Ventilo

Indications of protective ventilation and main settings

○ Protective ventilation should potentially be applied in all patients undergoing invasive and controlled ventilation as soon as possible after intubation [1-7].

○ Protective ventilation is not just tidal volume reduction, but a combination of ventilator settings and associated procedures [6,8-11].

○ A number of ventilator settings can have an impact on patient MORTALITY, it is therefore a significant responsibility to properly set the ventilation parameters [10,12,13]

Mechanical ventilation in the operating room (scheduled surgery)

Tidal volume (V_T)

Set to 6–10 mL/kg of Predicted Body Weight (PBW) [1,4,5,8,14]. Start with 8 mL/kg $_{PBW}$ and adjust after stabilization if needed.

Respiratory rate (RR)

Set to achieve either a $PaCO_2$ of 35–45 mmHg or end tidal CO_2 ($EtCO_2$) of 30–40. Alternatively, this setting can be based on the gradient between $PaCO_2$ and $EtCO_2$ when available. An important aim is also to avoid autoPEEP (inspiratory flow should be above 40 L/min to avoid prolonged inspiratory time (T_I) (target a Inspiratory:Expiratory (I:E) ratio of 1:3), especially in patients at risk of autoPEEP*). **The initial target is to achieve a minute ventilation around 100 mL/kg $_{PBW}$.**

Positive end-expiratory pressure (PEEP)

Set to 5–10 cmH_2O according to blood volume, hemodynamic stability, and Body Mass Index (BMI)[15-18].

Recruitment manoeuvres

May be appropriate in some situations after derecruitment and in patients at risk of atelectasis (BMI >40 kg/m^2)[19]. Several methods are possible, for example, a stepwise increase in the level of PEEP up to 20 cmH_2O for a few cycles and according to the hemodynamic tolerance[20,21]. Another method is to apply a continuous positive pressure of 30 cmH_2O for 30 seconds[7].

Minimize the fraction of inspired oxygen (FiO_2)

to keep the saturation of peripheral oxygen (SpO_2) at 90–94% if FiO_2 <60%. The target SpO_2 should be 88–92% if the FiO_2 ≥60%[22,23]. The purpose is to prevent hypoxemia and hyperoxemia (SpO_2 >94%)[22] as well as hyperoxia (FiO_2 >60%)[23,24].

Mechanical ventilation in ED or ICU (patients without ARDS)

Tidal volume (V_T)

Set to 6–10 mL/kg $_{PBW}$ [1,4,5,8]. Start with 8 mL/kg $_{PBW}$ and adjust after stabilization if needed.

Respiratory rate (RR)

Set to achieve $PaCO_2$ of 35–45 mmHg and absence of autoPEEP (inspiratory flow above 40 L/min to contain T_I, especially in patients at risk of autoPEEP*). The initial target is to achieve a minute ventilation around 150 mL/kg $_{PBW}$.

Positive end-expiratory pressure (PEEP)

Set to 5–12 cmH_2O according to BMI [15-17].

Minimize FiO_2

Set to keep SpO_2 at 90–94% if FiO_2 <60%, (target SpO_2 88–92% if FiO_2 ≥60%)[22,23]. The purpose is to prevent hypoxemia and hyperoxemia (SpO_2 >94%)[22] as well as hyperoxia (FiO_2 >60%).

Mechanical ventilation in ICU (patients with ARDS[25])

Tidal volume (V_T)

Set to 4–8 mL/kg $_{PBW}$. The target is to keep plateau pressure (P_{plat}) <30 cmH_2O and driving pressure ≤15 cmH_2O**[1,2,9-11,26,27]. In the absence of severe acidosis or hyperkalemia, ventilation could be immediately started at 6 mL/kg $_{PBW}$. Otherwise, start with 8 mL/kg $_{PBW}$ then quickly reduce to 6 mL/kg $_{PBW}$ after hemodynamic and metabolic stabilization.

Respiratory rate (RR)

Set to:

i. reach $PaCO_2$ of 40–75 mmHg (with pH >7.25) according to the clinical situation. Often RR >25/minute, especially if the RR was elevated before intubation, in case of fever (temperature >38°C), metabolic acidosis, or situations at risk of metabolic acidosis (oligo-anuria, shock, etc.),

ii. reduce the risk of autoPEEP (inspiratory flow above 40 L/min to set the T_I, especially in presence of autoPEEP*). The initial target is to achieve a minute ventilation around 150 mL/kg $_{PBW}$ according to clinical condition.

Positive end-expiratory pressure (PEEP)[9,13,28-31]

If PaO_2/FiO_2 >200 (or SpO_2/FiO_2 >235[32]) then use a PEEP of 6–12 cmH_2O according to BMI and hemodynamic condition.

