Feasibility of prolonged manual ventilation

CAPT Mark F Brady, MD, MPH, MMSc, DTM&H, FACEP, MC, USN
Alpert Medical School of Brown University, Providence, RI, USA

MHSRS Kissimmee, FL 3 August, 2026

Author List

Mark F Brady, MD, MPH[1]

Korinne Dankievitch, BS[2]

Soniya Regmi, MBBS[2]

Emily Kendall[2]

Xinzhi Zhang, MS[2]

Barret Zimmerman, MD[3]

Arthur S Slutsky, MD[2,4]

1. Alpert Medical School of Brown University, Providence, RI
2. SafeBVM, Boston, MA
3. Harvard Medical School / Mass General Brigham, Boston, MA
4. Li Ka Shing Knowledge Institute, St. Michael's Hospital, Unity Health Toronto; University of Toronto, CA

Disclosures

The opinions and assertions expressed herein are those of the author and do not reflect the official policy or position of the Department of Defense.

Dr. Mark Brady has no relevant financial relationships to disclose.

Authors Xinzhi Zhang, Korinne Dankievitch, Soniya Regmi and Emily Kendall were compensated through a DoD grant awarded to SafeBVM.

Arthur Slutsky is the part-time Chief Scientific Officer for SafeBVM.

UNCLASSIFIED

Disclosures

The U.S. Army Medical Research Acquisition Activity, 808 Schreider Street, Fort Detrick MD 21702-5014 is the awarding and administering acquisition office. This work was supported by The Assistant Secretary of Defense for Health Affairs endorsed by the Department of Defense, in the amount of $4,536,252 through the Peer Reviewed Medical Research Program under Award Number HT9425-23-1-0316. Opinions, interpretations, conclusions, and recommendations are those of the author(s) and are not necessarily endorsed by The Assistant Secretary of Defense for Health Affairs endorsed by the Department of Defense.

Personal Introduction

- Emergency Physician
- NIH- Fogarty Fellowship in Peru working on tuberculosis diagnostics
- Low resource medicine experience- Liberia, Cambodia, Peru, Bolivia
- Chief Operating Officer for the Memphis COVID-19 hospital (401 beds)

- Navy Reservist for ~15 years
- Deployed for COVID-19 to NYC civilian hospital
- SPMAGTF Force Surgeon
- Currently Navy Reserve Specialty Leader for Emergency Medicine

Background

- Manual ventilation with the resuscitator bag is used routinely in multiple settings, usually for short periods of time (CPR, transportation)
- Historical natural experiments (polio epidemic in Copenhagen- normal lungs) and low resource environments have necessitated prolonged manual ventilation, but performance metrics are lacking
- COVID-19 exposed the possibility of running out of ventilators
- Operational focus on prolonged field care warrants consideration of prolonged manual ventilation

Questions

1. Can personnel adequately manually ventilate an intubated patient for 8 hours?
    - Minute ventilation
    - BLS/ No BLS
2. Does a flow-limiting valve attached to the resuscitator bag affect prolonged ventilation performance or fatigue?
3. Does lung compliance affect manual ventilation performance?
4. Does a metronome affect prolonged manual ventilation performance?

