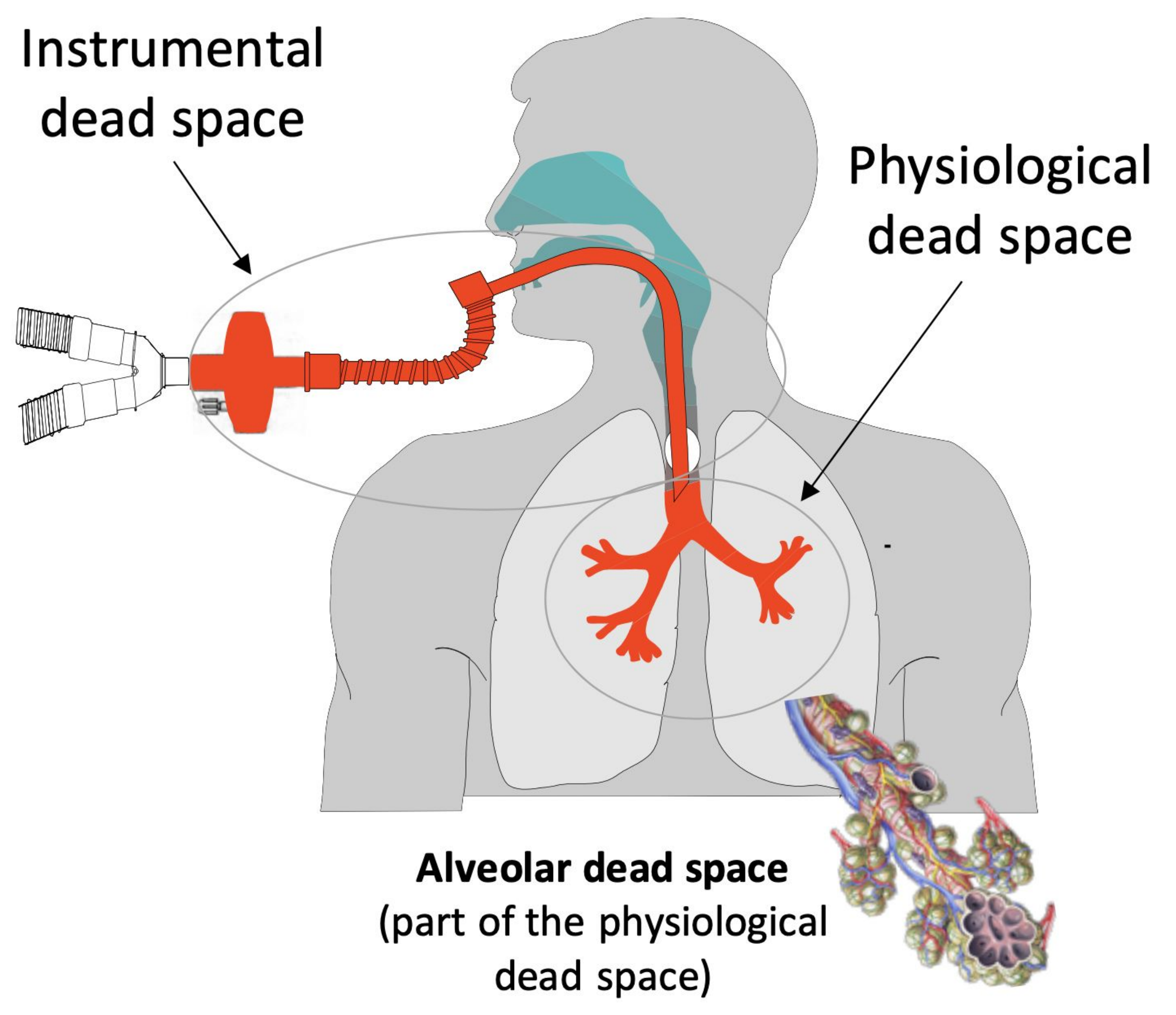
Ventilo

# What is dead space during invasive mechanical ventilation?

- Physiological dead space is different during spontaneous ventilation, non-invasive ventilation, invasive ventilation, and nasal high flow.
- During spontaneous ventilation, dead space ($V_D$) includes the upper airways (nasopharynx, oral cavity, and larynx), lower airways (trachea and bronchial tree) and alveolar dead space.

