# The Next Step to Optimal Ventilation: AVM 2

**Research results show that mechanical ventilation with a lower tidal volume delivery (6 instead of 11 mL/kg) decreases mortality and reduces the days with ventilator use [1]. Ventilation modes with adaptive control which use the Otis equation, Adaptive Support Ventilation (ASV) and Adaptive Ventilation mode (AVM), can deliver higher or excessive tidal volumes which do not promote lung protective ventilation [2,3]. To reduce tidal volume (Vt) and subsequently inspiration pressure (Pinsp) according to latest publications [4] imtmedical improved its Adaptive Ventilation Mode (AVM) to achieve lower inspiration pressure and tidal volumes. To achieve this goal, imtmedical has made extensive changes to the algorithms and invented a new targeting scheme to avoid excessive tidal volumes. AVM 2 is currently only available for researchers who are working on clinical studies to prove the concept behind our latest invention. We are proud to announce recent results of intensive research in the field of adaptive ventilation.**

## Breathing Power

Otis et al. derived their equation under the condition of a spontaneously breathing and non-ventilator supported humans [5]. Otis followed the assumption that the respiratory center of humans calculates the breathing frequency and the tidal volume exactly in a way that minimal energy of respiratory work is required. His intention was to understand and mathematically derive the natural breathing pattern of humans and he was not interested in creating new ventilation modes.

In 1991, Tehrani invented, on the basis of Otis formula, a new ventilation mode [6] which was brought to market by imtmedical and Hamilton Medical under the name AVM and ASV. In the meantime, research has continued in the field of lung protective ventilation and new indications regarding ventilator induced lung injury (VILI) are known [7-12]. However, AVM and ASV in its original form, is not explicitly designed to minimize or prevent VILI.

## Inspiratory Power

Imtmedical introduces the concept of mean inspiratory power, where inspiratory power is defined as the mechanical power which is delivered from the ventilator and remains in the patient; assuming intrinsic PEEP equals zero. Note that there is a difference between inspiratory power, total power [12] and driving power [7]. However, there is a significant difference between Otis breathing power (also known as work of breathing) and inspiratory power. Otis derived the mean power which is needed to breathe spontaneously without the support of a ventilator. The approach of inspiratory power relies on the principle how much power is delivered from the ventilator to the patient.

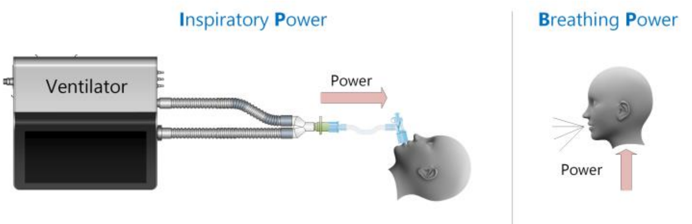


*Fig. 1 Difference between inspiratory power (generated by respirator) and breathing power (generated by humans). Work is usually expressed per breath and power as work per time.*

## Differences between AVM and AVM 2

The basic idea behind AVM and ASV is to calculate and choose the respiratory rate, which leads to minimal breathing power. With a set minute volume (MV), this frequency can be calculated by [6]:

$$f_{BP} = \frac{\sqrt{1 + \frac{4 \cdot \pi^2 \cdot RC \cdot (MV - f_{BP} \cdot V_d)}{V_d}} - 1}{2 \cdot \pi^2 \cdot RC}$$

where RC is the expiratory measured time constant.

Imtmedical continues to improve mechanical ventilation and introduced a new targeting scheme with the goal to optimize lung protective ventilation. To realize lung protection for a mechanical and mandatory ventilated patient, in an effective way as possible, the new targeting scheme automatically minimizes the mean inspiratory power supplied to the patient by the respirator. Accordingly, the optimum frequency ($f_{IP}$) is calculated which induces the lowest possible power under a given minute volume. Analogous to the equation of Otis, the optimal frequency can be calculated iteratively by a fixed-point iteration. However, for restrictive patients, it can be shown that the frequency $f_{IP}$ converges to the optimal frequency for minimal driving power.

