# Using COVID-19 ICU Respiratory Training Simulators

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**The coronavirus SARS-Cov-2 has led to an urgently worrying, universal problem: a lack in the amount of intensive care units (ICUs) with beds allowing patients to be put on mechanical ventilation and healthcare staff trained to operate these ventilators.**

At the outset of the SARS-COV-2 pandemic, it had not been determined why respiratory support in the ICU was necessary in COVID-19 patients. Experts spoke about "COVID-19 pneumonia" and "non-ARDS" (non-acute respiratory distress syndrome) [1], leading to confusion amongst those operating ventilators. This confusion stemmed from the fact that established guidelines for mechanical ventilation did not address this novel kind of respiratory failure.

However, very soon after this confusion was identified, guidelines were proposed [2,3] to help practitioners. This article provides information on how to use TestChest to represent COVID-19 patients in order to practice using respiratory support devices and to alleviate the shortage of expertise in providing effective respiratory care in the ICU to COVID-19 patients.

## TestChest: The autonomous lung simulator

TestChest is an autonomous lung simulator that provides two natural interfaces: the airway opening, to provide respiratory therapy and the ability to the measurement of lung function, and an artificial finger to measure oxygen saturation and plethysmography.

The trainer sets the disease and the breath pattern, and the trainee applies the respiratory therapy. TestChest will respond to the settings and therapy applied autonomously, without needing any further interaction from the trainer.

