Advances in respiratory monitoring during mechanical ventilation

Stephen Tunnell

Disclosures

Rationale – why Steve?

Chief Science Officer – Lungtreater Clinical Research Organization

Chief Executive Officer – VentDx Ltd Oxford UK

First Esophageal Balloon System (1988)

First Integrated Waveforms & Loops (1990)

First Respiratory Mechanics (Dynamic / Static) (1991)

First Measurement of Power from the Ventilator (1990, 96)

First Server Based Ventilator (2003)

Monitoring Definitions

Oxford Languages Dictionary

- Observe and check the progress or quality of (something) over a period of time; keep under systematic review

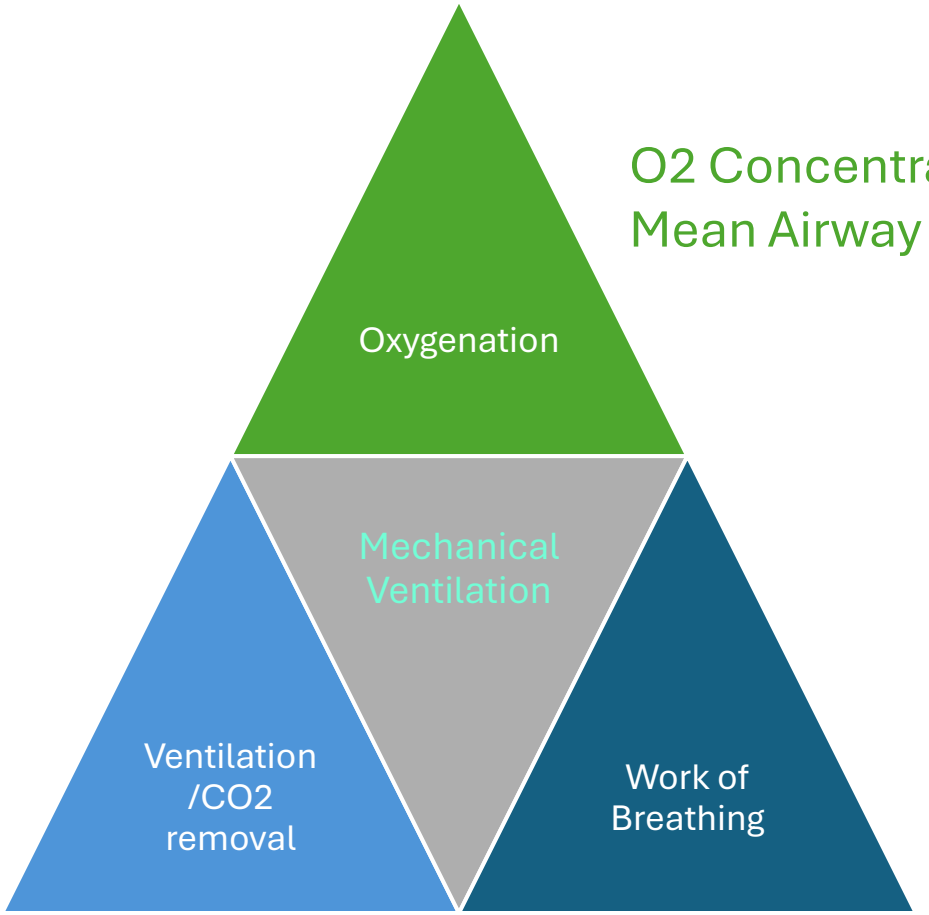
Merriam Webster Dictionary

- To watch, keep track of, or check usually for a special purpose

Steve’ definition

- Pay attention

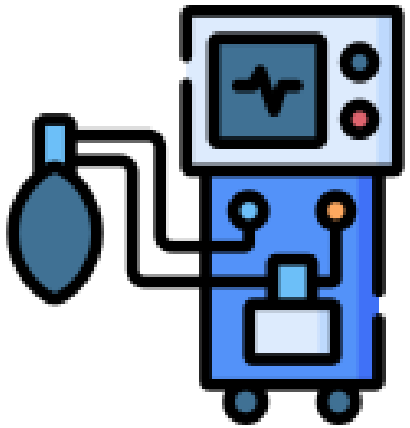
Before we dive into monitoring let's talk Mechanical Ventilation (Intended Use)