By definition, the $V_D$ during mechanical ventilation refers to the volume after the Y-piece (on the patient's side), through to the terminal bronchioles. This volume is ventilated and not, or poorly, perfused and the gases passing through do not participate in gas exchanges [1]. At the end of exhalation, this volume (or dead space) is rich in $CO_2$ and poor in oxygen. At the next breath, this volume of gas is re-inhaled.




$V_D$ is predictive of mortality in the acute respiratory distress syndrome (ARDS) [2]. It can be measured using volumetric capnography, a tool mainly used in research and whose interpretation is sometimes complex, this technique is rarely used in clinical routine [1].

It is also possible, as we have done in this application, to estimate the $V_D$ from the following equation:

$$\text{Total } V_D\ (V_{Dtotal}) = \text{Physiological } V_D\ (V_{Dphys}) + \text{Instrumental } V_D\ (V_{Dinstr})$$

A distinction must be drawn between **instrumental dead space** and **physiological dead space** (also known as anatomical dead space). The alveolar dead space, which is a part of the physiological dead space, can also be considered. This volume corresponds to alveoli that are well ventilated and not well perfused for different reasons including emphysema, thrombosed or compressed capillaries (especially when there is over distension such as in severe ARDS, emboli). This alveolar dead space is not taken into account in the calculations used in this application, which may in some cases underestimate the total physiological dead space.

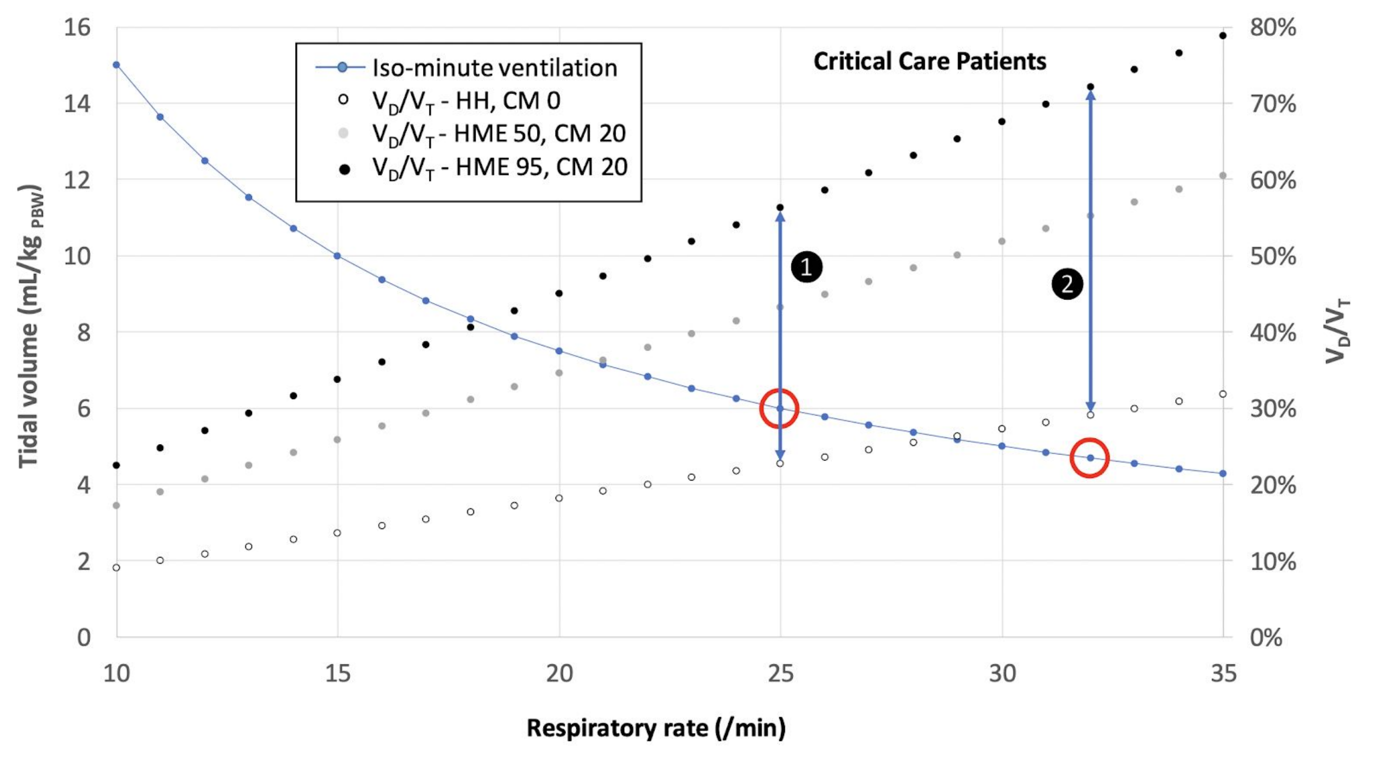
In 1955, Radford reported "a remarkable, but approximate, rule that the respiratory dead space in milliliters equals the body weight in pounds"[3]. The physiological or anatomical dead space can therefore be estimated at 1 mL/pound of PBW or 2.2 mL/kg $_{PBW}$. Several authors made adjustments to this estimation [4,5] for mechanical ventilation and even though Radford himself has acknowledged that this estimation of anatomical dead space had its limitations, this estimation, which allows the initial minute ventilation to be quantified, has been validated over time and remains used in the clinical setting [6,7].