Materials: FDA Approved Flow-limiting valve

https://safebvm.com/sotair/

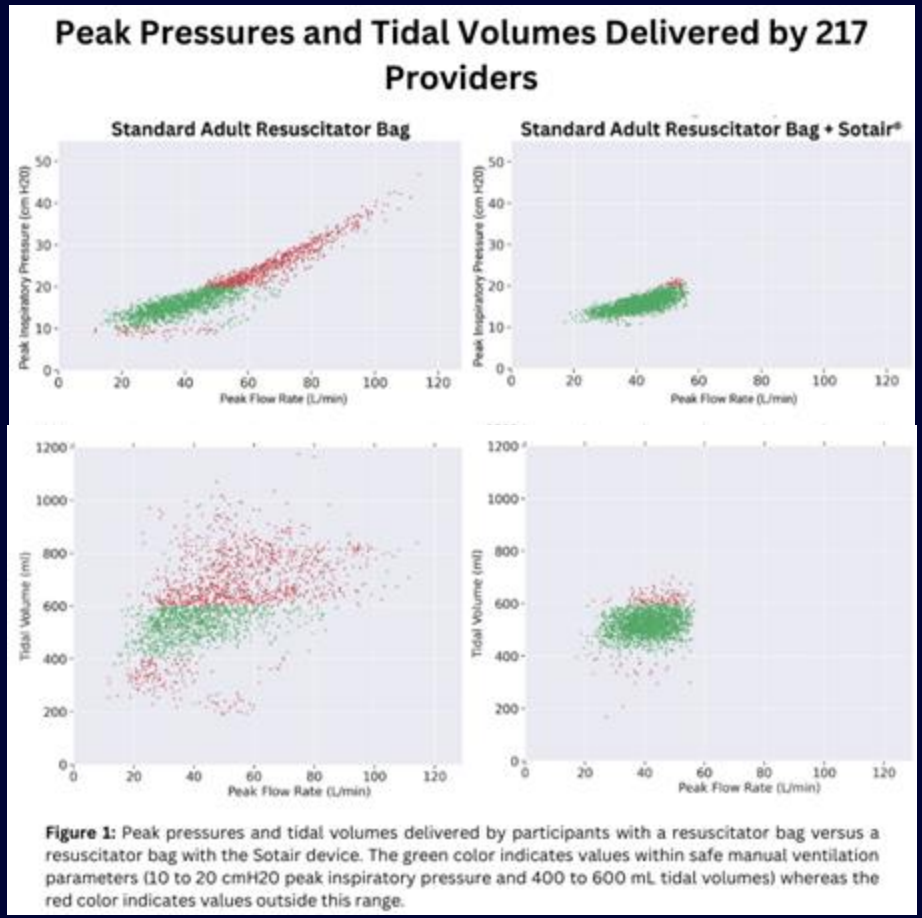


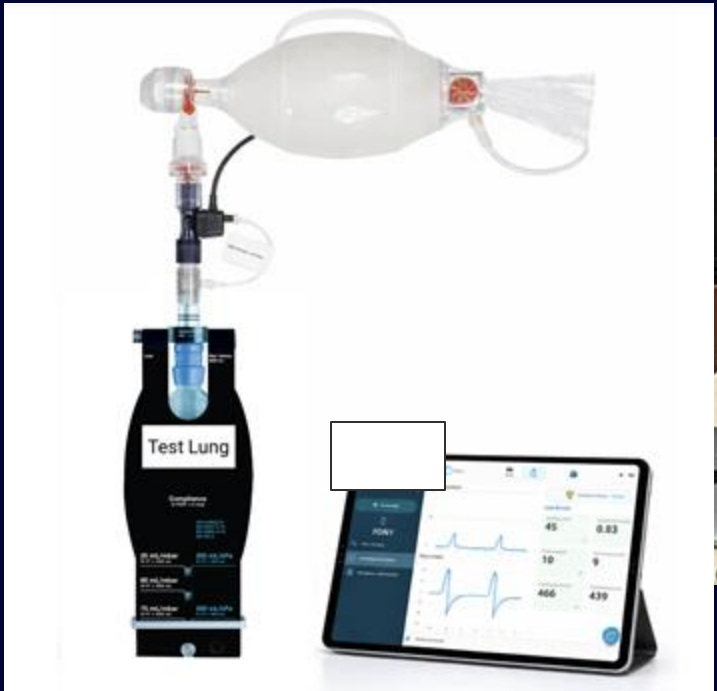
Figure 1: Peak pressures and tidal volumes delivered by participants with a resuscitator bag versus a resuscitator bag with the Sotair device. The green color indicates values within safe manual ventilation parameters (10 to 20 cmH20 peak inspiratory pressure and 400 to 600 mL tidal volumes) whereas the red color indicates values outside this range.

Kumar P, Holley JE, Justice JM, Slutsky AS, Brady MF. Manual ventilation performance in first responders using a flow-rate limiting device (Sotair). Presented at: EMS World Expo's International Scientific Symposium in partnership with UCLA's Prehospital Care Research Forum; September 2024; Las Vegas, NV.

