# CPER Journal Club

# Advancements in Ventilation Strategies during Cardiac Resuscitation

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Advanced Care Paramedic and Paramedic Research Lead, Ornge Air Ambulance and Critical Care Transport

TEMERTY FACULTY OF MEDICINE UNIVERSITY OF TORONTO

Sunnybrook HEALTH SCIENCES CENTRE

FIRST60 PREHOSPITAL, TRAUMA, RESUSCITATION SCIENCES

ornge lives uplifted

# Disclosures

- Chair, Advanced Life Support Task Force, International Liaison Committee on Resuscitation (ILCOR)
- Vice-Chair, Basic Life Support Writing Group, American Heart Association
- Senior Science Editor, American Heart Association
- Investigator Initiated Grant, ZOLL Medical, to study ventilation quality in out-of-hospital cardiac arrest

# Case Study

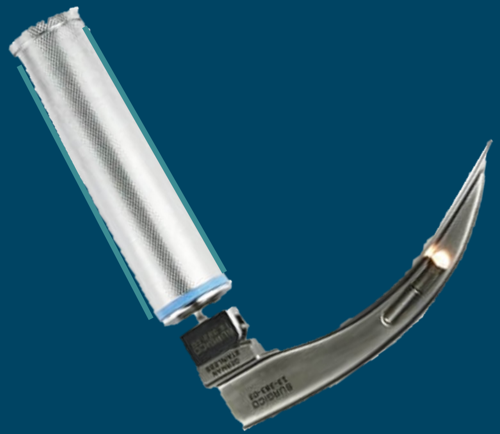
**Lights and siren response for a 36-year-old male who is in cardiac arrest. You arrive to find the patient in the living room. No bystander interventions**

**What are your priorities for care of this patient?**

Chest compressions
Defibrillation
Intravenous/Intraosseous Access
Medication administration
Airway insertion
Ventilation?

Key aspects of CPR

- Rate
- Depth
- Fraction
- Release
- Pauses



Vs

# Airway Trials

| Study | PART | AIRWAYS-2 | EUROPEA[illegible] |
|---|---|---|---|
| **Comparison** | ETT vs. King LT® | ETT vs. i-Gel® | ETT vs [illegible] |
| **Patients** | 3004 | 9296 | [illegible] |
| **Setting** | United States | United Kingdom [illegible] | [illegible]pe |
| **Provider** | Paramedics | Param[illegible] | Physicians |
| **Outcome** | 72 hour survival | [illegible]urvival | Neurological Survival |
| **Results** | King LT Be[illegible] | [illegible]o Difference | No Difference |
| | 1[illegible] | 6.4% vs. 6.8% | 4.3% vs. 4.2% |
| **Considerations** | [illegible]irst Pass [illegible]uccess<br>- Also difference in survival | - 79% First Pass Success<br>- Significant Crossover | - Non-inferiority<br>- More adverse events with BVM (failure)<br>- Significant Crossover |

What About The VENTILATIONS???

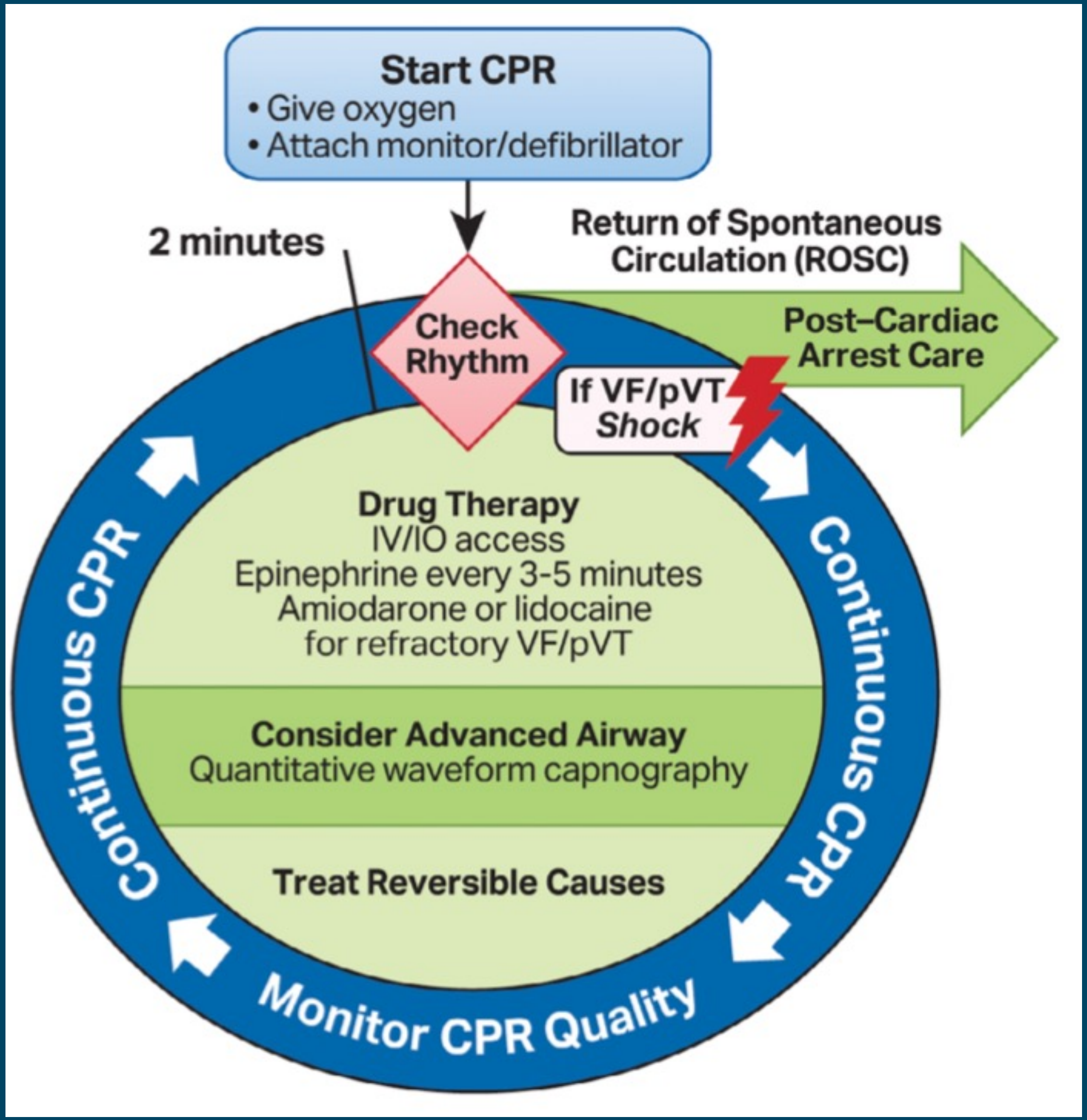
*Wang (2018) JAMA; Benger (2018) JAMA; Jabre (2018) JAMA*

# Ventilation

Required for oxygenation and removal of carbon dioxide

Hypoventilation (too little) results in hypoxia and build up of CO2 (respiratory acidosis)

Hyperventilation (too much) results in gastric insufflation and impacts hemodynamics




Avoid excessive ventilation

500-600 mL (or enough for chest rise)

30:2 compression-ventilation ratio

1 breath q. 6 seconds (10/min) with AA

Resuscitation
Volume 31, Issue 3, June 1996, Pages 231-234

Clinical paper

# Tidal volumes which are perceived to be adequate for resuscitation

Peter Baskett [a], Jerry Nolan [b], Michael Parr [c]

Resuscitation
Volume 43, Issue 1, December 1999, Pages 25-29

# Effects of smaller tidal volumes during basic life support ventilation in patients with respiratory arrest: good ventilation, less risk?

Volker Wenzel [a], Christian Keller [a] [b], Ahamed H. Idris [c], Volker Dörges [d], Karl H. Lindner [a], Joseph R. Brimacombe [b]

Resuscitation
Volume 44, Issue 1, March 2000, Pages 37-41

# Smaller tidal volumes with room-air are not sufficient to ensure adequate oxygenation during bag–valve–mask ventilation ☆

Volker Dörges [a], Hartmut Ocker [a], Sönke Hagelberg [a], Volker Wenzel [b], Ahamed H Idris [c], Peter Schmucker [a]

Cause chest rise and fall

Good ventilation and oxygenation

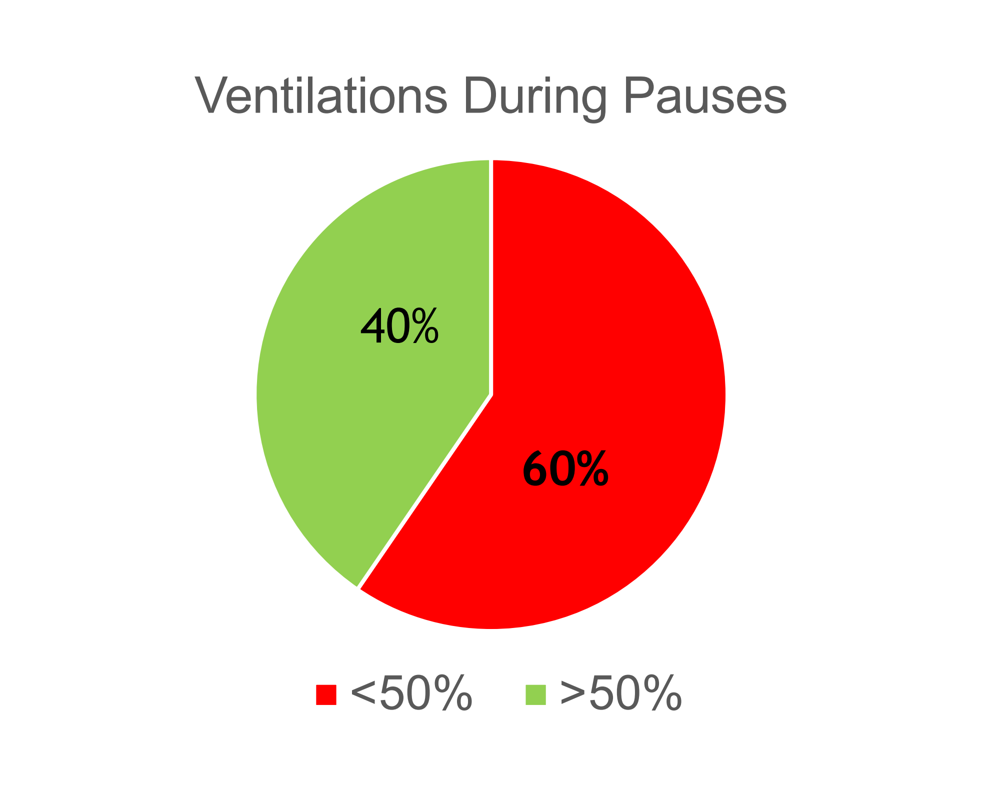
Reduced gastric insufflation

# Are We Meeting Guideline Recommendations??

# Bag-Valve-Mask Ventilation and Survival From Out-of-Hospital Cardiac Arrest: A Multicenter Study

Ahamed H. Idris, MD; Elisabete Aramendi Ecenarro, PhD; Brian Leroux, PhD; Xabier Jaureguibeitia, MSc; Betty Y. Yang, MD, MS; Sarah Shaver, MD; Mary P. Chang, MD, MPH; Tom Rea, MD, MPH; Peter Kudenchuk, MD; Jim Christenson, MD; Christian Vaillancourt, MD, MSc; Clifton Callaway, MD, PhD; David Salcido, PhD; Jonas Carson; Jennifer Blackwood, MPH; Henry E. Wang, MD, MS, MPH

