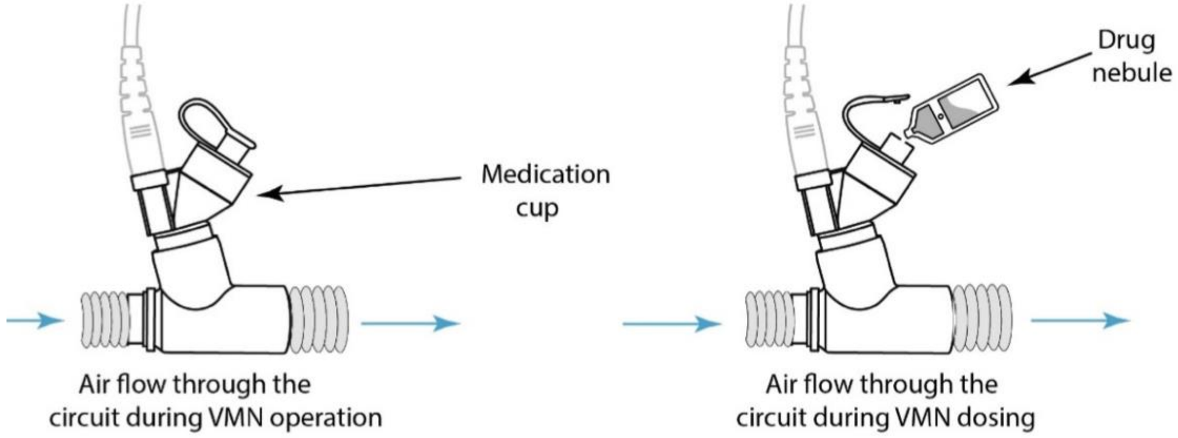

3. Y connection
Air vents: close


3. 吐氣期給藥
2. Y型接頭
1. 進氣端，Y型接管前15 cm


Patient
MDI or Respimat
AeroChamber Plus Flow-Vu
Anti-Static Valved Holding Chamber
Trudell Medical International

Nebuliser Type Influences risk of **release of patient-derived bioaerosol to environment**





Drug refill process for a **jet nebuliser (JN)** which results in an **open** ventilator.

For a a **vibrating mesh nebuliser (VMN)** which maintains the **closed** ventilator circuit and ***mitigates*** the risk of release of patient-derived bioaerosol to environment.

Joyce, M.; et al. Pharmaceutics 2021, 13, 199.

Average **particulate concentrations number** and **PEEP** during drug refill

Vibrating mesh nebulizer

Table 1. Median and IQR (interquartile range) particulate number concentrations across all test runs detected for simulated drug refill at the two-minute mark.

Particulate Number Concentrations (#/cm^{-3}) Median and IQR		
Vibrating Mesh Nebuliser	**Jet Nebuliser**	**JN with Endotracheal Tube Clamped**
0 (0.1–0.6)	710 (265–1211)	60 (31–140)