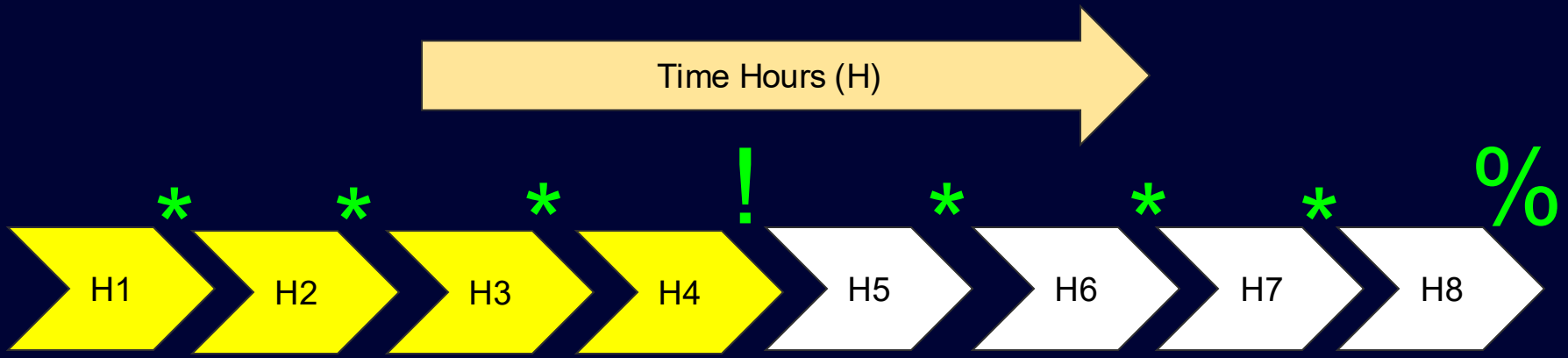
Materials: Comparison of Breath Limiting Devices

	APL “Pop-Off” Valve	Flow-Limiting Valve
Control mechanism	Pressure	Flow
Effect of control	Air releases	Flow stops
Low-compliance lungs (e.g. ARDS)	If hits pressure limit will not deliver adequate Tidal Volume	Will deliver Tidal Volume despite high pressures
Squeezing bag forcefully	No effect	Will stop flow if >55 L/min

Methods: Data collection setup



Methods: Participant Timeline



* 10 min break, Hourly Fatigue Questionnaire
! 30 min break, Hourly Fatigue Questionnaire
% 10 min break, Final Questionnaire

No Metronome | Metronome 12/ minute

Hourly Fatigue Scales

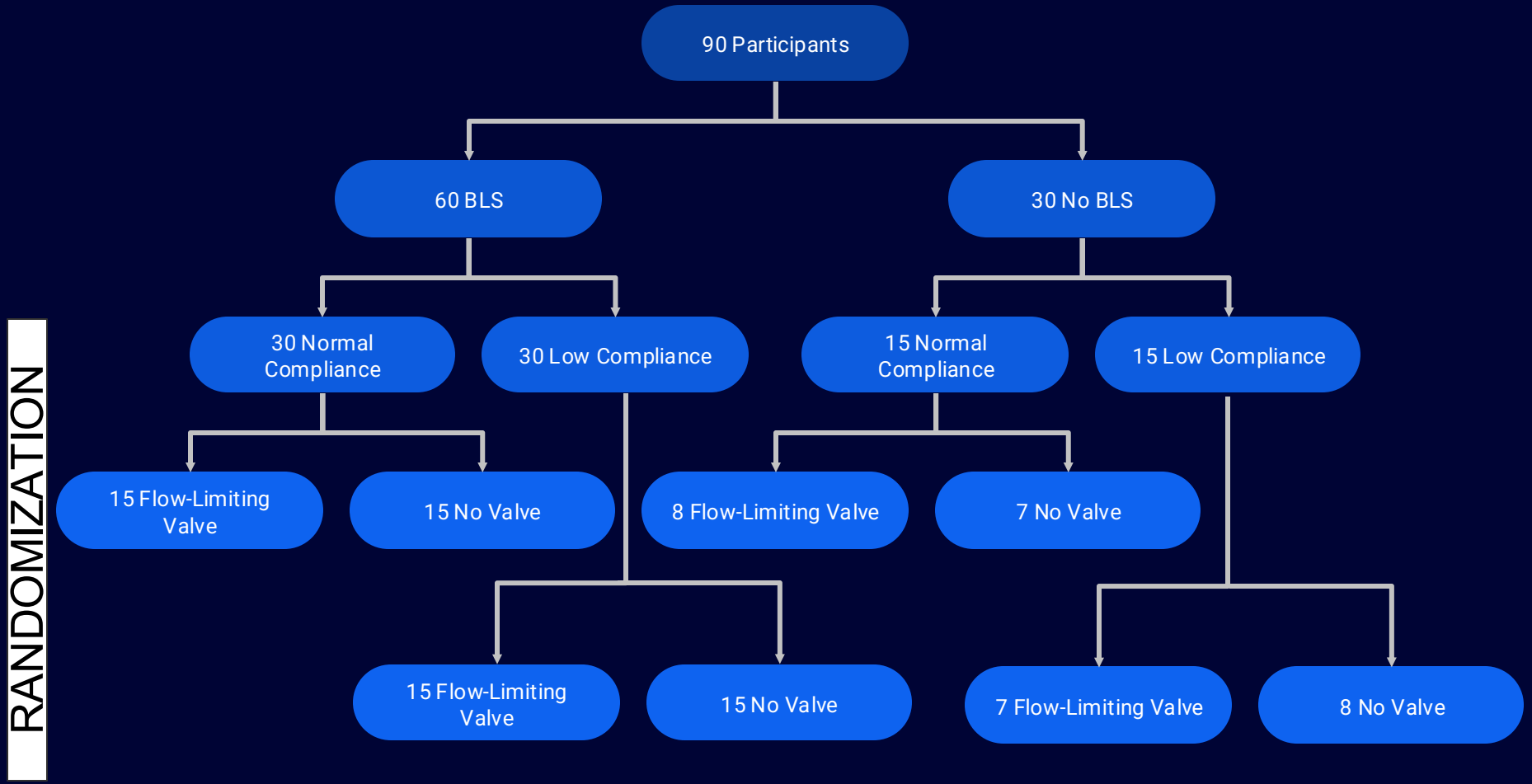
0–10 Borg Rating of Perceived Exertion Scale	
0	Rest
1	Really easy
2	Easy
3	Moderate
4	Sort of hard
5	Hard
6	
7	Really hard
8	
9	Really, really, hard
10	Maximal: just like my hardest race