O2 Concentration
Mean Airway Pressure

Minute Volume
Tidal Volume

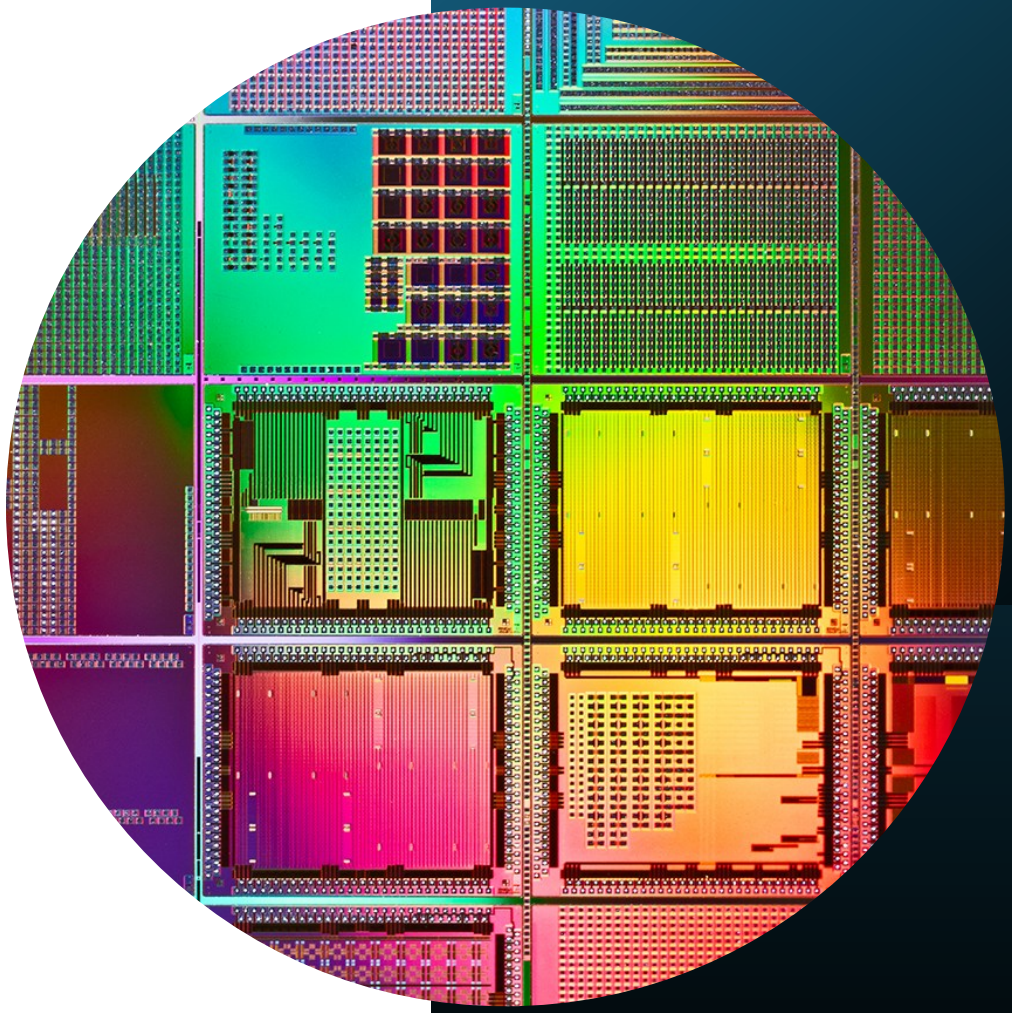
Imposed Work/
Driving Force/Power
Work to Trigger



We are applying a Machine(PEMS) to a Human in order to facilitate one or more of these three previous indications

How does the PEMS – Ventilator do that?

Controls its own force (metering or generating) to provide a targeted pressure or flow over time.