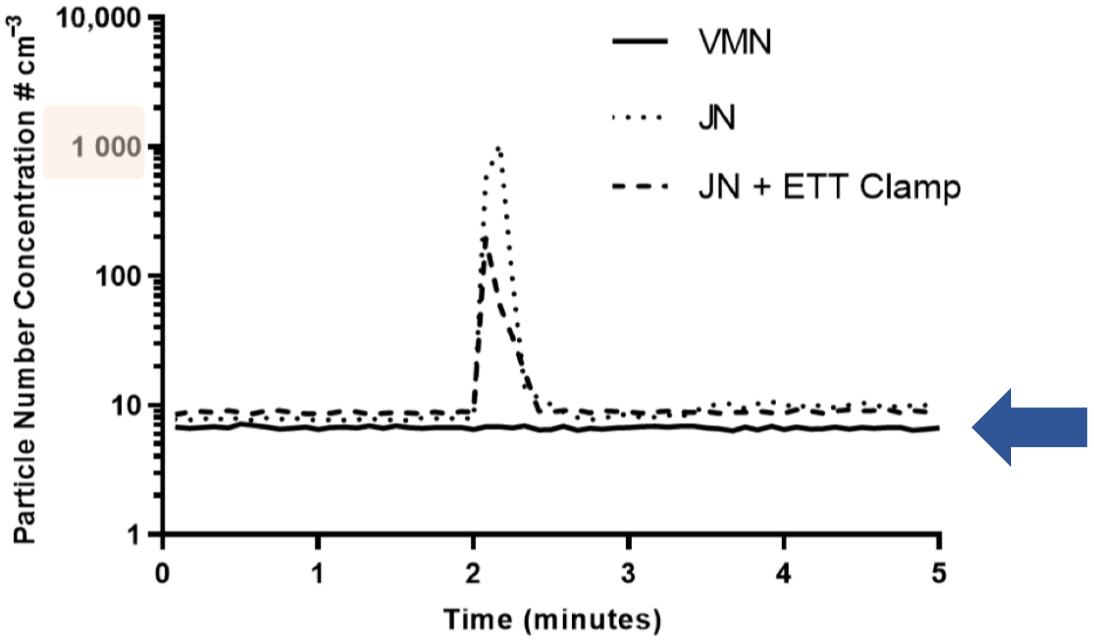
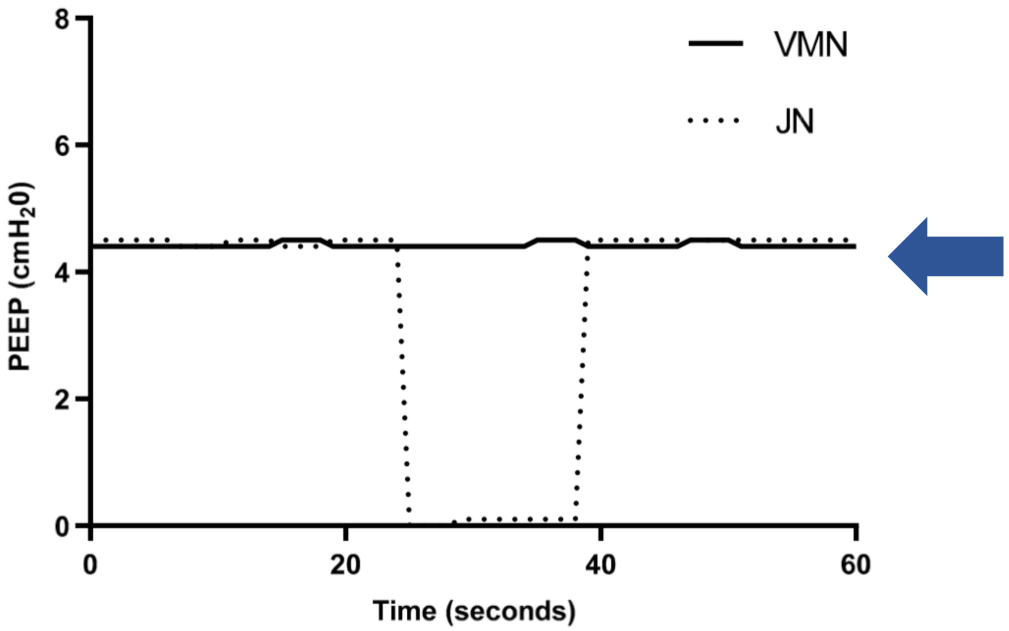


Table 2. Average ± SD PEEP (positive end expiratory pressure) during nebuliser drug refill.

PEEP (cmH_2O) Average ± SD	
Vibrating Mesh Nebuliser	**Jet Nebuliser**
4.4 ± 0.0	3.5 ± 1.9



Joyce, M.; et al. Pharmaceutics 2021, 13, 199.