Healthcare providers, athletes

Samn-Perelli Fatigue Scale

Item	Description	Scale
1	Very alert and fully awake	1
2	Very energetic but no longer at one's peak	2
3	Some vitality	3
4	A little tired and lacking energy	4
5	Moderate fatigue	5
6	Very tired and difficult in concentrating	6
7	Exhausted	7

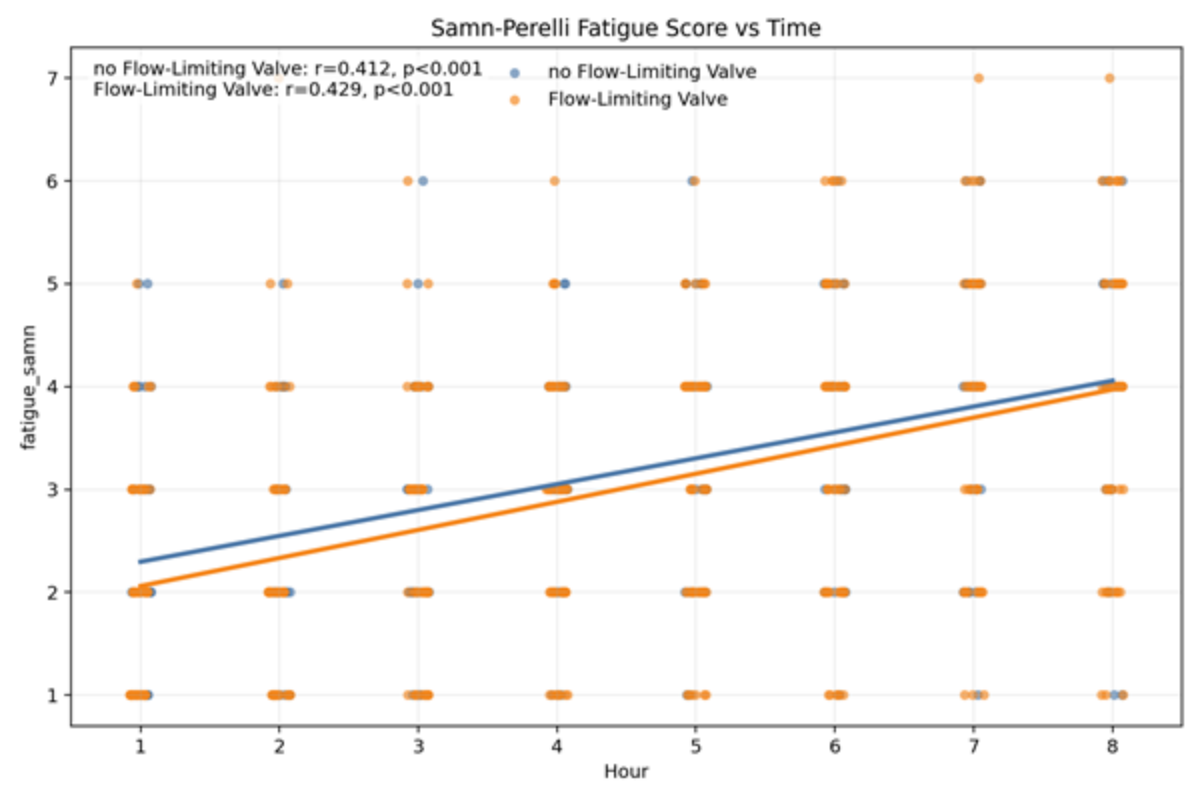
Pilots, shift workers, EMS



Normal compliance 73.5 mL/cmH2O; Low Compliance 24.5 mL/cmH2O

Results

Fatigue Trend Over Time (SAMN Scale)