Idris (2023) Circulation



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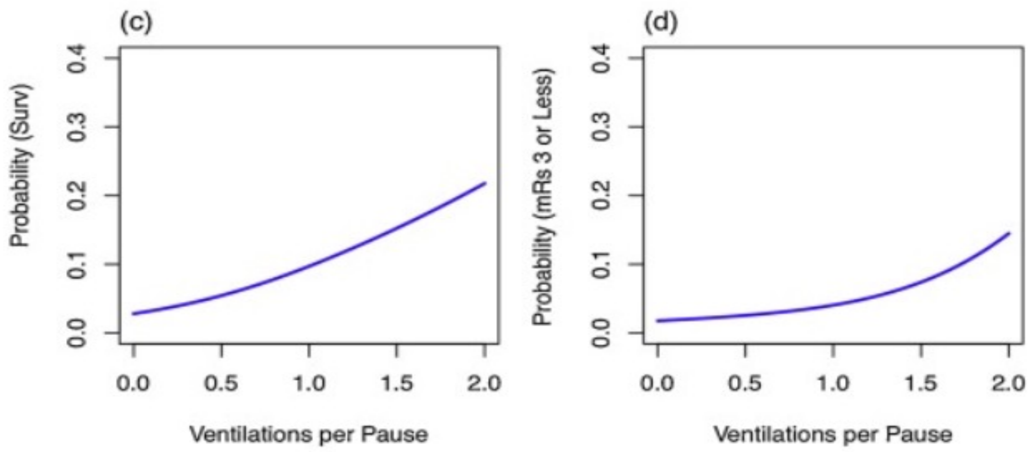



13.5% vs 4.1%

10.6% vs 2.4%

ELSEVIER
Resuscitation
Volume 73, Issue 1, April 2007, Pages 82-85

Clinical paper

# Do we hyperventilate cardiac arrest patients? ☆

John F. O'Neill [a], Charles D. Deakin [b]

| | | |
|---|---|---|
| X | Med. Respiratory Rate | 21/min (7–37) |
| X | Med. Tidal Volume | 619ml (374–923) |
| X | Med. Minute Vol. | 13.0L/min (4.6–21.3) |
| X | Med Peak Inspiratory Pr | 60.6 cmH20 (46–106) |

## Ventilation Rates and Pediatric In-Hospital Cardiac Arrest Survival Outcomes*

Robert M. Sutton, MD, MSCE[1], Ron W. Reeder, PhD[2], William P. Landis, BSE[1], Kathleen L. Meert, MD[3], Andrew R. Yates, MD[4], Ryan W. Morgan, MD, MTR[1], John T. Berger, MD[5], Christopher J. Newth, MD, FRACP[6], Joseph A. Carcillo, MD[7], Patrick S. McQuillen, MD[8], Rick E. Harrison, MD[9], Frank W. Moler, MD[10], Murray M. Pollack, MD[5,11], Todd C. Carpenter, MD[12], Daniel A. Notterman, MD[13], Richard Holubkov, PhD[2], J. Michael Dean, MD[2], Vinay M. Nadkarni, MD, MS[1], Robert A. Berg, MD[1] *Eunice Kennedy Shriver* National Institute of Child Health and Human Development Collaborative Pediatric Critical Care Research Network (CPCCRN)

Sutton 2019 Crit Care Med

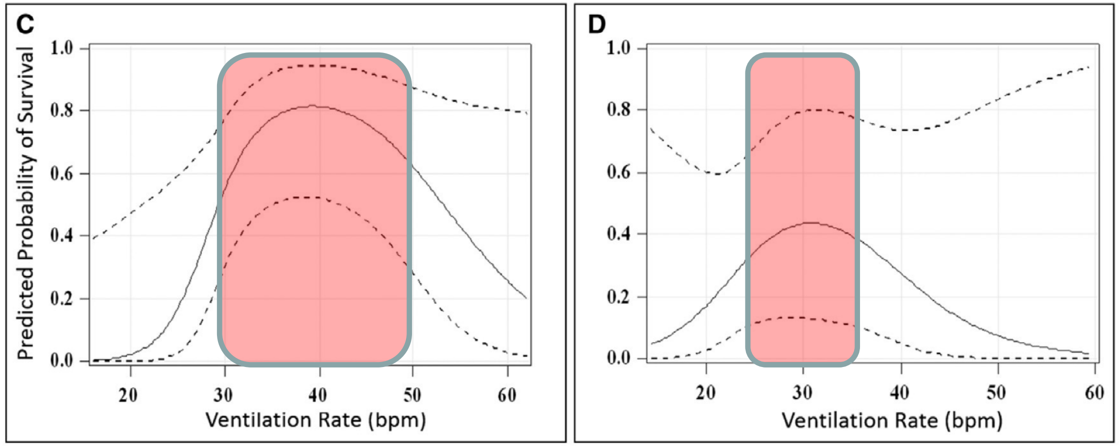
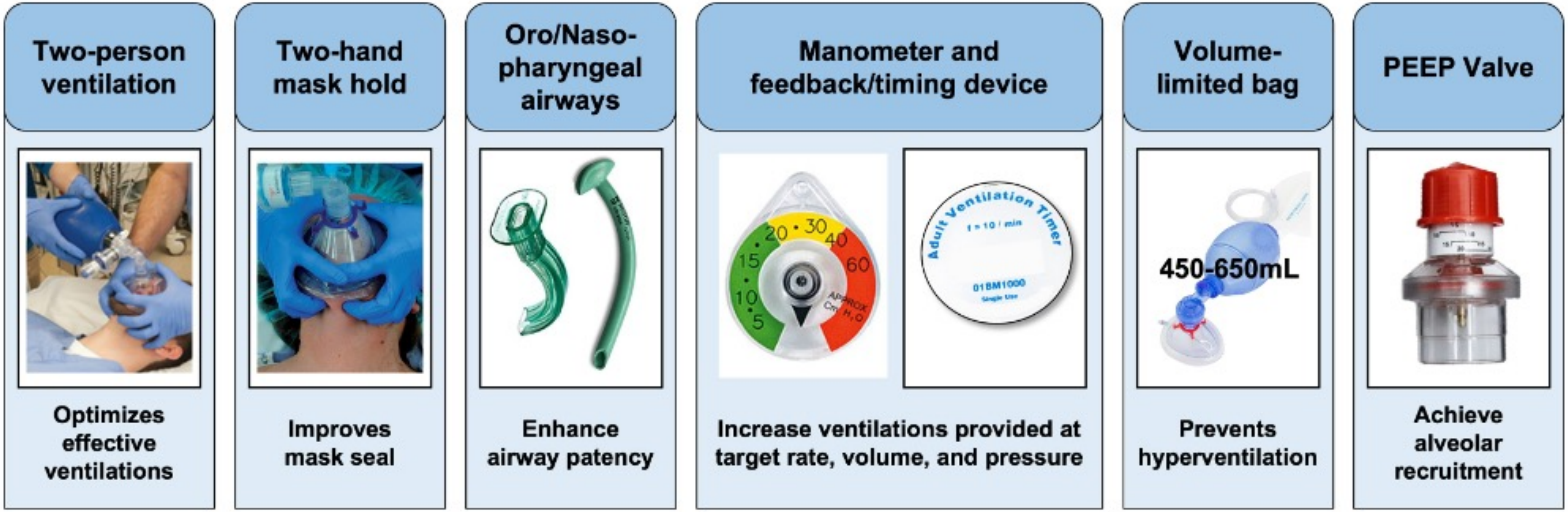



**Figure 2.** Evaluation of optimal ventilation rates using receiver operating characteristic area under the curve (AUC; **A** and **B**) and cubic spline analysis (**C** and **D**). Children less than 1 yr old (**A** and **C**), and older children greater than or equal to 1 yr old (**B** and **D**). *Solid line* in AUC analysis signifies the predicted survival rate, whereas the *dotted line* represents the 95% CI. bpm = breaths/min, Cut = optimal cut point, Sens = sensitivity, Spec = specificity.