Additional to the new target philosophy, AVM 2 includes further changes regarding I:E determination for stabilizing oxygenation and intrinsic PEEP limitation as well as a new algorithm to address the differences between spontaneous ventilation and mandatory ventilation.

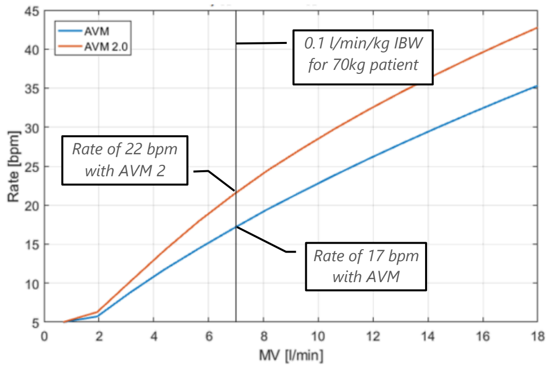


*Fig. 2 Comparison of respiratory rates of AVM (blue) and AVM 2 (red) in terms of set minute volume [MV] in case of a 70kg restrictive patient.*

## Comparison between AVM and AVM 2

Inspiratory power instead of breathing power, results in a higher respiratory rate, lower inspiratory pressures and lower tidal volumes. This supports our thesis that the optimization on inspiratory power could lead to a more lung protective ventilation. Which in turn could help to prevent ventilator induced lung injury.

### AVM


*Fig. 3 Ventilation with AVM of a 70kg patient. Vt/kg is 7.04 ml/kg, clearly above the recommended tidal volume for lung restrictive patients.*

### AVM 2

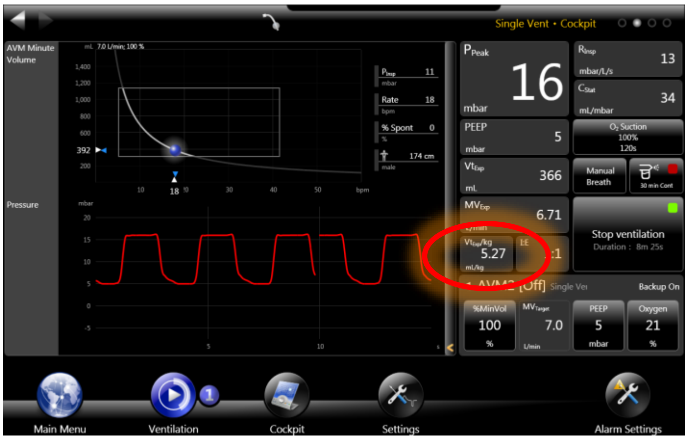


*Fig. 4 Ventilation with AVM 2. Inspiratory pressure has dropped by 6mbar, Vt/kg is more than 1.7ml/kg lower than with AVM. All values and parameters are within the recommendations of lung protective ventilation.*

## Clinical evaluation of AVM 2

Imtmedical launched clinical studies to check the practical suitability of AVM 2. On the one hand, we want to prove the basic concept behind AVM 2 and on the other, the approach of minimal inspiratory power shall be compared with the currently used targeting scheme of minimal breathing power. We expect that ventilation becomes more lung protective in particular for ARDS patients:

- Lower tidal volumes
- Lower inspiratory pressures and lower driving pressures
- Less ventilator induced lung injury

Furthermore, an influence in oxygenation and ventilation (Vt/Vd) might be possible because the mean pressure $P_{Mean}$ is expected to decrease with reduced inspiration pressure and the dead space ventilation increases with reduced tidal volumes. Based on clinical studies on lung protective ventilation and VILI, we expect significant advantages in the field of adaptive ventilation compared to the current algorithm of AVM.

## Literature, References


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