Moderate and statistically significant positive relationship between time and SAMN fatigue score in both groups.

Similar conclusions and statistical significance with Borg scale.

Flow-Limiting Valve Fatigue Comparison Using ANCOVA

SAMN

- **Interaction test (difference in slopes):**
  - F = 0.209, p = 0.648
- **Group effect with common slope:**
  - F = 2.334, p = 0.127

Borg

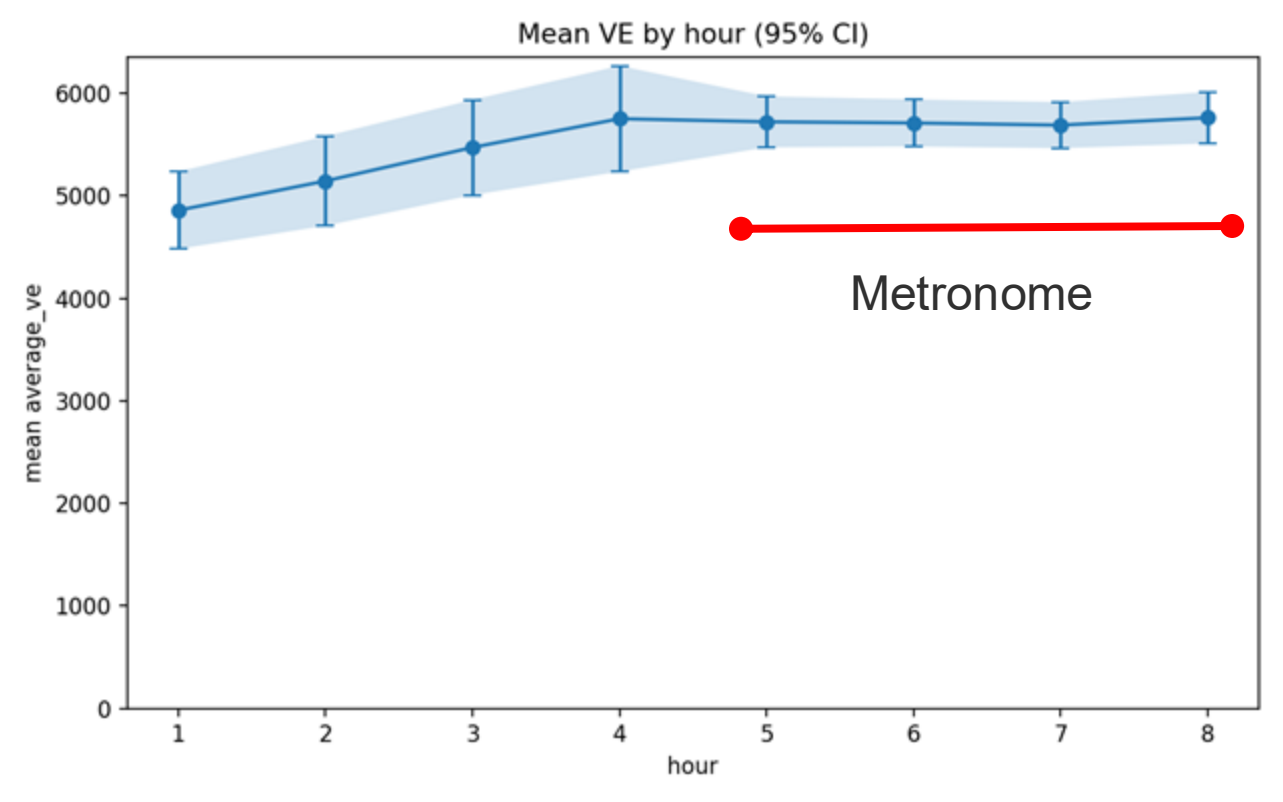
- **Interaction test (difference in slopes):**
  - F = 0.254, p = 0.614
- **Group effect with common slope:**
  - F = 0.025, p = 0.876