If PaO_2/FiO_2 ≤200 (or SpO_2/FiO_2 ≤235[32]) then use a PEEP set using the EXPRESS strategy[30] (set V_T 4–8 mL/kg $_{PBW}$, then increase PEEP until P_{plat} = 28 cmH_2O) or use the high PEEP/FiO_2 scale[31] ***. This high PEEP strategy should be continued if there are positive effects on oxygenation, if there is no hemodynamic impairment and if the P_{plat} remains <30 cmH_2O.

Minimize FiO_2

Set to keep SpO_2 at 88–92% as long as FiO_2 is ≥60%.

Associated procedures in ARDS

Patient monitoring should include repeated measurements of respiratory mechanics, especially P_{plat} and autoPEEP: P_{plat} with a end-inspiratory pause (to be sustained below 30 cmH_2O), autoPEEP with a end-expiratory pause [2,6,9,33]. Driving pressure can also be measured regularly and should be kept below 15 cmH_2O, however, its usefulness remains debated [9,34,35].

Curares/neuro-muscular blocking agents can be used for 24–48 hours for moderate to severe ARDS (PaO_2/FiO_2 <150), especially in case of patient/ventilator asynchronies, such as double triggering [36], but recent data show questionable efficiency [6,9,37,38].

Prone positioning for moderate to severe ARDS (PaO_2/FiO_2 <150), more than 16 hours/day [2,6,9,39,40].

Maximum reduction of dead space is part of ARDS management (use of Heated Humidifier, reduction in the use of connectors) to improve alveolar ventilation, especially CO_2 elimination, and to allow a maximum reduction in tidal volumes [9,27,41-45]. In the absence of ARDS, in cases of

protective ventilation with low tidal volumes and respiratory rate above 25, dead space reduction may also be relevant.

Routine **recruitment manoeuvres** are not recommended [2,6,9,46]. Use with caution in case of desaturation after derecruitment (e.g. disconnection or endotracheal suctioning), with particular caution in hypovolemic or hemodynamically unstable patients.

A **closed suctioning circuit** is part of the ARDS management in order to prevent repeated derecruitment during endotracheal suctioning. [9,47,48].

The use of **veno-venous ECMO** can be discussed in experienced centres, in patients with severe and persistent ARDS (PaO_2/FiO_2 <80 mmHg despite optimization of settings)[9,49-51].

Inhaled **Nitric Oxide (NO)** may be considered in case of failure of prone positioning and curares, before the use of Extracorporeal Membrane Oxygenation (ECMO) [9].

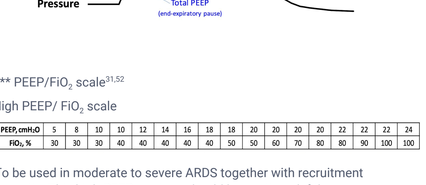
Routine use of **esophageal pressure** monitoring for PEEP setting, or transpulmonary pressure monitoring is not a requirement [52].

There is not enough data to make recommendations for the systematic utilization of corticosteroids and Extracorporeal Carbon Dioxide Removal ($ECCO_2R$) [9,11].

The use of **high frequency oscillation (HFO)** is strongly discouraged, except eventually as a last option in patients with refractory hypoxemia (PaO_2/FiO_2 <60 mmHg for several hours), without any evidence being provided [2,6,9,53].

Notes

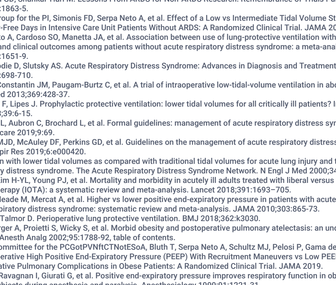
* Identifying autoPEEP (i.e. intrinsic-PEEP) on the flow curve. In case of suspected auto-PEEP or in case of doubt, it should be measured by a tele-expiratory pause. The measurement of auto-PEEP is one of the parameters to be systematically and regularly monitored [33].



** Driving pressure (ΔP)

$\Delta P = P_{plat} - PEEP_{tot}$ = end-inspiratory pause pressure - end-expiratory pause pressure = V_T/C_{stat}

Where $PEEP_{tot}$ is total PEEP and C_{stat} is lung compliance when stationary.



*** PEEP/FiO_2 scale[31,52]

High PEEP/ FiO_2 scale

PEEP, cmH_2O	5	8	10	10	12	14	16	18	18	20	20	20	20	22	22	22	24
FiO_2, %	30	30	30	40	40	40	40	40	50	50	60	70	80	80	90	100	100

To be used in moderate to severe ARDS together with recruitment capacity. This high PEEP strategy should be continued if there are positive effects on oxygenation, if there is no hemodynamic impairment and if P_{plat} remains <30 cmH_2O.

The objective is to keep SpO_2 between 88 and 92%.

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