Respiratory Mechanics in an Intubated Swine Model of Sustained G_x Acceleration Under Positive-Pressure Ventilation

Hayley N. Brawley, PhD[1], Jason Rall, PhD[2], Dave Freeman, MA[3], Jeffrey Mock, PhD[3], Charles Acron[3], Jesus Chaves[3], Bryce Christensen, MD[3,4], Taylor James, MD[6], and Craig D. Nowadly, MD[1,5,6]

1. Clinical and Operational Space Medicine Innovation Consortium (COSMIC), 59th Medical Wing Science and Technology, Lackland Air Force Base, TX; 2. Office of the Chief Scientist, 59th Medical Wing, Lackland Air Force Base, TX; 3. KBR Aerospace Environment Protection Laboratory, Inc., San Antonio, TX; 4. Pulmonary and Critical Care Medicine, Mike O'Callaghan Military Medical Center, Nellis Air Force Base, NV; 5. Division of Pulmonary & Critical Care Medicine, Department of Internal Medicine, University of Nevada, Las Vegas Kirk Kerkorian School of Medicine, Las Vegas, NV; 6. Department of Emergency Medicine, Brooke Army Medical Center, Fort Sam Houston, TX; 7. Department of Military and Emergency Medicine, Uniformed Services University, Bethesda, MD

INTRODUCTION

- Military, government, and commercial stakeholders are increasingly exploring the use of high performance remotely piloted aircraft, supersonic, hypersonic, sub-orbital, and orbital vehicles for the transportation of cargo, medical supplies, passengers, and casualties.
- Although sustained acceleration is well studied in spontaneously breathing humans (negative-pressure inspiration), the effects of sustained chest-to-back (anteroposterior) G_x on lung mechanics and regional aeration during positive-pressure, ventilator-delivered breathing have not been evaluated in a live, translational animal model.
- The MEDUSA II experiment was the first to place an injured, intubated, sedated, animal model into a sustained G_x acceleration environment
- This analysis constitutes a prespecified sub-analysis of the non-injured control cohort from the main MEDUSA II study.

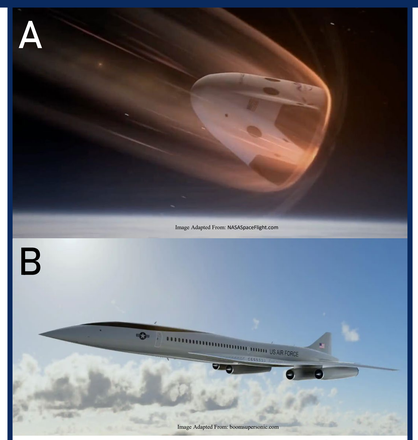

Figure 1: Artistic renderings from the A) re-entry capsule returning from low Earth orbit and B) a proposed supersonic USAF Aircraft

METHODS

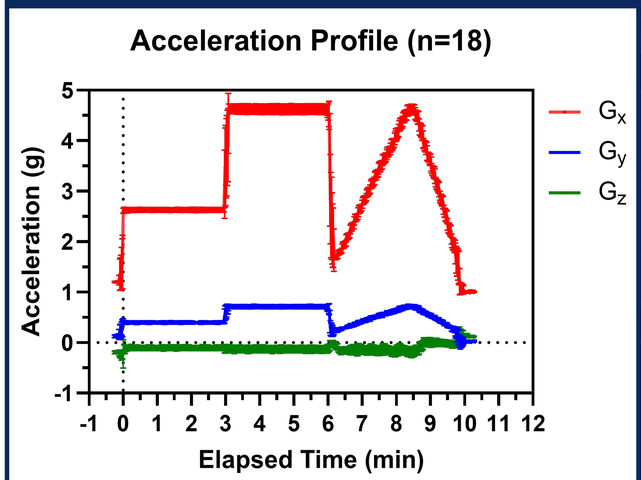

Figure 3: MEDUSA II Acceleration Profile.

- Yorkshire-cross swine (40-60 kg) were sedated, intubated, and mechanically ventilated in assist-control/volume control (AC/VC).
- Animals underwent a 9-minute sustained anteroposterior (chest-to-back) G_x centrifuge profile consisting of sequential 3-minute segments at 2.5 G_x 4.5 G_x, and variable 1.5-4.5 G_x.