Application of Aerosol Therapy in Ventilated Patients **during COVID-19 Pandemic**

Strategy

1. Do not use a jet nebulizer or pMDIs for aerosol delivery to ventilator-dependent patients with COVID-19 due to the breakage of the circuits for the placement of the device before aerosol therapy.
2. Use mesh nebulizers in critically ill patients with COVID-19 receiving ventilator support as they can stay in-line for up to 28 days, and reservoir design allows adding medication without requiring the ventilator circuit to be broken for aerosol drug delivery. Unlike jet nebulizer, the medication reservoir of mesh nebulizers is isolated from the breathing circuit that eliminates the nebulization of contaminated fluids.
3. Placing the mesh nebulizer prior to the humidifier can improve the efficiency of the treatment and further reduce retrograde contamination from the patient.
4. Attach a HEPA filter to the expiratory limb of the ventilator to reduce secondhand aerosol exposure and prevent the transmission of infectious droplet nuclei through the ventilators.
5. Do not combine aerosol therapy with pulmonary clearance techniques such as chest physical therapy and suctioning.
6. Use in-line, or closed system suction catheters if the patient with COVID-19 is intubated and needs endotracheal suctioning during mechanical ventilation because they can be utilized up to 7 days without having to break the ventilator circuit.
7. Wear personal protective equipment, including an N95 respirator, goggles/face shield, double gloves, gown or apron if the gown is not fluid resistant.

Ari, et al, Respiratory Medicine 167 (2020) 105987

Li *et al. Annals of Intensive Care* (2023) 13:63
https://doi.org/10.1186/s13613-023-01147-4

Annals of Intensive Care

RESEARCH **Open Access**

Check for updates

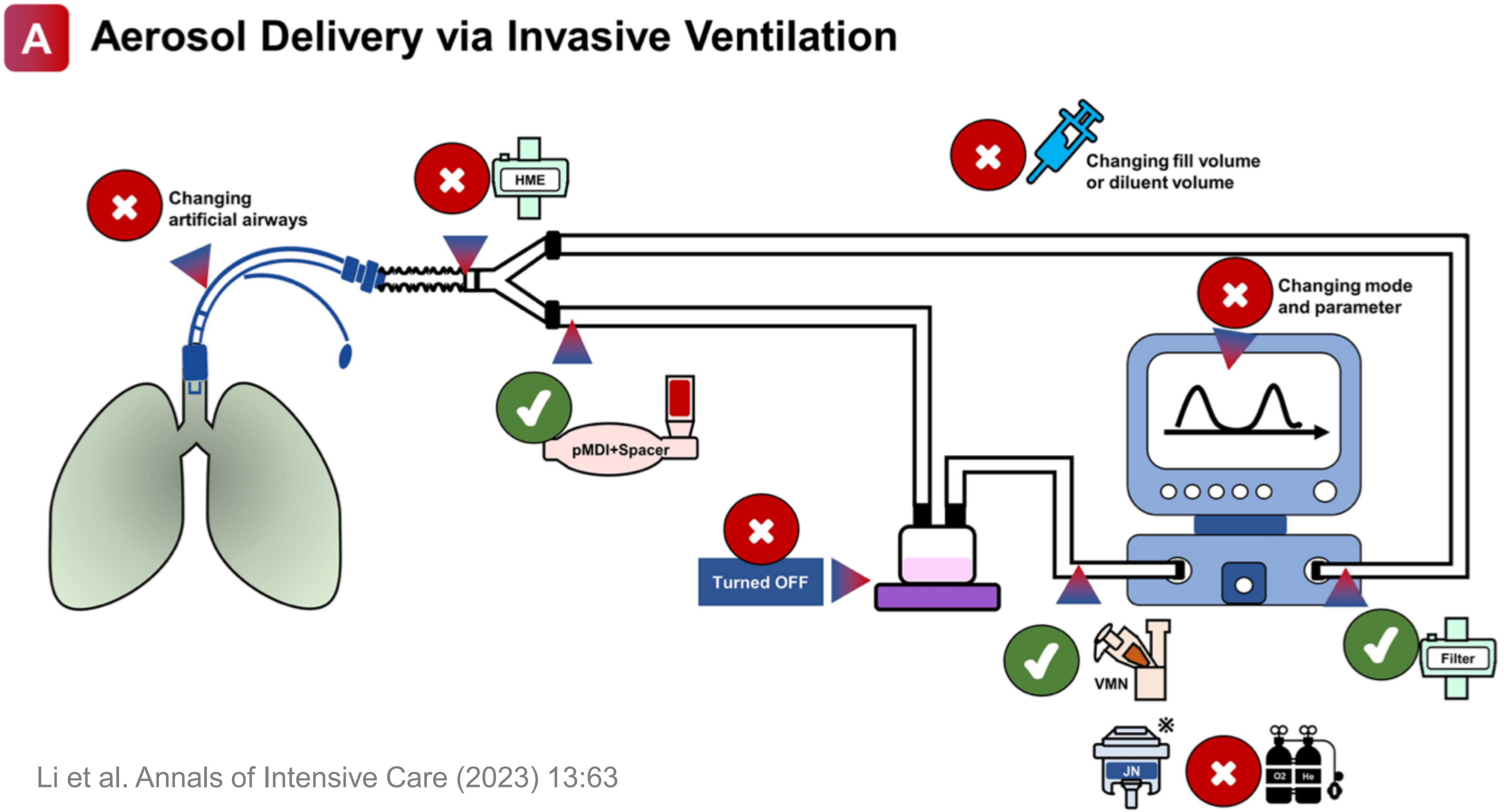
Aerosol therapy in adult critically ill patients: a consensus statement regarding aerosol administration strategies during various modes of respiratory support

