American Association for Respiratory Care

Guidance Document

Additional Ventilators May Pose a Risk to Hospital Gas Systems

The COVID-19 epidemic has placed hospitals in dire risk of having insufficient resources to treat the surge in patients. One critical resource is mechanical ventilation. As hospitals rush to increase ventilator inventory, they may be overlooking an important limiting resource; perhaps as important as ventilator circuits or even clinicians to operate the machines. That resource is the facilities medical gas supply.

Ventilators used in intensive facilities' care units, particularly in the United States, are usually connected to oxygen and air outlets at 50 psig linked by plumbing to huge liquid oxygen storage tanks and giant air compressors. These sources provide both flow and pressure necessary to allow the ventilator to assist the patient's breathing.

When designing a hospital, architects typically build in a surge capacity factor for medical gas supply lines. This factor may be close to 1.5 times the expected load. The expected load may be calculated in terms of the average annual air or oxygen usage per square foot of hospital floor space or perhaps per bed (see https://www.mdpi.com/2071-1050/10/8/2948). This fact could be of great concern for two reasons: First, clinicians are unlikely to be aware of this limitation as they plan to increase their ventilator inventory (and simultaneous number of ventilators in operation) by much more than 50% of the average usage and how this load is much different from the load calculated by architects. Second, facilities engineers are unlikely to understand the operation of mechanical ventilators and how that impacts their calculations of peak flow demand for oxygen and air. The result of this joint misunderstanding could result in an overload of the medical gas supply system for a hospital with resulting ventilator failure and potential ventilator damage. If the air compressor system and its associated dehumidifying system is overloaded, moisture can enter the hospital air lines and reach the ventilators causing ventilator failure. And a failure of the medical gas system puts all patients at risk, not just those on ventilators. One of us (RC) has actually seen both of these situations in a hospital secondary to failure of the dehumidifying system (not due to overload).

In an effort to address these concerns, we have created and make available a calculator that hospital planners can use to assess their particular gas consumption projections as a function of both patient census and ventilator operating characteristics. It will help them characterize the load on the gas supply system in terms of peak flow demand, and calculates the number of compressed gas cylinders required if there is not plumbing system available. This can be helpful for planning temporary hospitals.

Practical suggestions

1. Turn off oxygen to manual resuscitators until needed.
2. Use only the required oxygen concentration – avoid hyperoxemia (this is good practice under normal conditions).
3. Reduce the use of high flow nasal cannula delivery of oxygen (often 30-60 l/min) for oxygen conservation, reduction of environmental contamination and reported frequent failure rate.
4. Quick tip: Calculation of the oxygen use by a ventilator can be accomplished using the equation
   a. Oxygen (L/min) = $[(FIO_2 - 0.21)/0.79]$ x minute ventilation (respiratory frequency x tidal volume)
   b. If the ventilator has a bias flow (flow during expiration the equation can be modified)
   c. Oxygen (L/min) = $[(FIO_2 - 0.21)/0.79]$ x minute ventilation (respiratory frequency x tidal volume) + Bias flow (L/min) x $(FIO_2 - 0.21)/0.79$
5. Bias flows and Leaks:
   a. Bias flow with some ventilators can consume as much gas as the set minute ventilation. Consider reducing bias flow if possible. If bias flow cannot be reduced then consider changing the trigger to pressure triggering if possible.
   b. NIV devices with a single limb circuit with a fixed leak also consume gas resources. If oxygen is bled in and the internal blower provides the flow then the impact on oxygen use is unaffected by the leak. However in systems that blend oxygen prior to the leak (V-60) the use of oxygen consumption is high.

This calculator may be downloaded and freely distributed from http://www.aarc.org/wp-content/uploads/2020/04/calculator-medical-gas-consumption.xlsx

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Depiction of a strained liquid oxygen system.

Typical hospital liquid oxygen system including two main reservoirs and a smaller reserve reservoir. The vaporizing coils are in the foreground.