Physiological dead space is equally distributed between extrathoracic dead space and intrathoracic dead space [8]. The physiological dead space during invasive ventilation consists of the intrathoracic dead space, which is approximately 1.1 mL/kg $_{PBW}$ [9,10]. These values are only estimations and may vary according to the anatomy of each subject, gender, position, age and pathology (especially during ARDS, in case of substantial over distension which should be reduced with protective ventilation). The calculations proposed in this Ventilo App allow estimating the impact of dead space during mechanical ventilation on gas exchanges and the impact of dead space reduction on alveolar ventilation, and therefore on the efficiency of these exchanges.

**Alveolar ventilation ($V_{alv}$)** corresponds to the ventilation that is efficient for gas exchanges, i.e. minute ventilation minus dead space ventilation:

$$V_{alv} = (V_T - V_{Dtotal}) \times RR$$

In the context of protective ventilation, with lower tidal volumes (4–8 mL/kg $_{PBW}$) and elevated respiratory rates (often greater than 20-25/min in intensive care patients), alveolar ventilation is substantially reduced if the instrumental dead space is large (use of catheter mount or other connectors and heat and moisture exchangers). This is illustrated in the following figure.




The figure represents the impact of dead space on tidal volume ($V_D/V_T$) for different settings which provide the same minute ventilation (iso-minute ventilation blue line, corresponding to 150 mL/kg $_{PBW}$) on the main axis. The dead space ($V_D/V_T$) curves are shown on the secondary axis for situations with a Heated Humidifier (HH, white circles), heat and moisture exchangers of 50 and 95 mL (HME 50, HME 95, gray and black circles) and without or with catheter mount (CM 0 and CM 20 mL). In critically ill patients receiving protective ventilation, the impact of dead space can be substantial. For a tidal volume of 6 mL/kg $_{PBW}$ with a respiratory rate of 25/minute (case ❶), the $V_D/V_T$ decreases from 56% to 23% by reducing the dead space to a minimum. For a tidal volume of 5 mL/kg $_{PBW}$ with a respiratory rate of 32/minute (case ❷), the $V_D/V_T$ decreases from 72% to 29% by reducing the dead space to a minimum (calculations for a 165 cm woman).

Abbreviations:
$V_D$: dead space; $V_T$: tidal volume; HH: heated humidifier; HME: heat and moisture exchanger; CM: catheter mount.

## References

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