Jie Li[1*†], Kai Liu[2†], Shan Lyu[3†], Guoqiang Jing[4†], Bing Dai[5†], Rajiv Dhand[6], Hui-Ling Lin[7], Paolo Pelosi[8,25^], Ariel Berlinski[9], Jordi Rello[10,23,24], Antoni Torres[11,23], Charles-Edouard Luyt[12], Jean-Bernard Michotte[13], Qin Lu[14], Gregory Reychler[15,21,22], Laurent Vecellio[16], Armèle Dornelas de Andrade[17], Jean-Jacques Rouby[18], James B. Fink[1,19] and Stephan Ehrmann[20]

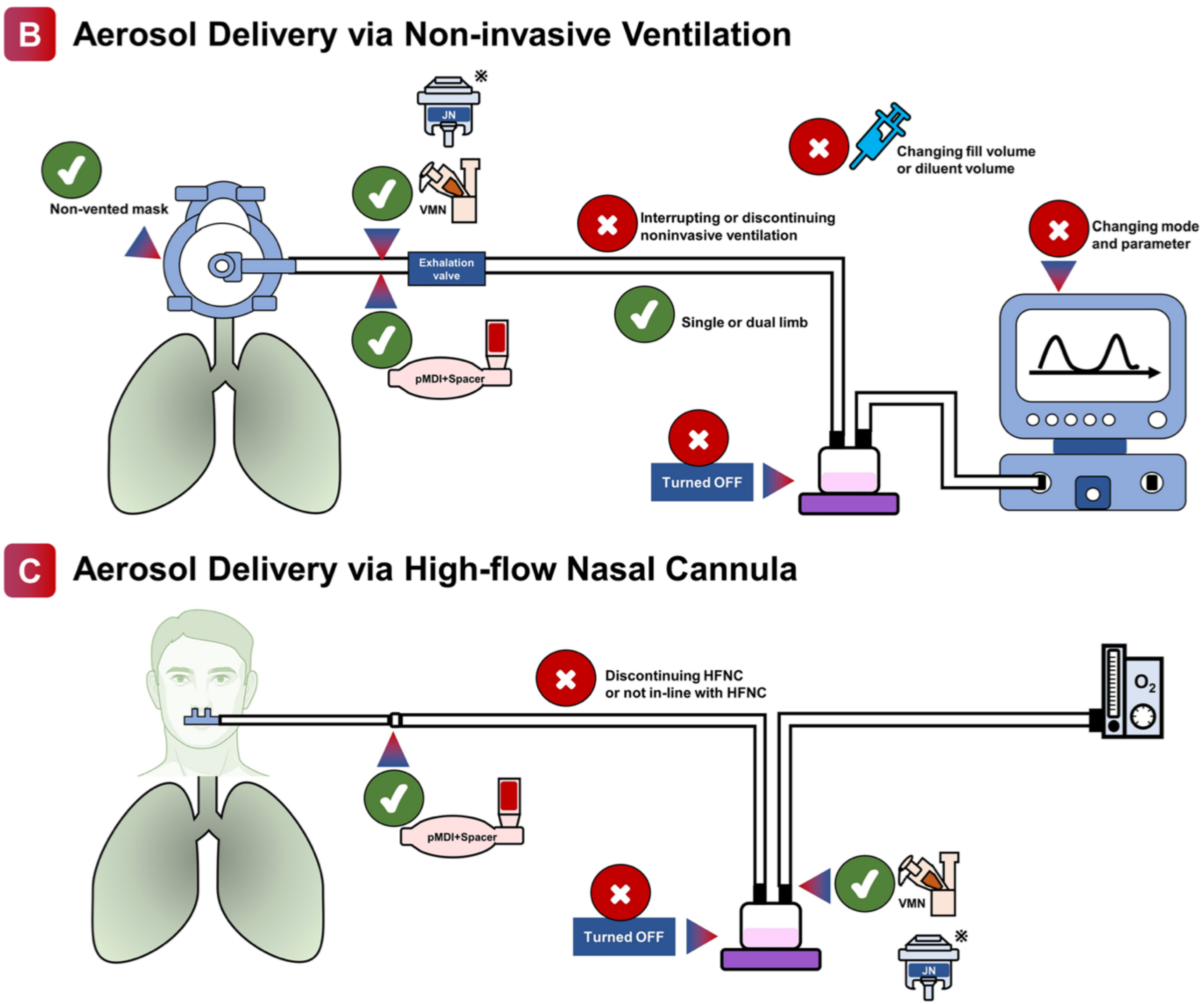
★ Position

MDI / SMI: **Inspiratory limbs,15cm from Y piece**

VMN: **heated humidifier inlet**



Li et al. Annals of Intensive Care (2023) 13:63

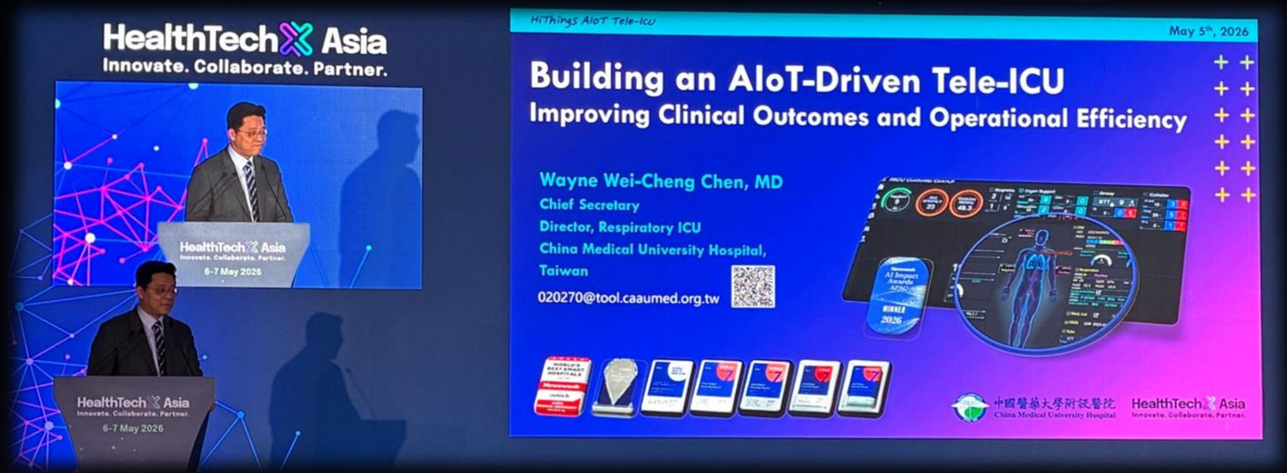


NIPPV

High flow Nasal cannula

※ in some in vitro experiments a continuous JN placed in those positions is less efficient than VMN for aerosol delivery.