# How Can We Improve Ventilations?

# 1. Training

# 2. Clinical Practice




Lyng (2022) Prehospital Emergency Care & Dr. Nichole Bosson

RESUSCITATION 193 (2023) 109991

ELSEVIER

Available online at ScienceDirect

Resuscitation

journal homepage: www.elsevier.com/locate/resuscitation

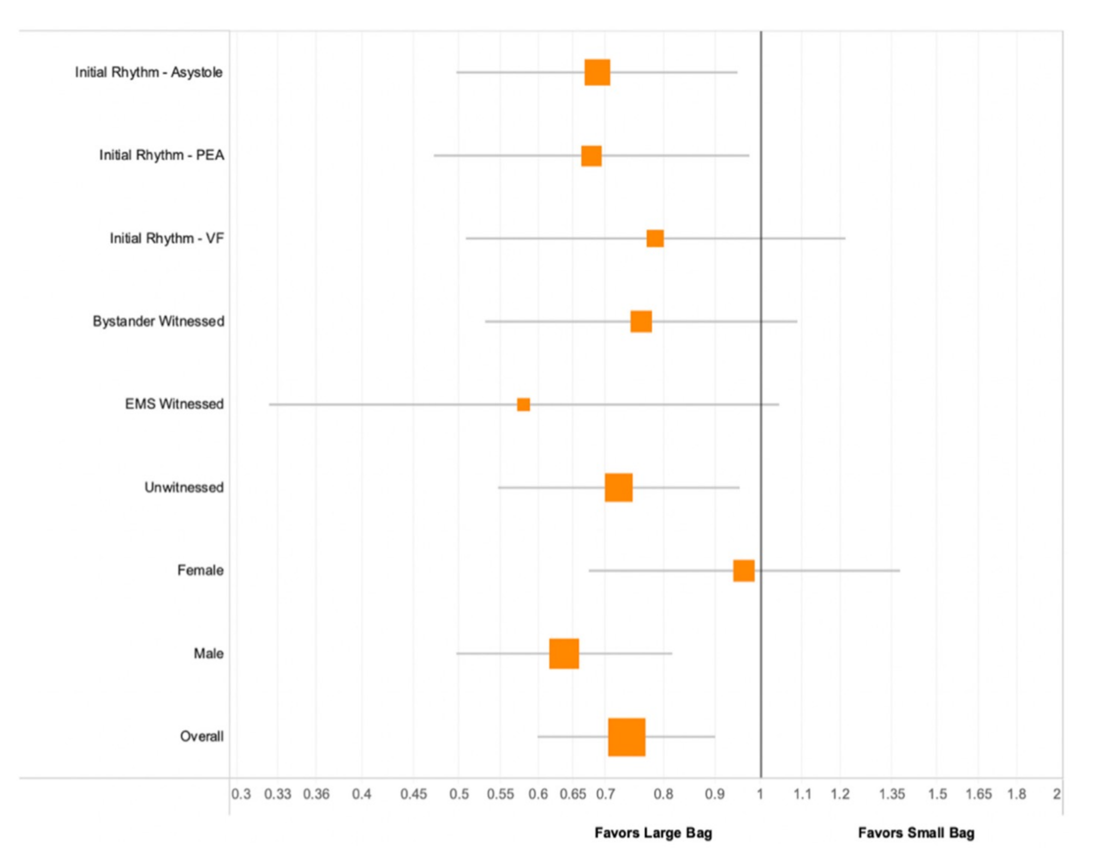
EUROPEAN RESUSCITATION COUNCIL

Clinical paper

# Association of small adult ventilation bags with return of spontaneous circulation in out of hospital cardiac arrest

*Bonnie D. Snyder*[a,*], *Molly R. Van Dyke*[a], *Robert G. Walker*[b], *Andrew J. Latimer*[a], *Bartholomew C. Grabman*[e], *Charles Maynard*[d], *Thomas D. Rea*[a], *Nicholas J. Johnson*[a], *Michael R. Sayre*[a,c], *Catherine R. Counts*[a,c]

Retrospective before-and-after study
Single site - Seattle Washington
N = 1993 ALS/BLS providers



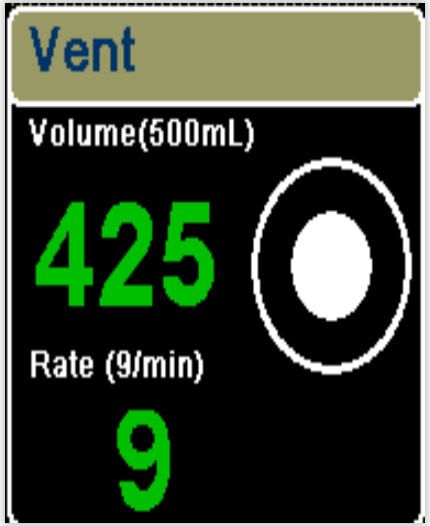

ROSC at ED 33% vs 40%,
OR 0.74 (0.61, 0.90), P<0.003

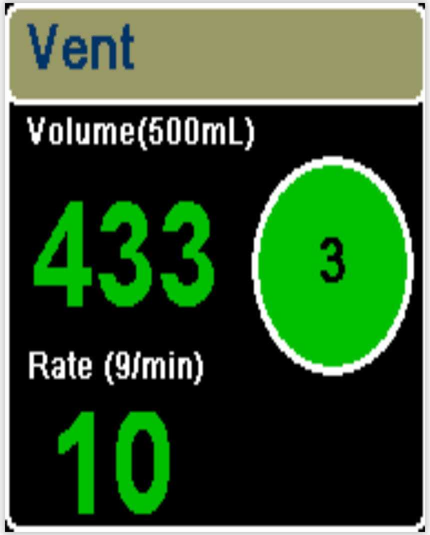
# 3. Ventilation Feedback

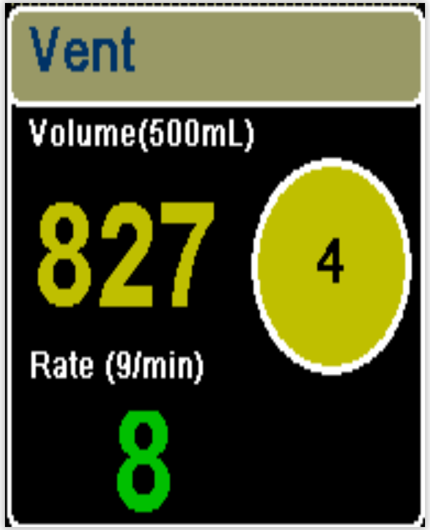
- Disposable flow sensor/reusable cable
- Real-time display:
    - Ventilation volume
    - Ventilation rate
    - Ventilation quality indicator
    - Countdown timer


ZOLL®

# Ventilation Real-time Feedback



# Simulation Testing of Ventilation Technology

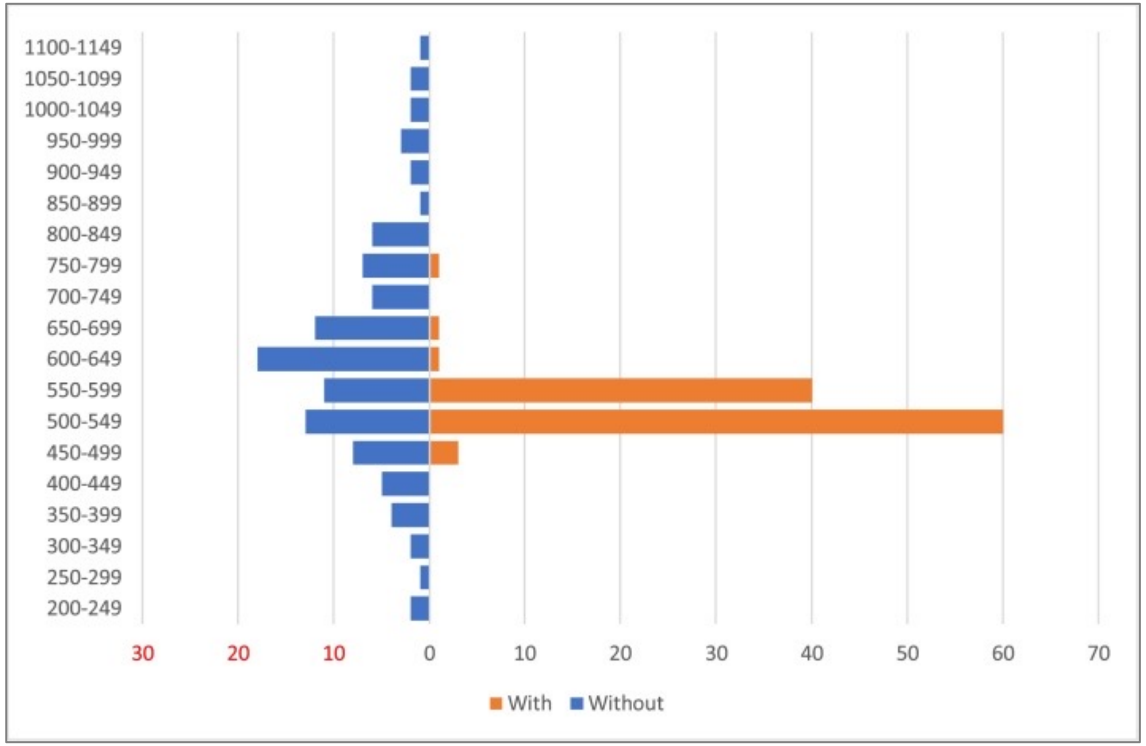
| | No Feedback | Feedback | P |
|---|---|---|---|
| Compressions in target for rate (%) | 36 ± 36 | 76 ± 26 | < 0.01 |
| Compressions in target for depth (%) | 34 ± 30 | 70 ± 25 | < 0.01 |
| Compressions in target for rate and depth (%) | 16 ± 25 | 55 ± 28 | < 0.01 |
| Ventilations in target for rate (%) | 41 ± 23 | 71 ± 16 | < 0.01 |
| Ventilations in target for volume (%) | 31 ± 32 | 79 ± 15 | < 0.01 |
| Ventilations in target for rate and volume (%) | 10 ± 14 | 63 ± 18 | < 0.01 |

Data are presented as Mean±SD. Paired t-tests were used for statistical analysis.