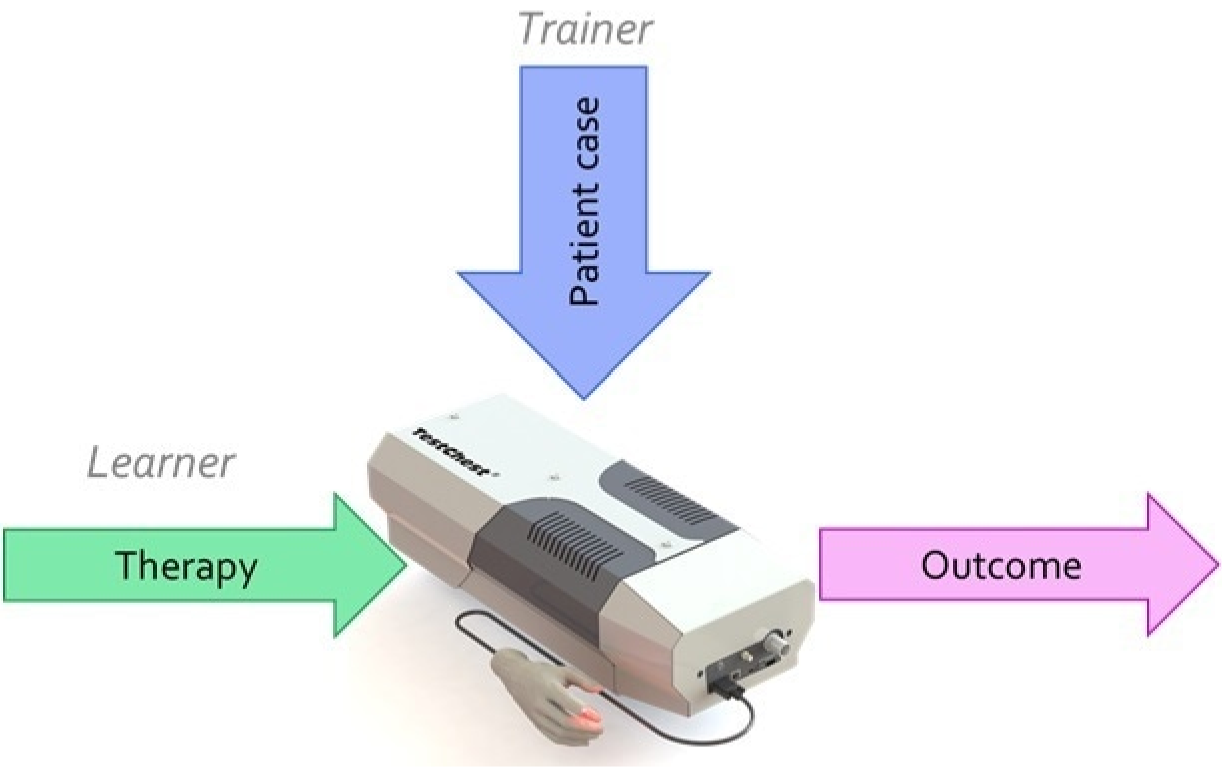


***Figure 1.*** *Autonomous lung simulator TestChest. The trainer sets a patient case and TestChest reacts autonomously to the therapy attempts of the trainee, without further interaction from the trainer. Outcomes are oxygen saturation, airway pressures, tidal volumes, respiratory rate, and other physiological responses. Image Credit: neosim AG*

## Method to set TestChest to simulate COVID-19 patients

Three successive scenarios are created to train operators to use mechanical ventilators for COVID-19 patients arriving in the ICU.

The overall goals of the simulation are to be able to practice the following:

- Selecting the appropriate ventilation mode
- Adjusting settings to achieve adequate $SpO_2$ and adequate end-tidal $CO_2$
- Applying lung-protective ventilation, including tidal volume (VT), plateau, positive end-expiratory pressure (PEEP).

The table below provides detailed information about setting the TestChest to achieve the different patient groups as described in [4], Type L and Type H.

**Table 1.** TestChest parameters set to provide COVID-19-like patient for training. Detailed explanation in [5]. Source: neosim AG

| Parameter | | COVID-19 Type L: spontaneous breathing | COVID-19 Type L: paralysis, first hours | COVID-19 Type H: late stage (ARDS) |
|---|---|---|---|---|
| CW | ml/hPa | 93 | 93 | 93 |
| $V'CO_2$ | mlSTPD | 250 | 197 | 250 |
| P0.1 | hPa/100 ms | 8 | 0 | 1 |
| Crs | ml/hPa | 52 | 52 | 35 |
| Raw | hPa/(L/s)@1 L/s | Rp5 | Rp5 | Rp5 |
| f (spont) | /min | 40 | 0 | 0 |
| FRCmin | ml | 1102 | 1102 | 1102 |
| LowerInflection | hPa | 1 | 1 | 12 |
| UpperInflection | hPa | 35 | 35 | 35 |
| C1 | ml/hPa | 52 | 52 | 8 |
| C3 | ml/hPa | 8 | 8 | 8 |
| Pthreshold | hPa | 80 | 80 | 35 |
| Pcollapse | hPa | 0 | 0 | 10 |
| RClh | s | 0.5 | 0.5 | 0.5 |
| Rcrecol | s | 10 | 10 | 10 |
| FRCpred | ml | 1750 | 1750 | 1750 |
| Tdelay | s | 1 | 1 | 1 |
| Vdaw | arbitrary | large | large | large |
| Cr | ml/hPa | 2 | 2 | 15 |
| RCcollapse | s | 10 | 10 | 1 |
| Pdiff | mmHg | 400 | 400 | 300 |
| QT | ml/min | 6000 | 4000 | 6000 |
| POPv@Pcardio=10 hPa | % | 50 | 50 | 50 |
| POPv@Pcardio=20 hPa | % | 60 | 60 | 60 |
| POPv@Pcardio=30 hPa | % | 70 | 70 | 70 |
| Leak level | arbitrary | none | none | none |
| HeartRate | /min | 90 | 70 | 80 |

It is important to note that the parameters of TestChest may need to be adapted to the rapidly evolving knowledge of COVID-19.

## Scenario 1: COVID-19 Type L; respiratory failure and spontaneous breathing after intubation or return to spontaneous breathing.

Patients arrive in the hospital with a very high respiratory drive due to intense hypoxemia. They present a high dead space that can be explained by a reduction of hypoxic pulmonary vasoconstriction and the presence of multiple pulmonary microthrombosis. These patients have a high compliance and respond to $FiO_2$, some PEEP and anti-Trendelenburg position.

Ventilation challenges:

- Choosing the right mode
- Setting up the spontaneous breathing parameters such as trigger, e-cycling, PEEP, and $FiO_2$
- Setting alarms.