Li et al. Annals of Intensive Care (2023) 13:63



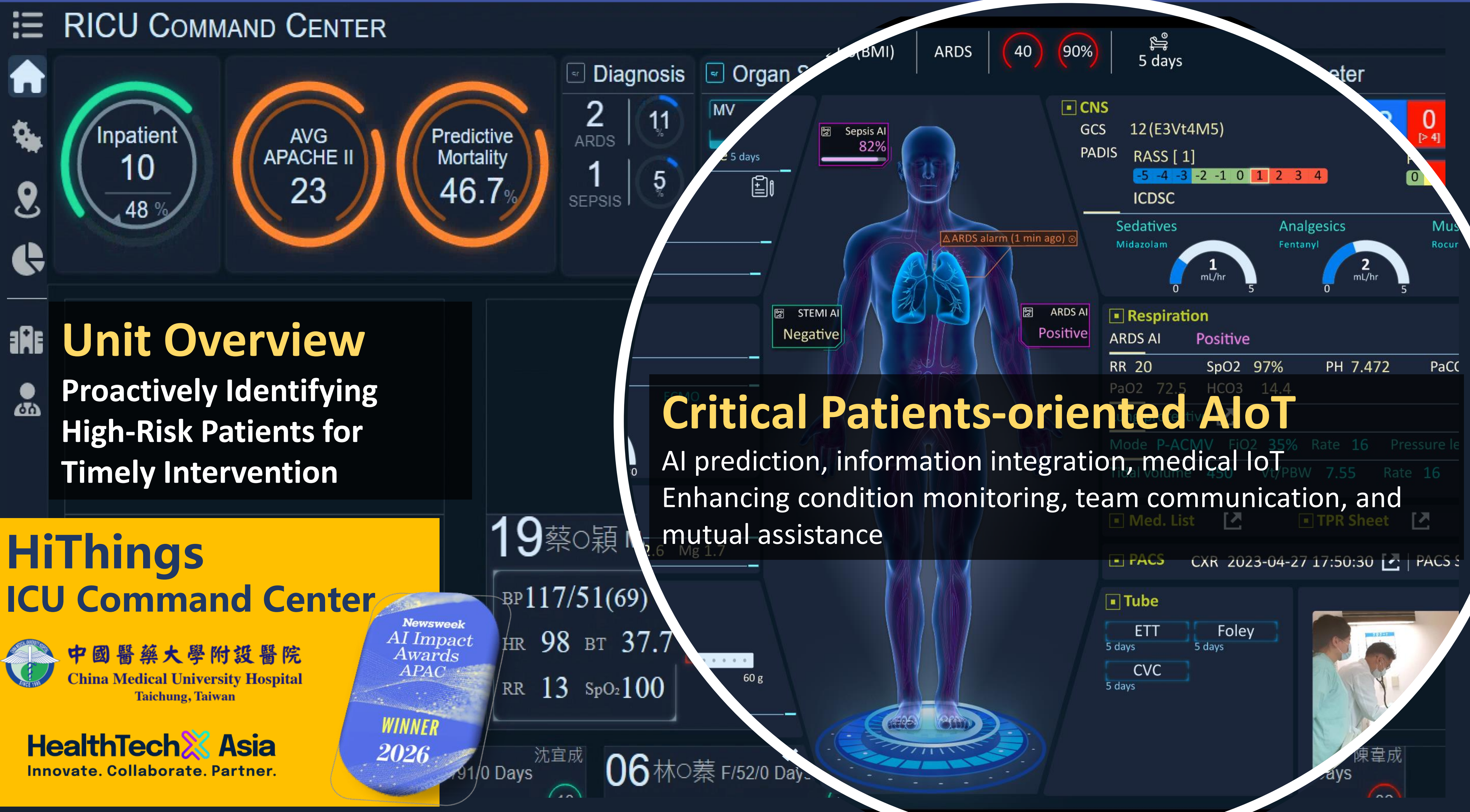
Scaling Healthcare Ecosystem | Workflow, Ambient AI, and Agentic AI