With these functions in mind let's look at what's occurring and what monitoring is basic

Oxygenation	Oxygen Concentration delivered
	End Expiratory Pressure
	Mean Airway Pressure
CO_2 removal/ Ventilation	Volume per breath and delivered over time
	Expired CO_2
Force	Pressures (dynamic & static)
	Driving Pressures
Desynchrony	Waveform Analysis
Respiratory Drive	Respiratory Rate
	P 0.1

Now let's expand this list to include items that are out of the box (PEMS) – Patient Centric.

Oxygenation	Oxygen Concentration delivered	Blood Gases (PaO2 & SaO2)
	End Expiratory Pressure	Oximetry
	Mean Airway Pressure	
CO2 removal/ Ventilation	Volume per breath and delivered over time	Blood gases (PaCO2)
	Expired CO2 (ETCO2)	Volumetric Capnography
Force	Pressures (dynamic & static)	IL-6, IL-8, and CXCL1*
	Driving Pressures	MP
Desynchrony	Waveform analysis	Signs of work, agony and discomfort
Respiratory Drive	Respiratory Rate	Physical assessment
	P 0.1	P es

* Research only

State of the Art Monitoring

Let’s go with Oxford:

1. Observe and check the progress or quality over time.

2. Keep under systematic review.

State of the Art Monitoring

Let’s go with Oxford:

1. Observe and check the progress or **quality over time**.

2. Keep under systematic review.

Quality of Mechanical Ventilation Monitoring

Summary of Mortality Trends

Period	ARDS Mortality (%)	General ICU Mortality (%)	Key Advances
1980s	60–70	40–50	“Baby lung” concept (1987)
1990s	40–50	30–40	Optimal PEEP Low Vt, Pes
2000	31–40	25–35	ARDSNet low VT, Driving Pressure
2020	30–60 (COVID: 48–54)	30–70 (COVID: high)	NIV, HFNC, EIT
2025 (Est.)	30	20–30	EIT, IST, AI

Advanced Monitoring

AI must meet HI

Objective: Optimize ventilation to minimize ventilator-induced lung injury (VILI) and improve patient outcomes through real-time monitoring

Key Parameters:

- 02 Concentration
- Waveforms
- Mechanical Power
- Transpulmonary Pressure

Advanced Parameters

- Total Deadspace
- Mechanical Power
- Effective Lung Volume
- Effective Pulmonary Perfusion
- Lung Heterogeneity

References

- **Lung structure in ARDS**. *Chest*, journal.chestnet.org (1987).
- **ARDS**. *JAMA*, jamanetwork.com (1994).
- **Low tidal volume in ARDS**. *NEJM*, www.nejm.org (2000).
- **Mortality in ventilated patients**. *PubMed*, pubmed.ncbi.nlm.nih.gov (2005).
- **ARDS mortality trends**. *PMC*, pmc.ncbi.nlm.nih.gov (2020).
- **COVID-19 ventilation**. *EpicResearch*, epicresearch.org (2020).
- **Emory COVID-19 outcomes**. *Emory News*, news.emory.edu (2020).

References

- **Ventilator-induced Lung Injury Promotes Inflammation.** ATS Journals, www.atsjournals.org (2023).
- **Ventilator-induced lung injury results in oxidative stress.** ResearchGate, www.researchgate.net (2024).
- **Flow starvation during square-flow assisted ventilation**. Critical Care, ccforum.biomedcentral.com (2021).
- **Noninvasive Measurement of Lung Function Using the Inspired Sinewave Technique in Mechanically Ventilated Patients With Acute Brain Injury**. *Journals.lww.com*, journals.lww.com (2025).
- **Electrical impedance tomography in acute respiratory distress syndrome**. *Critical Care*, ccforum.biomedcentral.com (2022).
- **Ventilator-induced Lung Injury Promotes Inflammation**. *ATS Journals*, www.atsjournals.org (2023).
- **Electrical Impedance Tomography for Monitoring Lung Ventilation**. *Respiratory Research*, respiratory-research.biomedcentral.com (2021).

Thank You