Summary for trainers:

**Table 2.** Source: neosim AG

| Lung mechanics | Metabolism | Spontaneous breathing | Hemodynamics |
|---|---|---|---|
| • Crs = 52 ml/mbar.<br>• Raw=5 (without tube),<br>• No lower inflection point<br>• UIP at 35 mbar<br>• Not recruitable | • V'$CO_2$ = 250 ml/min STPD | • Pinsp= -14 mbar,<br>• Ti=1.4 sec,<br>• f=40 /min | • Pulseoximeter pleth will react to high inspiratory pressure (high intrathoracic pressure)<br>• C.O.= 6 L/min |

The hemodynamics are very basic and are only visible on pulseoximeter pleth curve.

## Scenario 2: COVID-19 Type L; exacerbated respiratory failure after paralysis to avoid self-inflicted lung damage due to high respiratory drive.

If a patient's respiratory drive is very high, they may be at risk from lung damage caused by uncontrolled inspiratory effort, severe lung injury, and asynchronies. Paralysis can help in these cases.

Ventilation challenges:

- Switching to an appropriate mode
- Setting the parameters like VT, rate, $FiO_2$, PEEP, to achieve adequate gas exchange and oxygen saturation
- Setting alarms to accommodate the new patient condition.

Summary for trainer:

**Table 3.** Source: neosim AG

| Lung mechanics | Metabolism | Spontaneous breathing | Hemodynamics |
|---|---|---|---|
| • Crs = 52 ml/mbar.<br>• Raw=5 (without tube),<br>• No lower inflection point<br>• UIP at 35 mbar<br>• Not recruitable | • V'$CO_2$ = 250 ml/min STPD | • None | • Pulseoximeter pleth will react to high inspiratory pressure (high intrathoracic pressure)<br>• C.O.= 6 L/min |

Paralysis will create a slight drop in $V_{LEE}$ requiring PEEP to increase $SpO_2$.

## Scenario 3: COVID-19 Type H; exacerbation respiratory failure low compliance ARDS stage

Unfortunately, some patients with COVID-19 can progress to a low compliance ARDS.

Ventilation challenges are:

- The titration of $FiO_2$ and PEEP
- Reducing of VT to maintain 6 ml/kg, driving pressure <14 $cmH_2O$
- Not exceeding a plateau pressure of 30 $cmH_2O$ (<28)
- Recruiting trials and evaluations
- Setting alarms to accommodate the new patient condition.

Summary for trainer:

**Table 4.** Source: neosim AG

| Lung mechanics | Metabolism | Spontaneous breathing | Hemodynamics |
|---|---|---|---|
| • Crs = 35 ml/mbar,<br>• Raw=5 (without tube),<br>• LIP=8 mbar<br>• UIP=35 mbar<br>• Venous admixture (QsQt) about 37%<br>• Recruitable with Pinsp >35 mbar<br>• Recruitment will take 10 seconds to achieve a QsQt reduction from 37% to 15%<br>• Lung collapse if pressure (PEEP) falls below 10 mbar (suction) | • $V'CO_2$ = 250 ml/min STPD | • None | • Pulseoximeter pleth will react to high inspiratory pressure (high intrathoracic pressure)<br>• C.O. = 6 L/min |

# Summary

TestChest provides mechanisms to simulate COVID-19 patients to facilitate the training of healthcare practitioners in operating mechanical ventilators. The TestChest's response is autonomous, so trainers do not need to enter any outcome variables because they are created automatically in direct response to the trainee’s actions.

## Acknowledgments

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## About neosim AG

neosim is a Swiss company founded by experts with strong background in lung physiology and mechanical ventilation of intensive care patients. The mission of neosim is to bring high-fidelity physiology and pathophysiology to the patient simulator community.

For training and education of clinicians, especially respiratory therapists and intensive care professionals, neosim simulators create realistic breathing in health and disease. In contrast to other simulators, neosim’s simulators can be treated with intensive care therapy methods and responds like a real human patient. The result manifests itself clinically and can be measured quantitatively with state-of-the-art monitoring in real-time.

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