HealthTechX Asia

May 6-7, 2026

Singapore

Medical AIoT X Digital Twin X Remote Collaboration



Unit Overview

Proactively Identifying High-Risk Patients for Timely Intervention

Critical Patients-oriented AIoT

AI prediction, information integration, medical IoT
Enhancing condition monitoring, team communication, and mutual assistance

HiThings
ICU Command Center

中國醫藥大學附設醫院
China Medical University Hospital
Taichung, Taiwan

HealthTechX Asia
Innovate. Collaborate. Partner.

Newsweek
AI Impact Awards
APAC
WINNER
2026

離線強化學習（Offline Reinforcement Learning）

分析既有臨床資料，在真實醫療情境中做出更符合臨床需求的治療決策。

1. 以「無呼吸器天數 (VFD)」作為核心評估指標，導向脫離成功
2. 利用「混合行動空間 (Hybrid Action Space)」提升治療精準度與安全性
3. 強化安全性約束：確保跨醫院數據的通用性

[Submitted on 17 Jun 2025 (v1), last revised 15 Jan 2026 (this version, v2)]

Advancing Safe Mechanical Ventilation Using Offline RL With Hybrid Actions and Clinically Aligned Rewards

Muhammad Hamza Yousuf, Jason Li, Sahar Vahdati, Raphael Theilen, Jakob Wittenstein, Jens Lehmann

Invasive mechanical ventilation (MV) is a life-sustaining therapy commonly used in the intensive care unit (ICU) for patients with severe and acute conditions. These patients frequently rely on MV for breathing. Given the high risk of death in such cases, optimal MV settings can reduce mortality, minimize ventilator-induced lung injury, shorten ICU stays, and ease the strain on healthcare resources. However, optimizing MV settings remains a complex and error-prone process due to patient-specific variability. While Offline Reinforcement Learning (RL) shows promise for optimizing MV settings, current methods struggle with the hybrid (continuous and discrete) nature of MV settings. Discretizing continuous settings leads to exponential growth in the action space, which limits the number of optimizable settings. Converting the predictions back to continuous can cause a distribution shift, compromising safety and performance. To address this challenge, in the IntelliLung project, we are developing an AI-based approach where we constrain the action space and employ factored action critics. This approach allows us to scale to six optimizable settings compared to 2-3 in previous studies. We adapt SOTA offline RL algorithms to operate directly on hybrid action spaces, avoiding the pitfalls of discretization. We also introduce a clinically grounded reward function based on ventilator-free days and physiological targets. Using multiobjective optimization for reward selection, we show that this leads to a more equitable consideration of all clinically relevant objectives. Notably, we develop a system in close collaboration with healthcare professionals that is aligned with real-world clinical objectives and designed with future deployment in mind.

Comments: Accepted to AAAI-26
Subjects: **Machine Learning (cs.LG)**; Artificial Intelligence (cs.AI)
Cite as: arXiv:2506.14375 **[cs.LG]**
(or arXiv:2506.14375v2 **[cs.LG]** for this version)
https://doi.org/10.48550/arXiv.2506.14375

Summary

Prevalence

BD, ICS, Abx
Nebulizer most
Different MV settings

Drugs

AE: Short-acting, Nebulizer
May add long-acting BD when condition is stable

Devices

MDI / SMI+ spacer/Chamber > VMN > JN

Deposition

of the aerosol therapy

Central airway
Limited by secretion and atelectasis

Ventilator settings

MDI / SMI: **Inspiratory limbs,15cm from Y piece**
VMN: **heated humidifier inlet**
Vt ↑, RR ↓, ↓ Inspiratory flow
MDI: inspiration, SMI: **Y-connector, expiration**
30-60s interval, ↑ dose

中國醫藥大學附設醫院 胸腔內科暨重症系 陳韋成醫師