Simulation of Sudden Respiratory Distress in Ventilated Subjects: Development and Validation

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INTRODUCTION

Mechanical ventilation is a common life saving intervention in emergency and trauma care. Education and training on mechanical ventilation is a critical part of CCATT. The environment and limited resources during aeromedical transport create additional challenges. Sudden respiratory deterioration (RD) in a mechanically ventilated patient is uncommon but requires fast identification and rapid resolution. We endeavored to create a simulation system of common causes of RD in a ventilated patient using a realistic simulator with a computerized lung model (Aurora, IngMar Medical, Pitt, PA) operating with a physiology engine (Pulse Physiology Engine, Kitware Inc.,) allowing the simulator to respond without instructor intervention.

METHODS

We created 7 simulations to represent serious RD events. The format for each was (1) stable baseline MV, (2) RD phase, (3) resolution phase. Simulation variables were based on published data from ventilated humans (normal, ARDS, COPD). Simulation input variables: ventilator settings; lung mechanics (resistance, compliance, breathing effort); lung physiology (shunt, dead space). Simulation output variables: ventilator (V_T and peak/mean/plateau pressure); patient (pH, P_aCO_2, P_aO_2, hemodynamics). Upon implementation, acceptable phase (2) responses from students will include concordance with the ARDSnet PEEP/F_IO_2 tables, lung protection (safe V_T dosage and pressures) with acceptable gas exchange. Simulation output variables were deemed validated if error compared to expected values was < 10%. The seven scenarios were 1) Worsening hypoxemia in mild ARDS, 2) COPD with bronchospasm, 3) TBI with worsening ARDS, 4)Tension pneumothorax, 5) Right mainstem intubation, 6) Hypoxemia with pneumonia and secretions, and 7) Plugged endotracheal tube.

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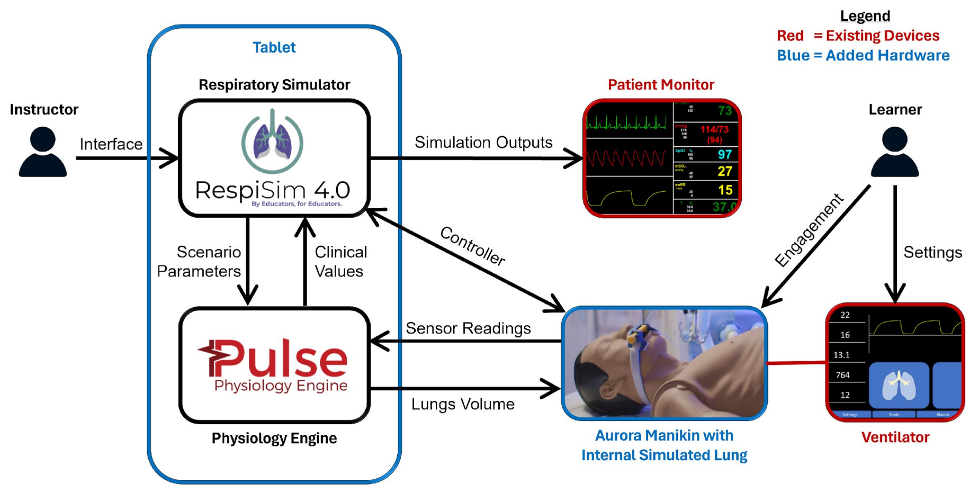
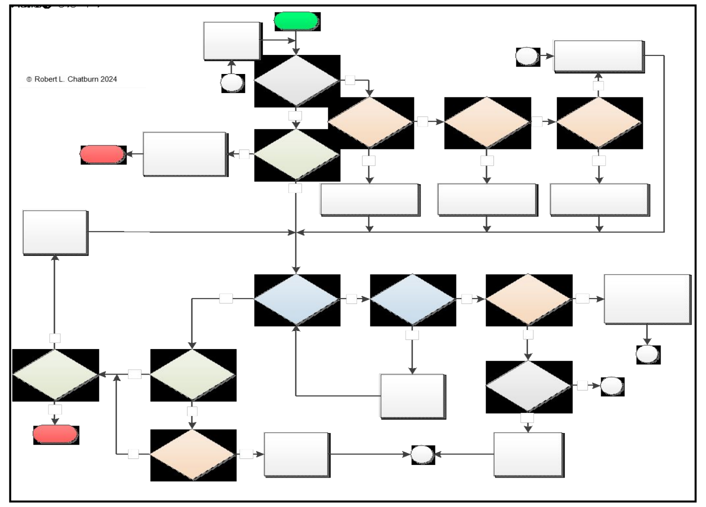
SYSTEM DESCRIPTION



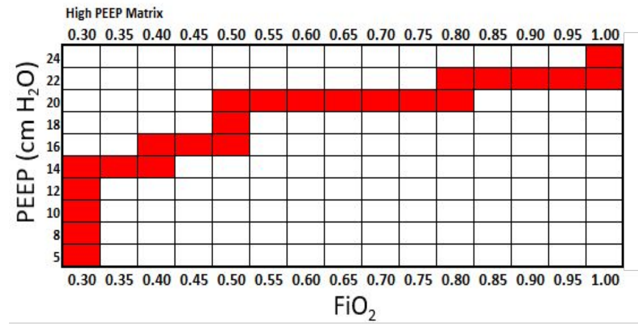
VENTILATION/OXYGENATION GOALS

Safe Ventilation Targets	
pH	7.30 - 7.40
SpO_2	90 - 94%
PEEP	on ARDSnet table
V_T dosage	4 - 8 mL/kg PBW
ΔP	< 15 cm H_2O
P_{plat}	< 30 cm H_2O
ARDS Mild	>= 200
ARDS Mod	>= 100 and < 200
ARDS Sev	< 100



