# SIMULATION OF LUNG MECHANICS DURING CRITICAL CARE VENTILATION

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**Background:** Patient simulation is an effective way to allow clinicians to learn through hands-on experience. The realism of high fidelity patient simulators such as the SimMan® 3G (Laerdal, Stavanger, Norway) has led to more widespread use for training. As the popularity of training with patient simulators has increased, the desire to present complex critical care scenarios has also increased. We evaluated the lung mechanics of two lung simulators during critical care ventilation, including commonly used pressure support and volume controlled ventilation modes. We compared the lung mechanics of the Siemens Lung Simulator (920, Siemens, Elema, Sweden) and the SimMan® 3G with those of the Michigan Training and Test Lung (TTL, Michigan Instruments, Grand Rapids, MI). We also investigated potential changes to the simulator lungs that would allow a broader range of respiratory scenarios by modifying the SimMan® 3G.

**Methods:** The Esprit ventilator (Philips Medical, Carlsbad, CA) was used to ventilate the Michigan TTL, SimMan® 3G and the Siemens 920 for a variety of ventilation modes, tidal volumes, respiratory rates, and PEEP levels while the NICO® monitor (Philips, Wallingford, CT) recorded the lung mechanics parameters. Normal lung mechanics were defined as those observed with the Michigan TTL, set to have normal resistance (approximately 3 cm $H_2O$ $l^{-1}sec^{-1}$) and normal compliance (approximately 50 mL/cm $H_2O$). We made several modifications to the SimMan® 3G, including adding 650 grams of weight to the top of each lung plate and eliminating the elbow connectors on the small tubing between the chest walls and the lungs in order to slightly reduce airway resistance. We retested the modified lungs using the same ventilation modes.

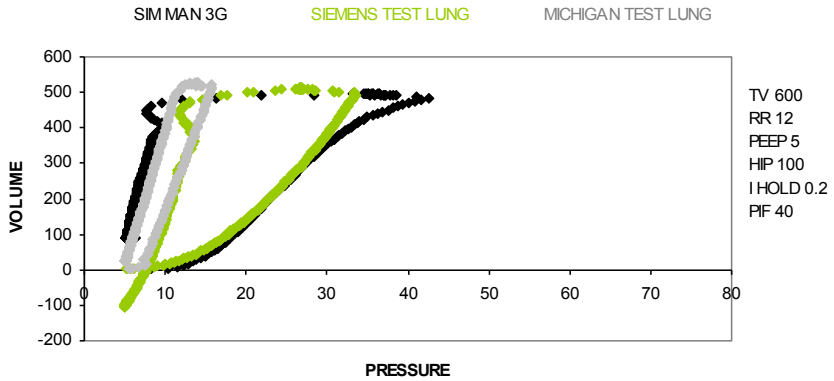


*Figure 1. Standard Anesthesia Ventilation Settings, Volume Control Mode, PEEP = 5 $cmH_2O$. For SimMan 3G, Michigan TTL, and Siemens 920, the peak inspiratory pressure was 41.8, 15.7, and 33.5 $cmH_20$; the dynamic compliance was 27.4, 57.7 and 21.3 ml/$cmH_20$; and the resistance was 32.9, 3.1, 10.3 $cmH_2O$ $l^{-1}sec^{-1}$, respectively. For the SimMan 3G, interference with the chest wall caused a "break in the loop" of the pressure-volume curve.*

**Results:** During volume controlled ventilation with normal tidal volume, compliance and resistance settings and zero PEEP, the unmodified SimMan® 3G performs acceptably, though resistance is slightly above normal and compliance

slightly below normal. However, we observed high peak inspiratory and plateau pressures during many settings of critical care ventilation for the Siemens 920 and the SimMan® 3G which resulted in high pressure alarms from the ventilator (Fig 1). Large tidal volumes (> 700 mL) pose a challenge for both simulators, especially with PEEP > 0 cm $H_2O$. After modifications to the SimMan® 3G lung were made, PEEP set to 0-10 cm $H_2O$, tidal volume up to 1000 mL, and high inspiratory flow were compatible in most cases.

**Discussion:** We suggest that for critical care ventilation scenarios, the simulation experience can be improved if 650 grams of weight is added to each of the lung plates and the elbow connectors on the small tubing between the chest walls and the lungs are removed. With these modifications, standard ventilation with zero PEEP remains possible, albeit at slightly elevated pressures compared to the unaltered lungs.