

Oxygen consumption of non-invasive ventilation modes in ICU ventilators

Sir,

In the recent wave of the coronavirus disease-2019 (COVID-19) pandemic, the intensive care units (ICUs) were flooded with patients who needed non-invasive ventilation (NIV). The oxygen utilisation went to the roof making everyone run amok. Due to the shortage of oxygen supply, anaesthesiologists were forced to use oxygen judiciously in the ICUs.

For all oxygen delivery devices, we know the exact rate of supply of oxygen per minute. So, we can adjust the

flow of oxygen and conserve oxygen utilisation. But in ICU ventilators for NIV and invasive ventilation, we do not know the exact requirement of oxygen per minute.

Stuart and Klein^[1] mentioned a method of estimating gas consumption in an ICU ventilator [Table 1].

Since this calculation is for intubated patients on ventilator, a high flow rate may be needed for NIV because of the leak and the oxygen utilisation is likely to go up.

Table 1: Stuart *et al.*^[1] method of estimating gas consumption in an Intensive Care Ventilator

Gas consumption = (minute ventilation+bias flow) × [(FIO₂-0.2)/0.8] + cycling requirement.

A more accurate approximation can be obtained using:

Gas consumption = [minute volume + (bias flow × [Ti/(Ti+Te)]) × [(FIO₂-0.2)/0.8] + cycling requirement.

(Ti – Inspiratory time; Te – Expiratory time; FIO₂ – Inspiratory oxygen concentration)

Table 2: Oxygen usage by Non-invasive ventilation (NIV)/Invasive ventilation in different ventilators

VENTILATOR	MAKE	MODEL	NIV– Oxygenutilisation	Invasive ventilation –Oxygen utilisation
Mindray	Shenzhen Mindray Bio-Medical Electronics Co., Limited	Mindray SV 300	45 L/min	14.5 L/min
Drager	Dragerwerk AG & Co.	Drager Savina	47 L/min	15.5 L/min
Altima	Medion Healthcare Private Limited	Altima	33 L/min	11.5 L/min
Maquet	Maquet Critical Care AB	SERVO s Base unit	49 L/min	10 L/min
Vela	Care fusion	Vela 16532-10	57.3 L/min	15 L/min
Schiller	TECME S. A	Graphnet Ts	49.6 L/min	14 L/min
Orion G	Air Liquide Medical Systems Private Limited	Orion G	45 L/min	12 L/min
Bharat Electronics Ltd (BEL)	Bharat Electronics Limited	PM-CARES CV200	57.3 L/min	15.5 L/min

This table is based on flow rates under experimental conditions. Please note that flow rates may vary considerably depending on patient factors, oxygen supply factors and device/ventilator modes, most notably bias flow settings. Please consult manufacturer specifications when making any estimations as newer data may be available

The mechanical ventilator may generate flow by using the pressure gradient between the supply piped gas and the atmosphere. Alternatively, the ventilator may generate flow by means of a gas compressor turbine. These methods have the advantage of being able to generate the sort of high flows which are required for NIV (to compensate for leak around the edges of the mask). For most ICU ventilators, the maximum flow rate is approximately 200–250 L/min.

According to a study by Anderson *et al.*,^[2] the peak inspiratory flow in a calmly breathing person seems to be 5-10 L/min, but with exercise (or respiratory distress) it can go up to 30-40 L/min. At peak exercise, the authors recorded peak inspiratory flow rates (PIFRs) of around 250 L/min from their healthy volunteers. There is a direct relationship between increase in PIFR and handgrip exercise.^[3] Amato *et al.*^[4] observed eight ventilated patients (four patients had acute respiratory distress syndrome) and found that some ended up with PIFR of up to 155 L/min. Then, if a 25% leak is added as the acceptable maximum ceiling (a leak in the circuit, a deflated cuff, an ill-fitted mask), an adult ventilator would probably need to produce at least around 200 L/min of flow. This is indeed the case for most of the existing models.

Obviously, the ability to produce these high flow rates is dependent on the reliability of the hospitals' gas supply. If the central supply pressure is inadequate, the ventilator will not be able to produce such high flows. The technical specifications for these devices usually quote a minimum supply gas flow rate as 120 L/min, or a minimum supply pressure of 200 kPa. We can refer the service manual of the ventilators for the maximum flow that the ventilator can generate.

To meet the flow rate in NIV, how much oxygen will be utilised is a million-dollar question. To know

the oxygen utilisation per minute for different ICU ventilators, we have conducted a study by connecting D-type cylinders to the ICU ventilators and calculated the oxygen utilisation per minute. The minute flow rate (adjusting respiratory rate and tidal volume) and flow trigger were kept constant in all patients.

For the commonly used ICU ventilators, the minimum usage of oxygen per minute when on 100% fractional inspired concentration of oxygen and a tight fitting mask can vary according to the make and model of the ventilator [Table 2].

The average usage of oxygen per minute for NIV in an ICU ventilator is around 40-50 L. That will be around 57,600-72,000 L/day of gaseous oxygen equivalent to 67-84 L of liquid oxygen per day for a patient. So, it is easy to calculate the one-day usage of oxygen in each ICU.

Since constant up-gradation of central oxygen supply and Medical Gas Pipeline System is to be done based upon anticipated future requirements as per Indian Society of Anaesthesiologists (ISA National) Advisory and Position Statement, this calculation of usage of oxygen for NIV will be much useful.^[5] But future studies are needed to calculate the flow rate for ICU ventilators and their oxygen requirement depending upon the lung compliance.

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Conflicts of interest

There are no conflicts of interest.

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