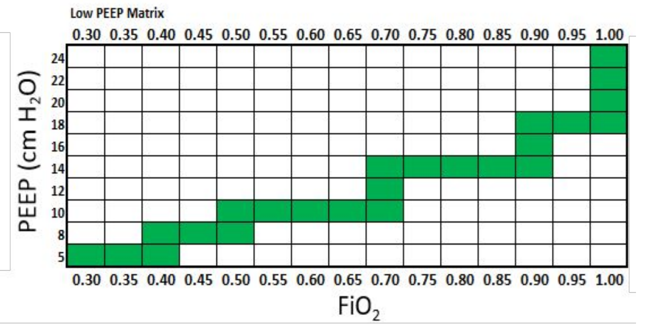
ARDS High PEEP Table

FIO_2	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.5	0.5	0.5-0.8	0.8	0.9	1.00
PEEP	5	8	10	12	14	14	16	16	18	20	22	22	22-24

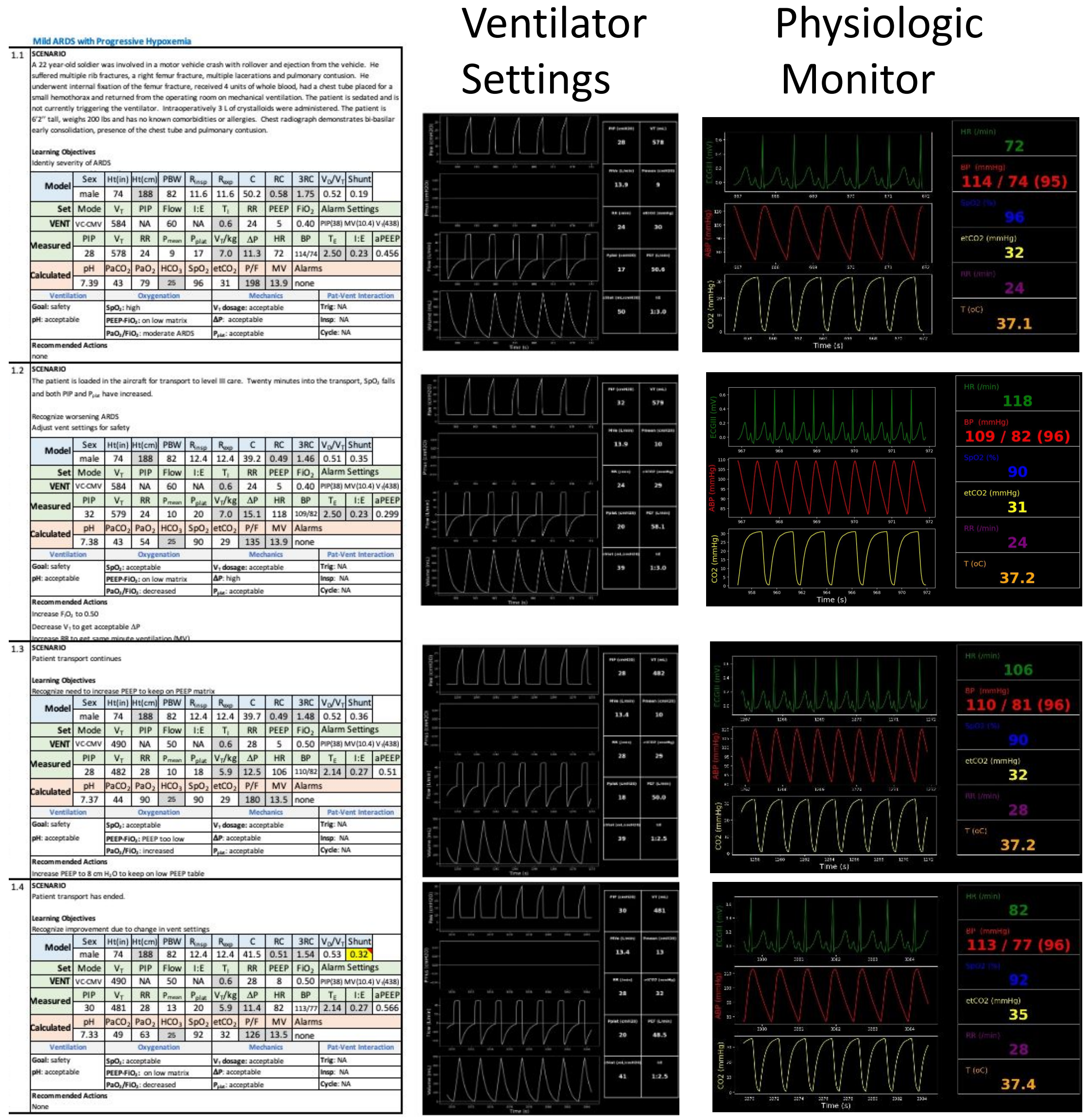


ARDS Low PEEP Table

FIO_2	0.3	0.4	0.4	0.5	0.5	0.6	0.7	0.7	0.7	0.8	0.9	0.9	0.9	1.00
PEEP	5	5	8	8	10	10	10	12	14	14	14	16	18	18-24



SIMULATION MILD ARDS WITH WORSENING HYPOXEMIA



CONCLUSIONS

The Pulse Physiology Engine generated expected simulated physiological outputs in response to ventilator setting changes for the simulated disease states. This project demonstrates a training system that could be more realistic and more efficient than instructor dependent methods.