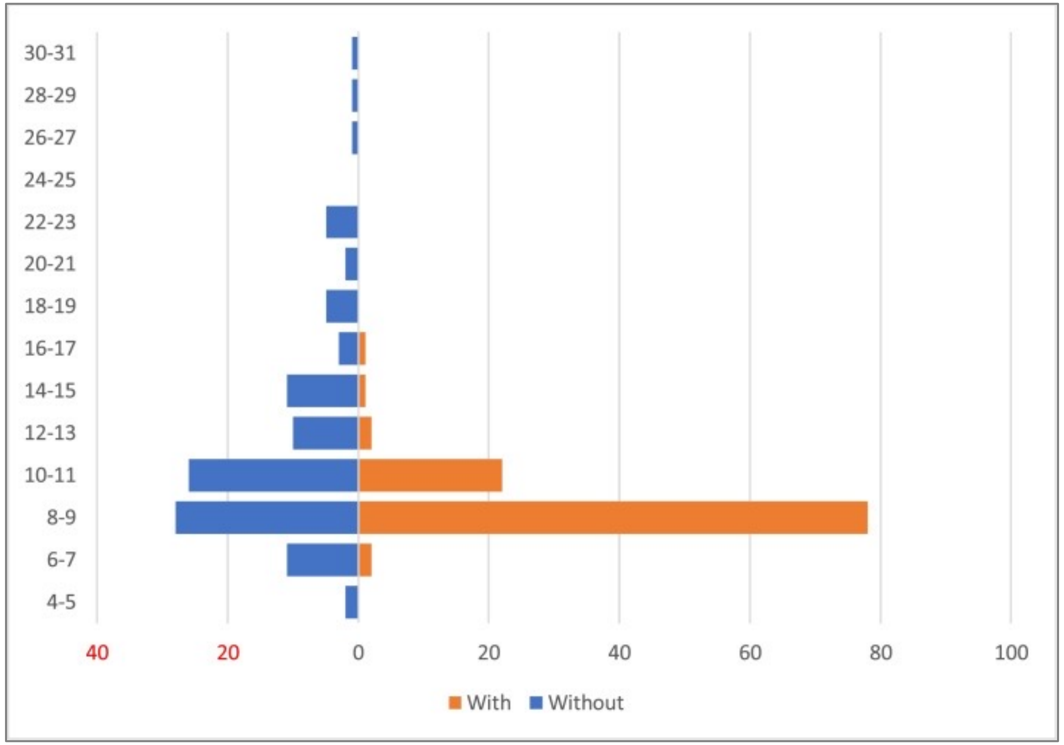
Gould (2020) Practice Innovations in Emergency Medicine

# Ventilation Feedback During Simulated Cardiac Resuscitation

## Ventilation Volume




## Ventilation Rate

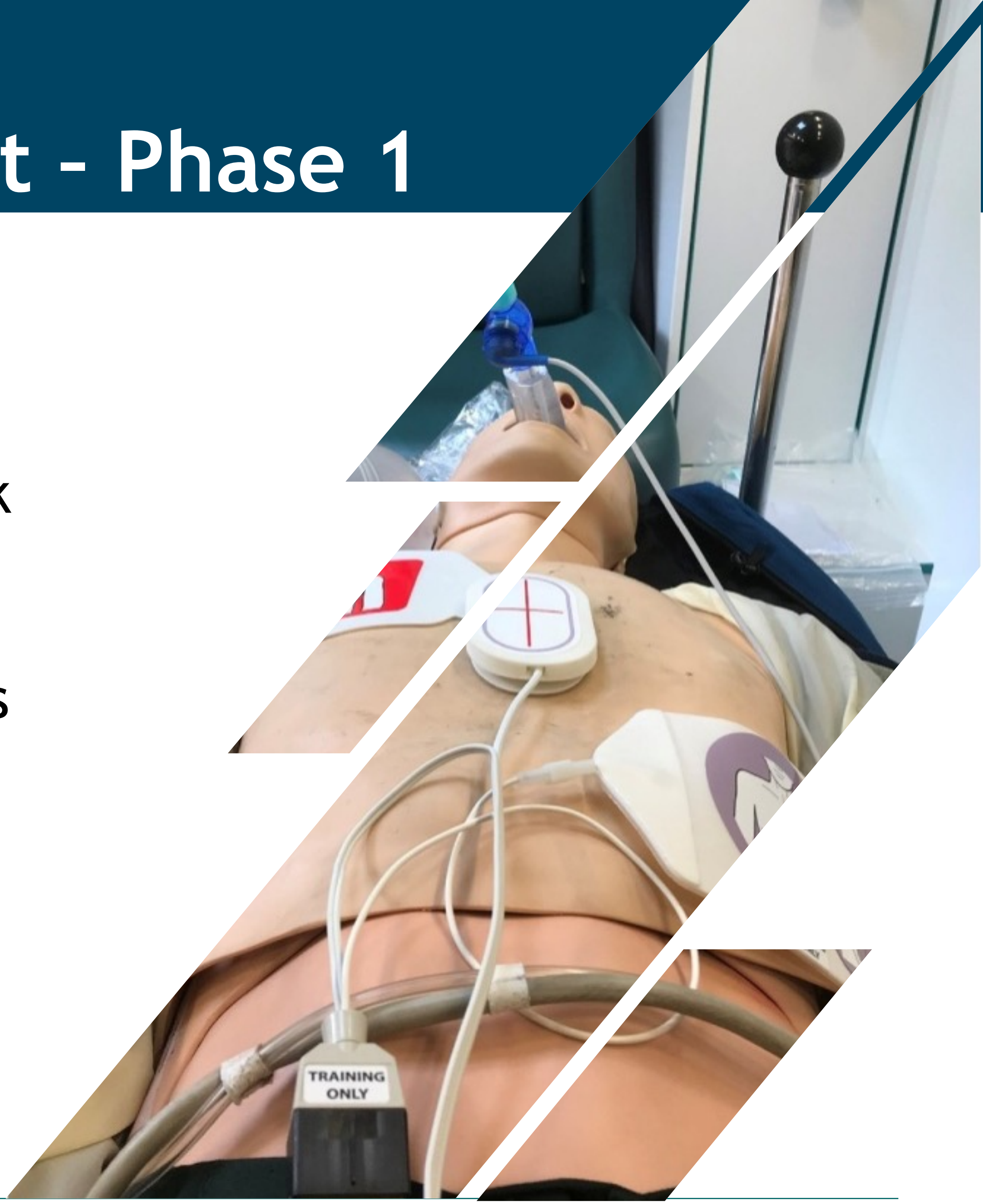



Charlton (2021) Resuscitation Plus

# Improving Ventilation During Out-of-Hospital Cardiac Arrest - Phase 1

## Phase 1: Before-and-after Study

- Examining importance of real-time feedback for improving ventilation quality
- 412 patients; 6 Canadian paramedic services
- **GOAL: determine impact of real-time feedback on performance**



# Improving Ventilation During Out-of-Hospital Cardiac Arrest - Phase 1

**Primary Outcome: Proportion of cases where volume is consistent with AHA Guidelines**

Secondary Outcomes: Proportion of cases where rate is consistent with AHA Guidelines

Also examine:

- Minute ventilation
- BVM vs Advanced Airway
- intra-arrest vs post-arrest
- Association with ROSC (exploratory)

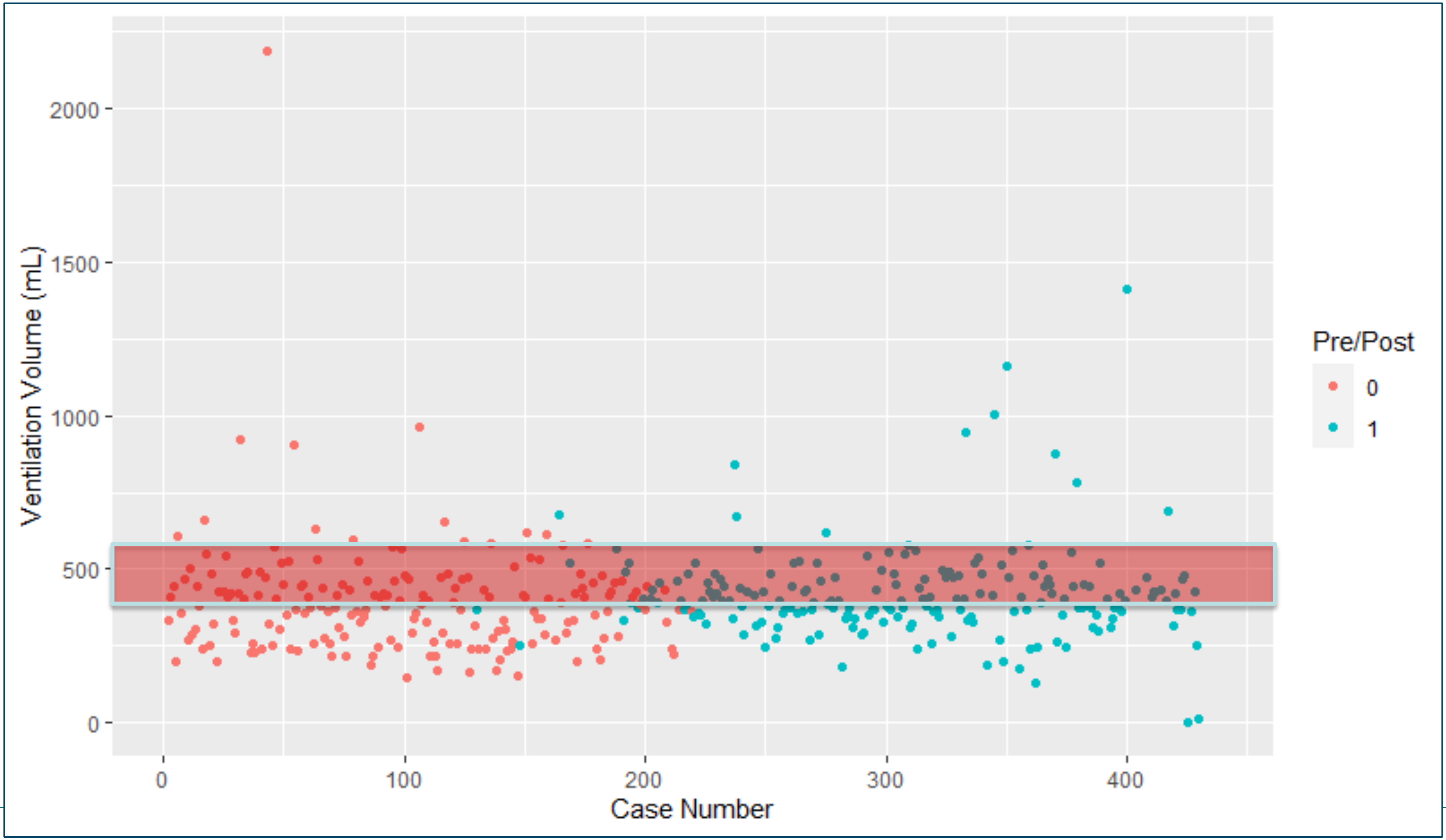
# Demographic Characteristics

| Variable | Overall<br>n = 412 |
|---|---|
| Age (Yr), median (IQR) | 67 (55, 78) |
| Male sex, n (%) | 263 (68) |
| Bystander CPR, n (%) | 145 (38) |
| Private Location, n (%) | 321 (83) |
| Witnessed Arrest, n (%) | 192 (49) |
| Initial Cardiac Rhythm, n (%) | |
| Shockable Rhythm (VF/pVT) | 53 (14) |
| Pulseless Electrical Activity | 117 (30) |
| Asystole | 213 (55) |
| Advanced Airway, n (%) | |
| Endotracheal Intubation | 69 (18) |
| Supraglottic Airway | 262 (68) |
| Bag-Valve-Mask | 54 (14) |
| ROSC | 113 (28) |
| Avg CPR Depth, mean (SD) | 6.0 (5.4) |
| Avg CPR Rate, mean (SD) | 117 (10.9) |