For both SAMN and Borg, the **interaction term was not significant**

> **Indicates** the rate of fatigue increase over time did **not differ significantly** between the Flow-Limiting Valve and No Valve groups.

After adjusting for hour, there was **no significant overall group difference** in fatigue level for either metric.

Minute Ventilation n=90

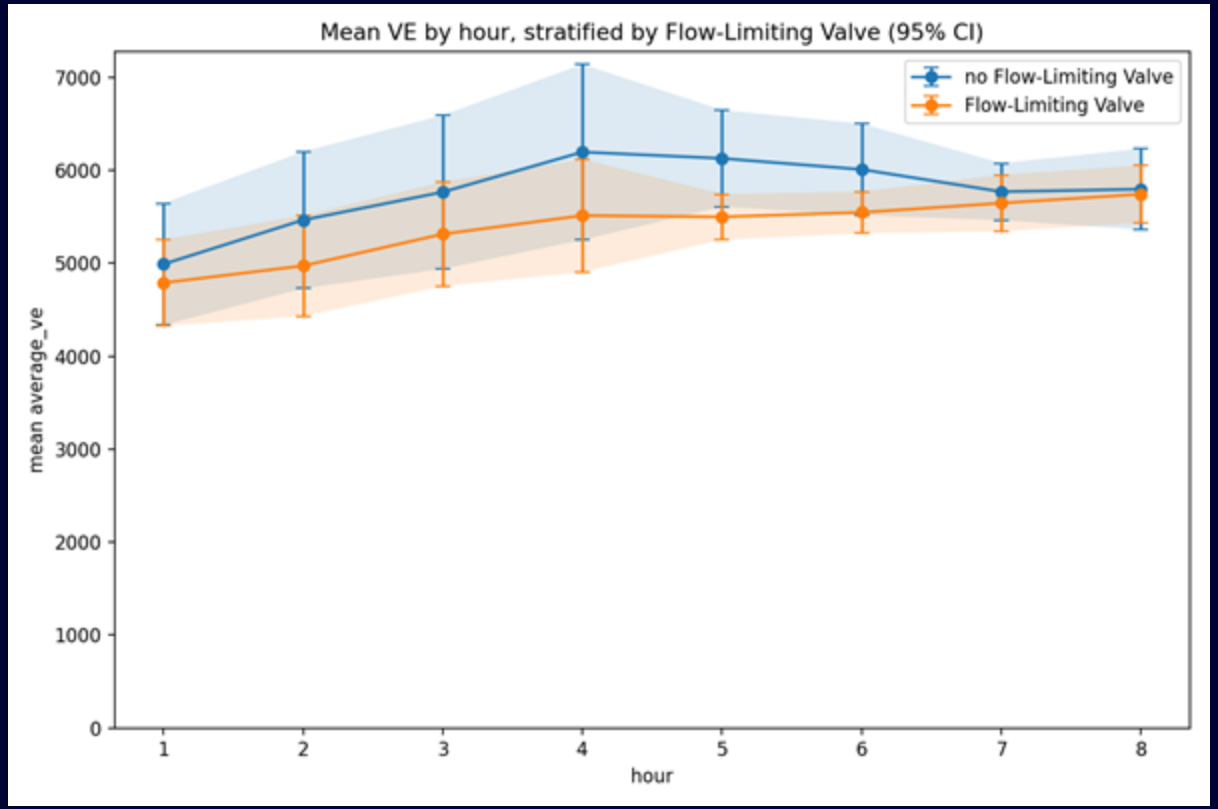


Overall minute ventilation was 5,505 ± 1,763 mL/min

Increase hours 1–4 (+300 mL/min/hr, 95% CI 215.8–385.1; $p < 0.001$)