# Ventilation Characteristics

| Variable | Overall | Without Feedback | With Feedback |
|---|---|---|---|
| Avg Ventilation Rate, Median (IQR) | 13 (10, 17) | 14 (11, 19) | 12 (10, 17) |
| Avg Ventilation Volume, Median (IQR) | 395 (324, 466) | 374 (274, 453) | 401 (353, 472) |
| Proportion Ventilation Rate Met Target, Mean (SD) | 41 (33) | 29 (19) | 52 (38) |
| Proportion Ventilation Volume Met Target, Mean (SD) | 25 (17) | 21 (16) | 28 (17) |
| Proportion Overall Ventilation Met Target, Mean (SD) | 13 (15) | 7 (10) | 18 (17) |

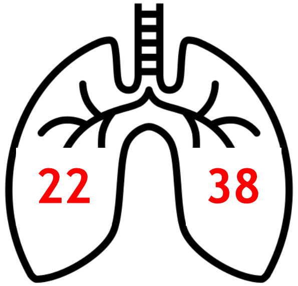
# Average Ventilation Volume per Case

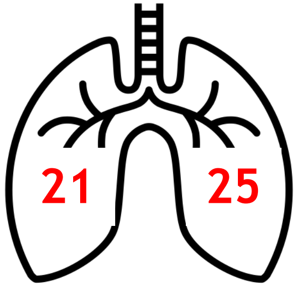


# Average Ventilation Rate per Case

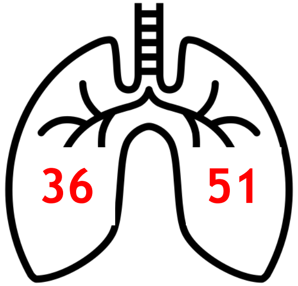
# Secondary Analyses

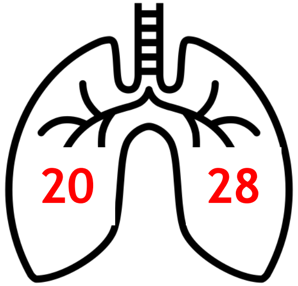
**Without** an Advanced Airway

Rate



Depth



**With** an Advanced Airway

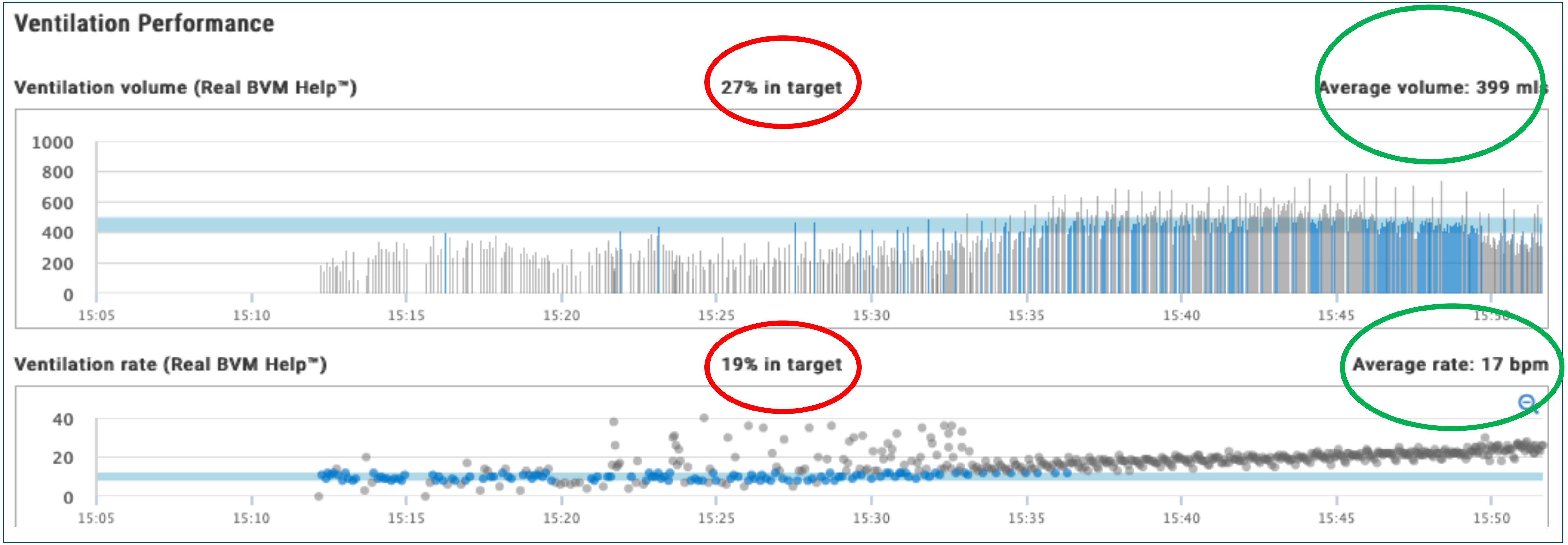
Rate



Depth


# Association of Ventilation and ROSC

| Variables | Odds Ratio | 95% Confidence Interval |
|---|---|---|
| Age | 1.00 | 0.99, 1.02 |
| Male Sex | 0.77 | 0.42, 1.43 |
| Bystander CPR | 1.05 | 0.59, 1.88 |
| Witness Status | | |
| EMS Witnessed | 1.89 | 0.71, 5.04 |
| Bystander Witnessed | 2.40 | 1.31, 4.39 |
| Initial Shockable Rhythm | 2.59 | 1.25, 5.38** |
| Advanced Airway | | |
| Endotracheal Intubation | 2.41 | 0.91, 6.38 |
| Supraglottic Airway | 1.07 | 0.46, 2.48 |
| **Ventilation rate** | **1.12** | **0.99, 1.26** |
| **Ventilation volume** | **1.17** | **0.96, 1.42** |

# Sample Case Without Feedback

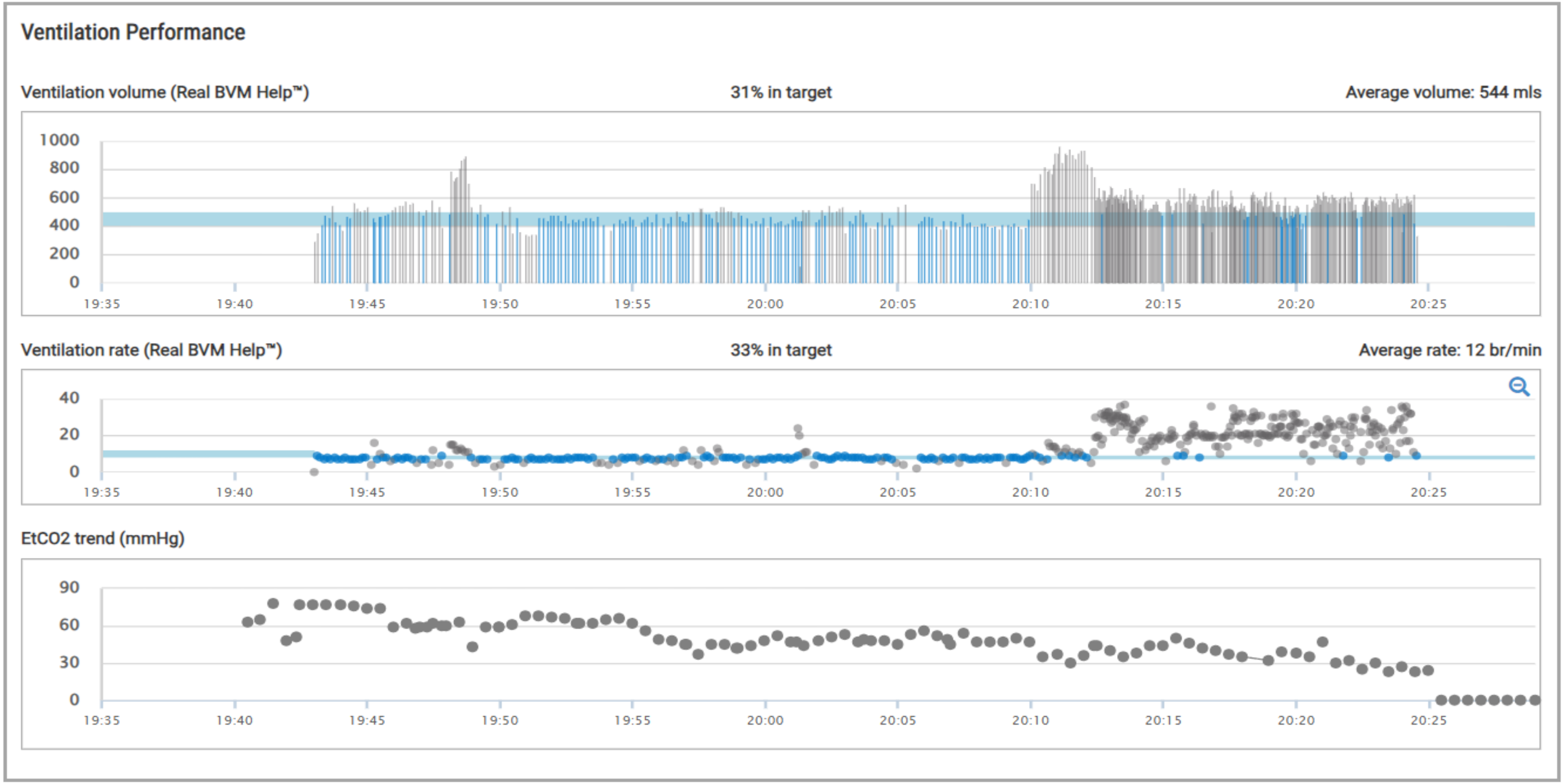


# Sample Case With Ventilation Feedback

# Case of Interfacility Transfer


*Case Courtesy of Lethbridge Fire and EMS

# Clinical Handover Case

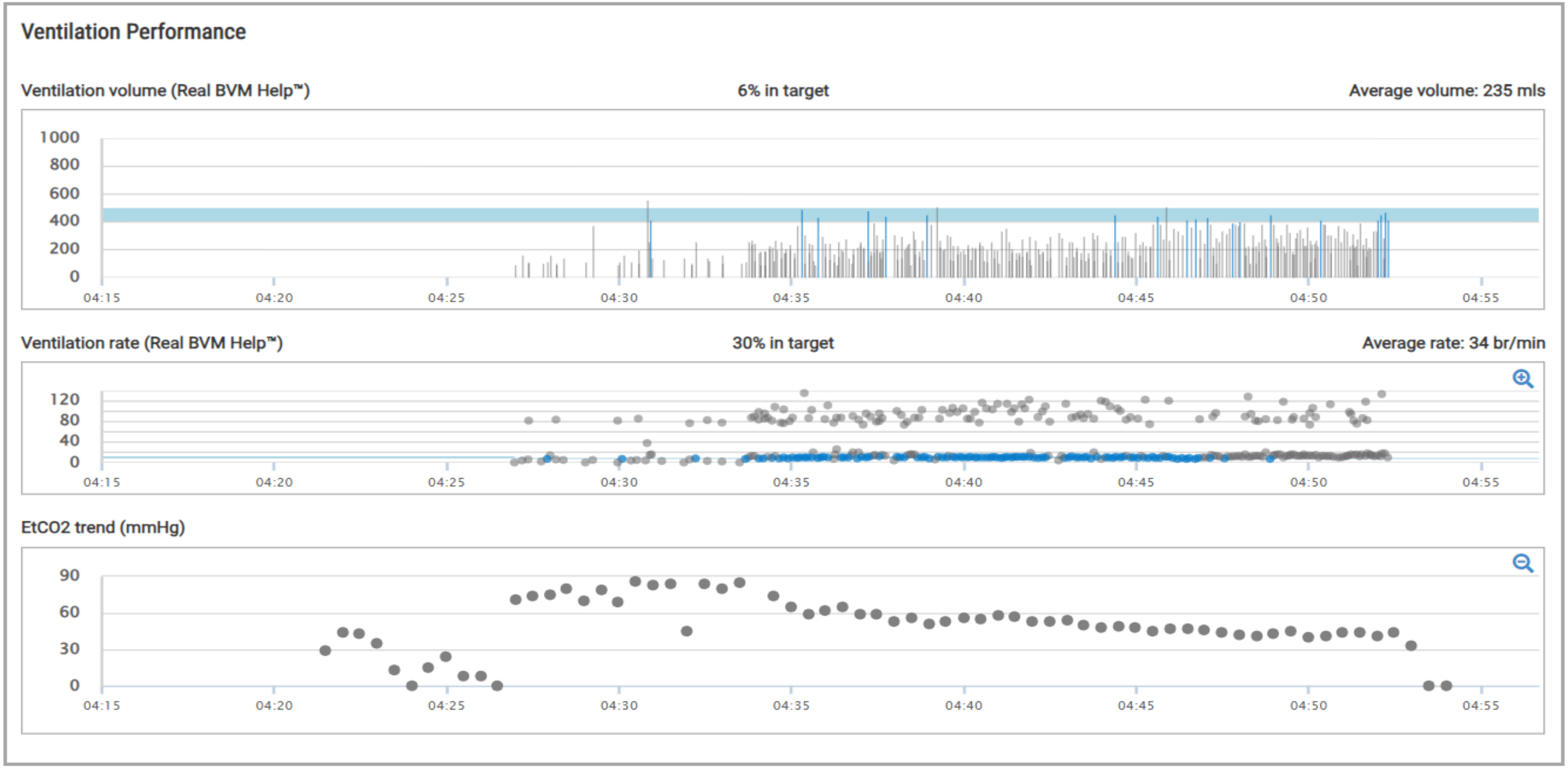



*Case Courtesy of Lethbridge Fire and EMS

# Challenges with Ventilation Feedback

- Paramedic used to “feel” of BVM when ventilating and watching chest rise
- ETC02 vs. ventilation feedback
- “Run in” effect
- CPR vs ventilation feedback
- Ensuring feedback is “turned” on
- Chest compression interference

# mCPR interference




*Case Courtesy of Lethbridge Fire and EMS

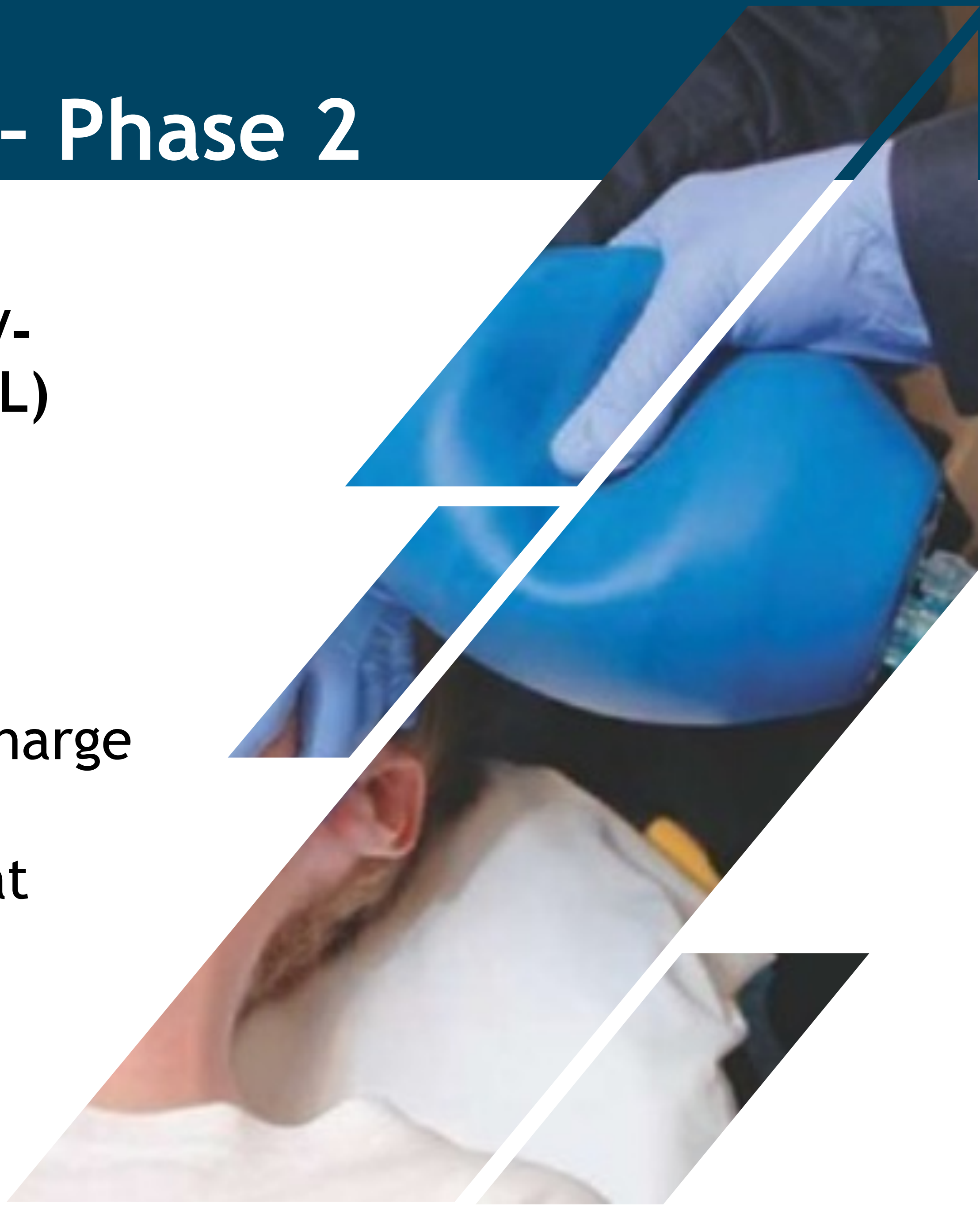
# OPTImizing Ventilation During Out-of-Hospital Cardiac Arrest - Phase 2

## Phase 2: Clinical Trial

- Cluster Randomized Controlled Trial
- Examining different volume and/or rate of ventilation during cardiac resuscitation
- 2000 patients; 6 paramedic services
- **GOAL: determine the optimal ventilation strategy during cardiac arrest resuscitation**

# OPTImizing Ventilation During Out-of-Hospital Cardiac Arrest - Phase 2

- **Primary Comparison: Low volume (300 +/- 50mL) vs. Standard Volume (500 +/- 50mL)**
- Also examine impact of rate and minute ventilation
- Primary Outcome: Survival to hospital discharge
- Secondary Outcome: Neurologic outcome at discharge, ROSC, admission