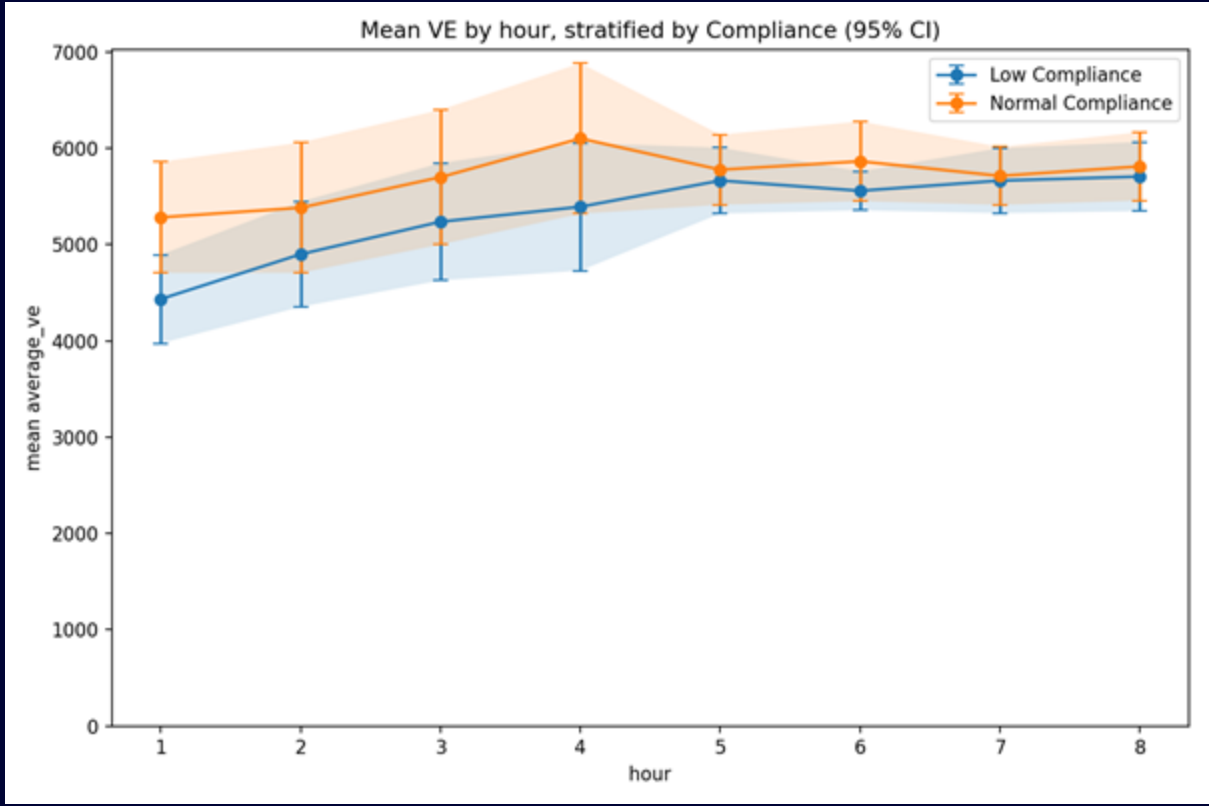
Plateau hours 5-8 (+8.7 mL/min/hour, 95% CI −78.8 to 96.2; p=0.845)