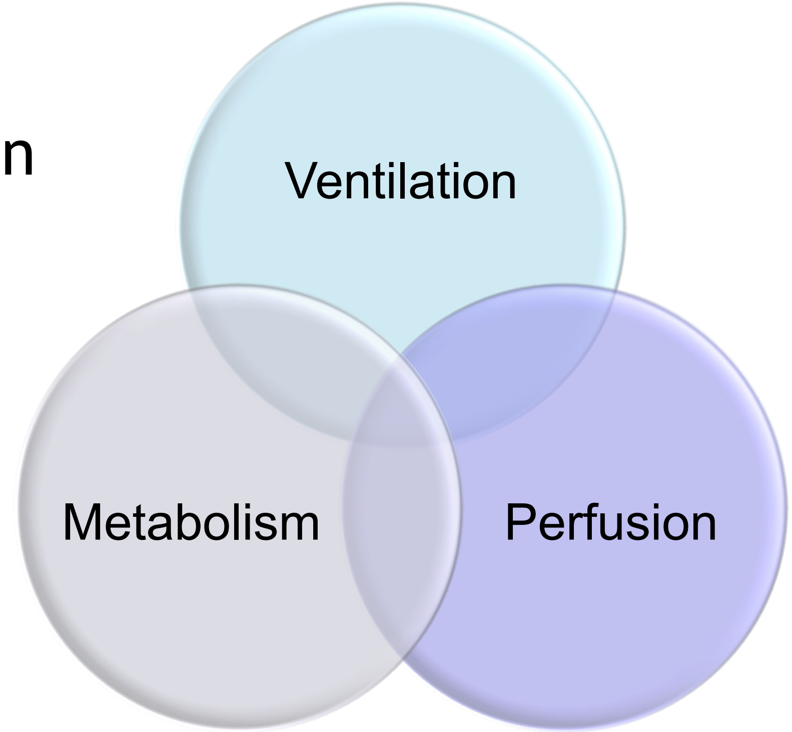


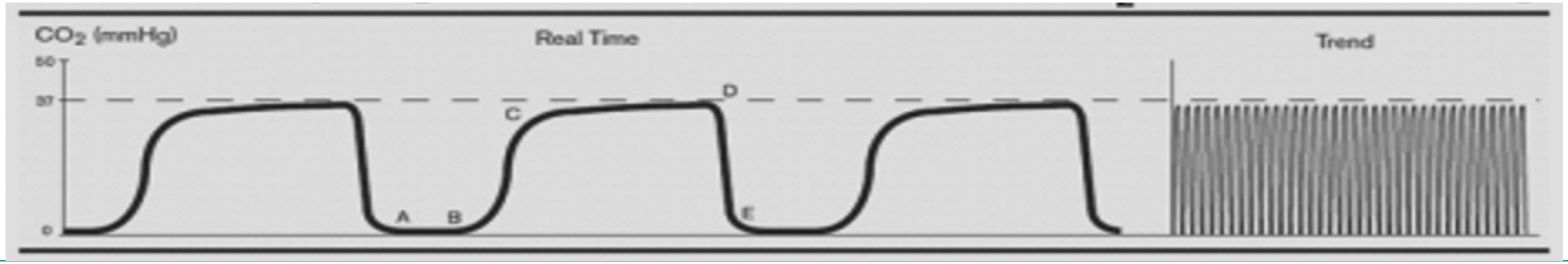
# Future of Ventilations


Picture Courtesy: AI Powered Healthcare

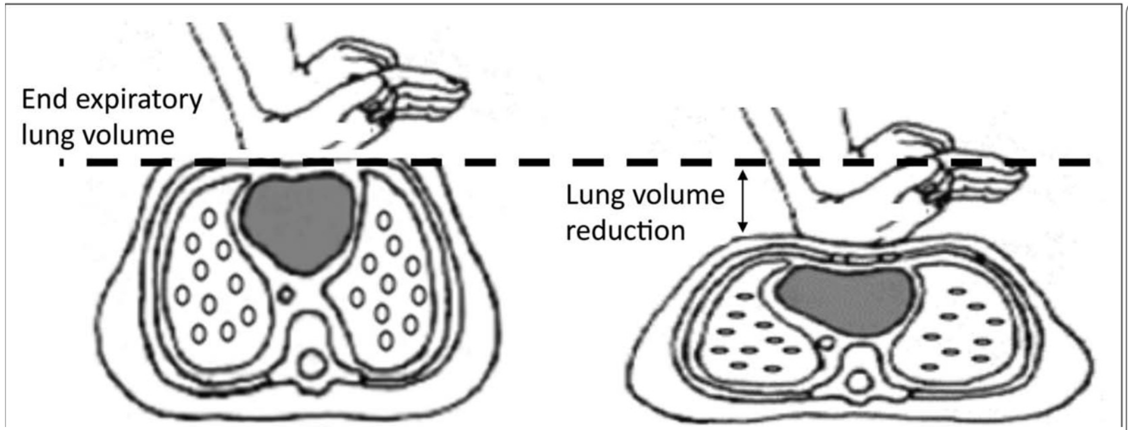
# Ventilation and ETCO2

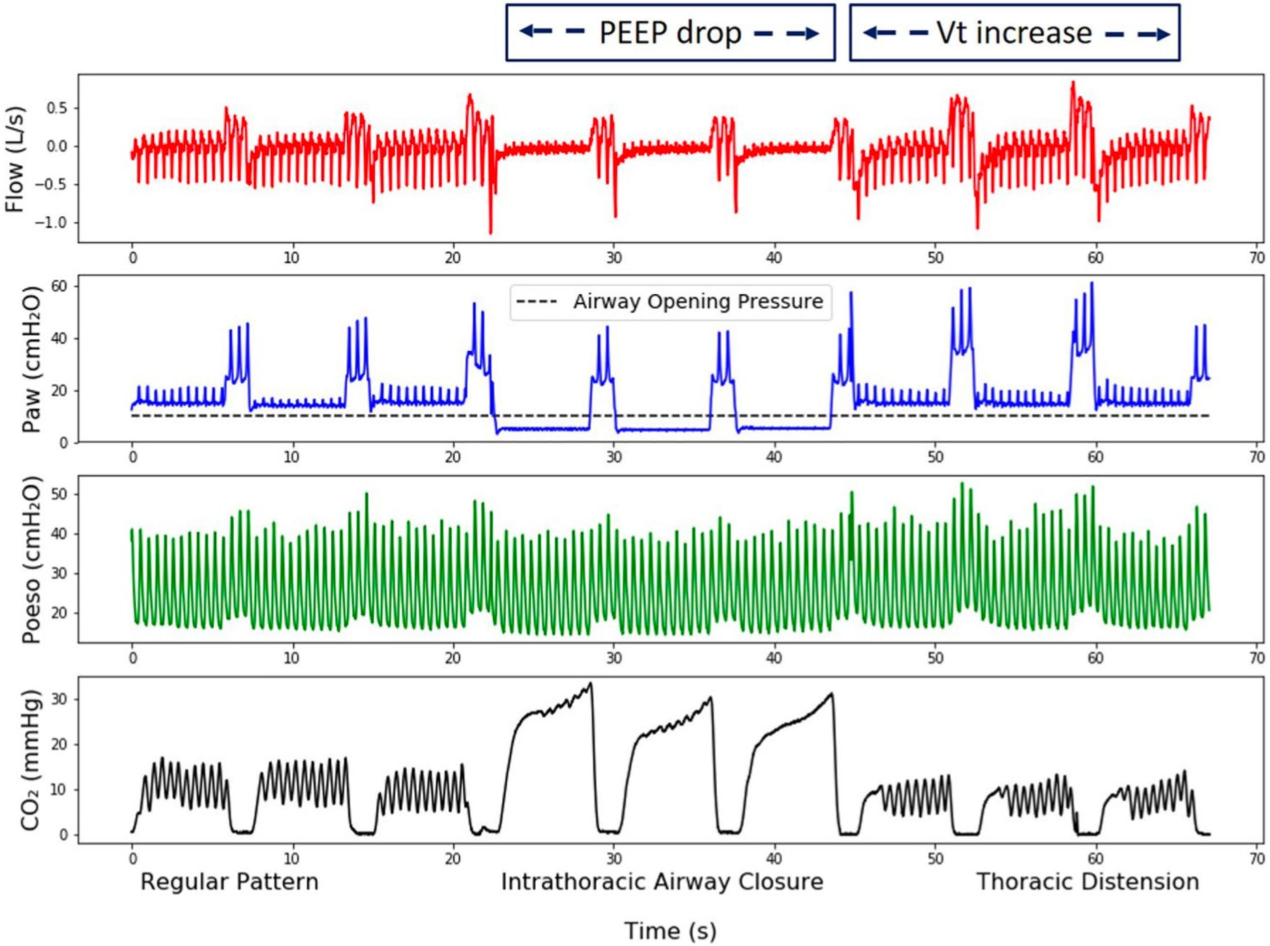
- Endotracheal tube confirmation
- CPR quality indicator
- Early ROSC indicator
- Prognostication



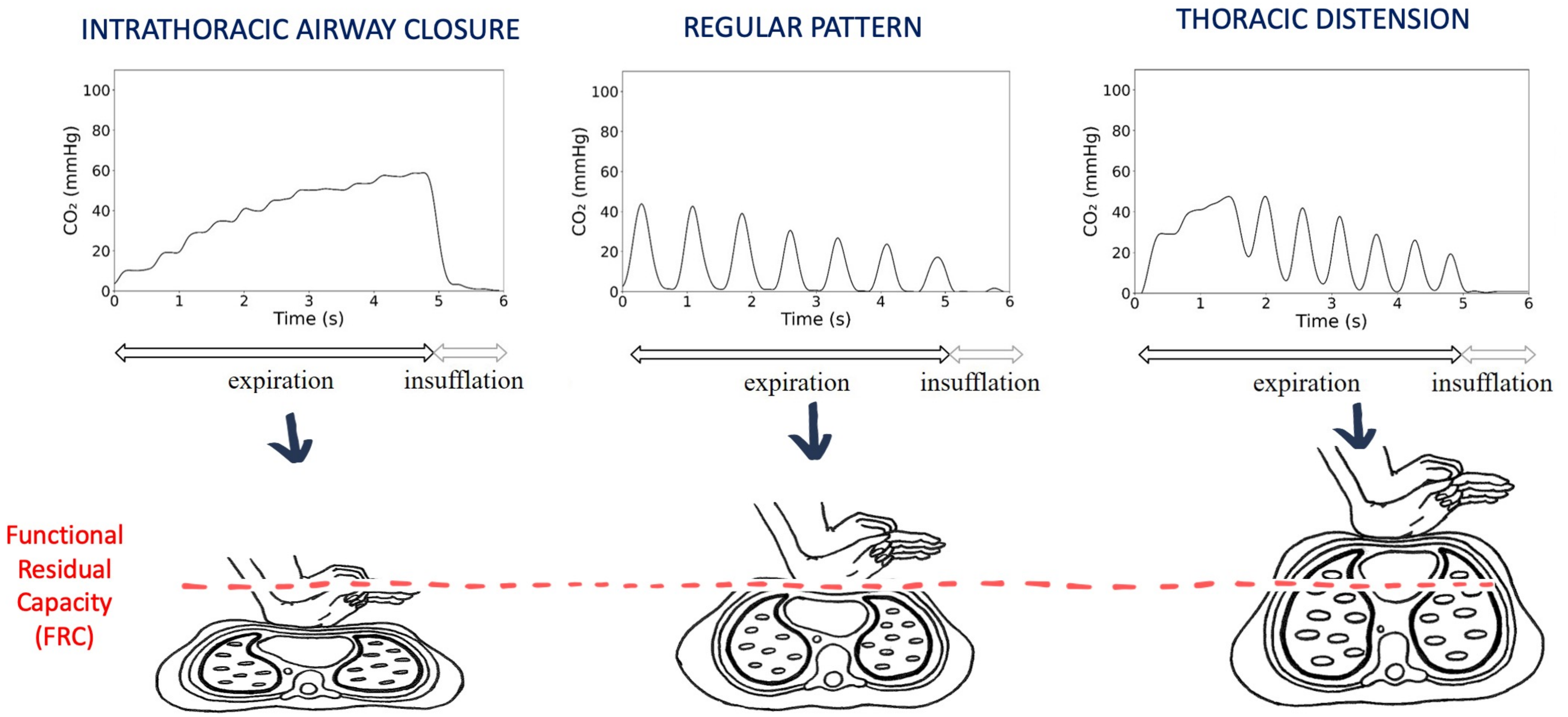



# Chest compressions and ETCO2



# Use of ETCO2




**Reduction of lung volume below FRC may impact gas exchanges and CRALE**

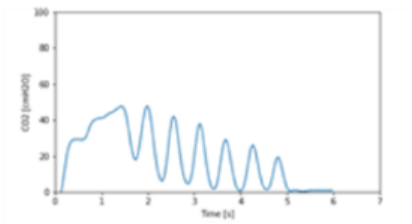
**High insufflated volumes (above FRC) may limit thoracic decompression and impede circulation**

Lesimple (2022) Critical Care

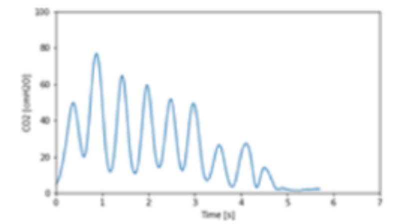
# Use of ETCO2

## CO2 PATTERNS IDENTIFICATION

Thoracic distension

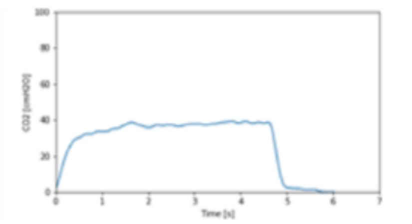


Regular pattern



Functional Residual Capacity

Intrathoracic airway closure

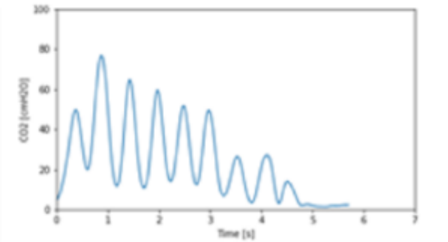


## VENTILATORY STRATEGY

REDUCE VOLUME

INCREASE PEEP

## TARGETED VENTILATION



*Picture Courtesy of A. Lesimple (2023)

# Take Home

VENTILATIONS ARE IMPORTANT

OFTEN PERFORMED INCORRECTLY

NEED TO MEASURE AND IMPROVE VENTILATION QUALITY

UNDERSTAND OPTIMAL VENTILATION (CAN WE INDIVIDUALIZE)

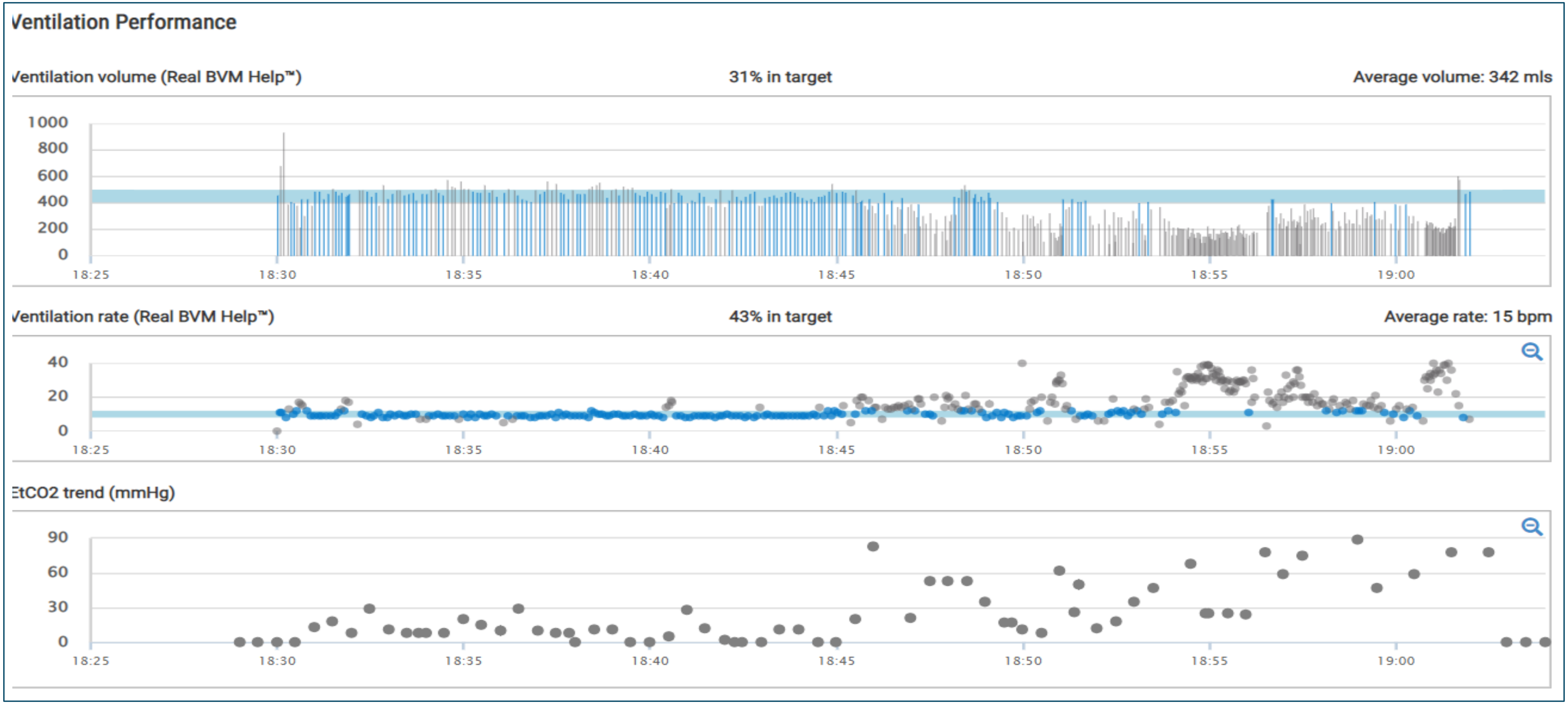
# Thank You!

@IanR_Drennan

Idrennan@ornge.ca

# Sample Case With Ventilation Feedback

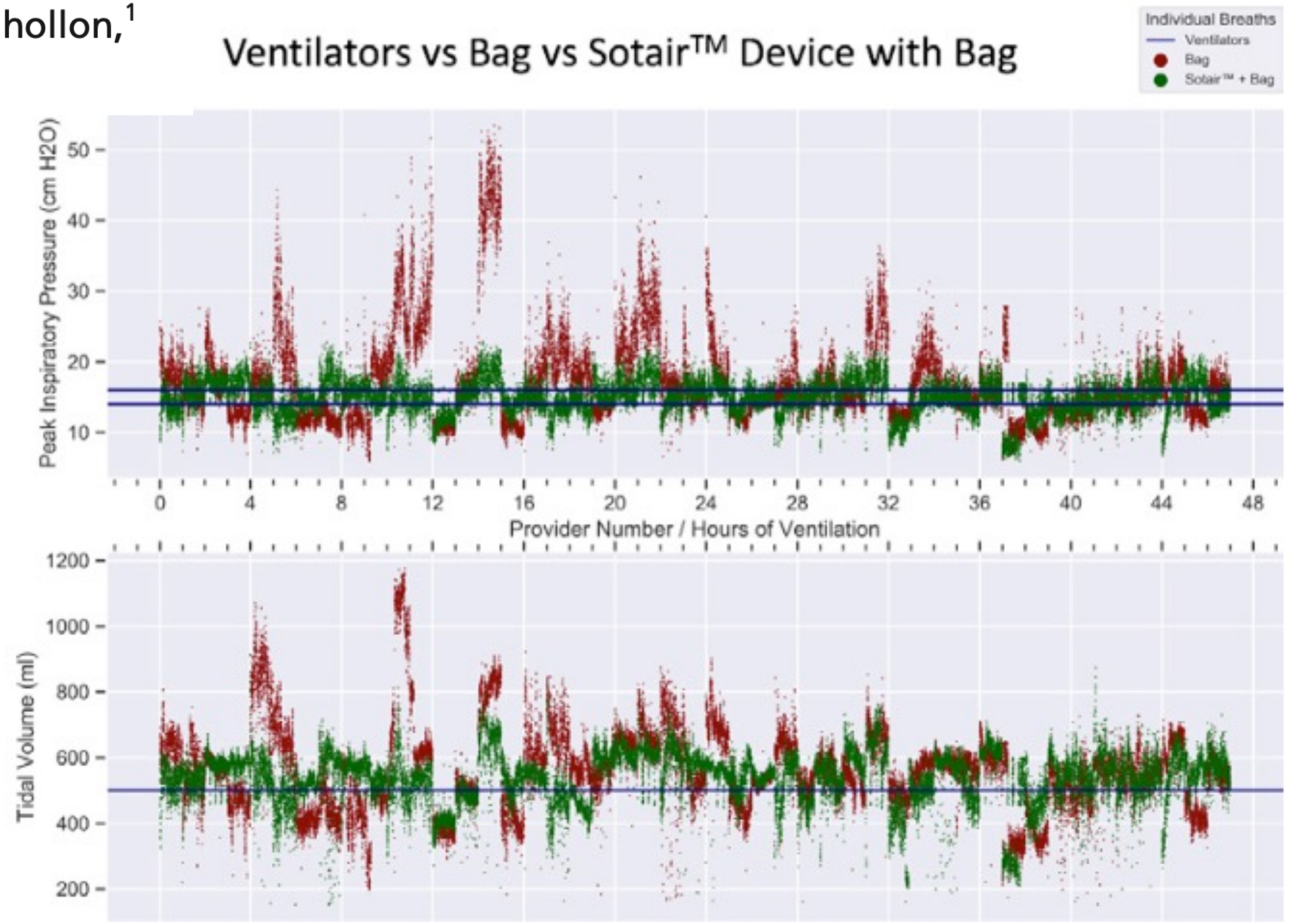
# Sample Cases After Ventilation Feedback



Original research

# Feasibility of manual ventilation replacing mechanical ventilation

Mark F Brady,[1] Nicole K Weber,[2] Richard Walker, III,[1] Joseph E Holley,[1] Samantha A Ni,[1] Shane Young,[1] Ethan D Monhollon,[1] Randy S Carpenter,[3] Jack W Tsao[2]



# Zoll AccuVent Device

- Works by measuring differential pressure
- Measurement occurs resistor
- Resistor is a small flap which sits in the center of the device