Minute Ventilation With and Without Flow-Limiting Valve



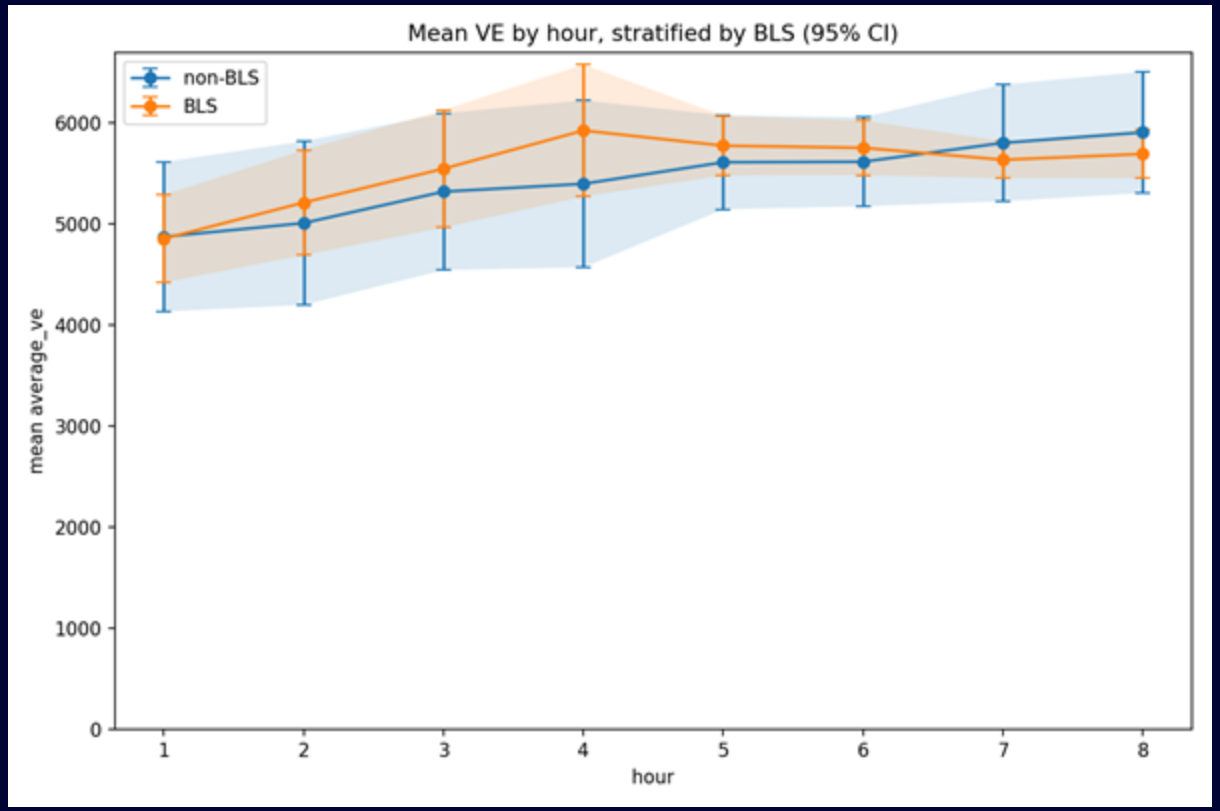
Flow-Limiting Valve showed a negative adjusted association with minute ventilation (−400 mL/min), but this did not reach statistical significance (p = 0.0568)

Minute Ventilation Normal vs Low Lung Compliance



Compliance was **not** significantly associated with minute ventilation in the adjusted model.

Minute Ventilation BLS vs Non BLS



Having BLS was **not** significantly associated with minute ventilation in the adjusted model.

Discussion: Fatigue

- None of the 90 participants stopped because of fatigue or injury.
- With and without the Flow-Limiting Valve there was a significant trend towards more fatigue over time on both scales
    - There was no significant difference in either fatigue scale between the group who used the Flow-Limiting Valve and the group that did not.
- Suggests feasibility of prolonged manual ventilation for adequate ventilation, and that the Flow-Limiting Valve does not affect fatigue

Discussion: Minute Ventilation

- A multivariate regression analysis of minute ventilation demonstrated significant effects with respect to:
  - time (increased +0.30 L/min per hour for first 4 hours, $p < 0.001$)
  - presence of a metronome (decreased variability)
- There were no significant effects caused by:
  - Compliance
  - having BLS certification
  - use of the Flow-Limiting Valve (−0.40 L/min, $p = 0.0568$)

Discussion: Clinical Applications and Operations

- This study supports prolonged manual ventilation as a possible option in settings where mechanical ventilation is not available
- Non-BLS participants performed as well as BLS-trained participants, suggesting that non-medical personnel might be used for prolonged ventilation after a brief training
- Low lung compliance did not affect performance
- Metronomes significantly decreased minute ventilation variability
- Human performance (fatigue scales and minute ventilation) shows no negative effect from a Flow-Limiting Valve

Thank you

mbrady4@brownhealth.org
mark.f.brady2.mil@us.navy.mil