Figure 2: KBR Aerospace Environmental Protection Laboratory Centrifuge

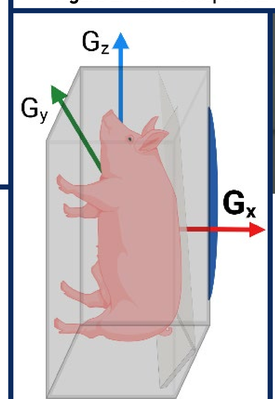

Figure 4: Orientation During Acceleration (G_x, G_y, G_z)

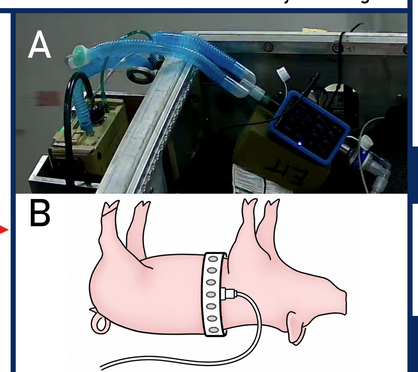

Figure 5: A) Citrex H5 Ventilator Tester in-line with Zoll 731 Ventilator and Endotracheal Tube B) Mock-up of Electrical Impedance Tomography (EIT) Band on Swine Chest

RESULTS

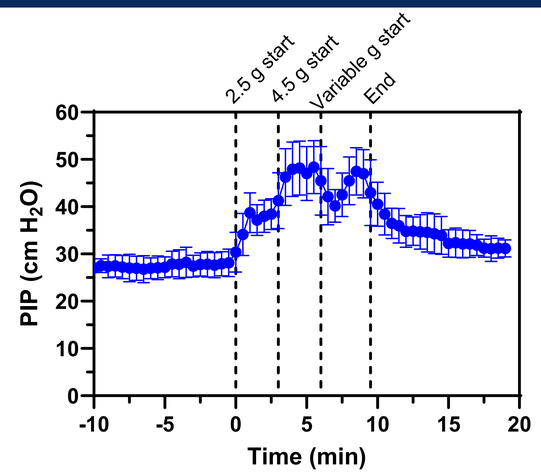

Figure 6. The effects of acceleration and on Peak Inspiratory Pressure (PIP).

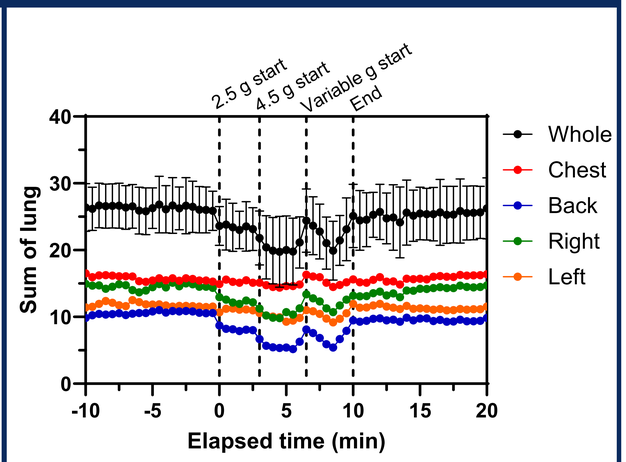

Figure 8. The effects of acceleration of ventilation within the whole chest (black) and different regions (colors).

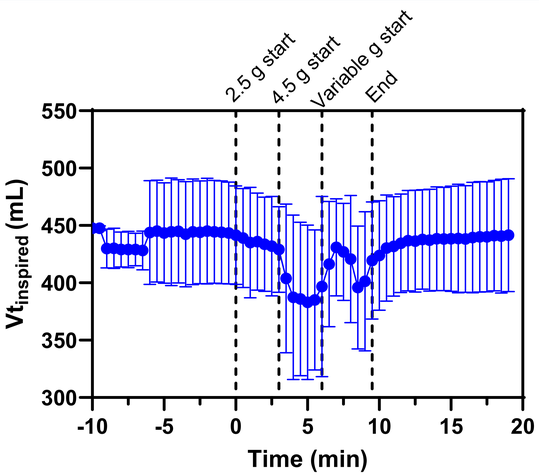

Figure 7. The effects of acceleration and on Tidal Volume Inspired ($Vt_{inspired}$)

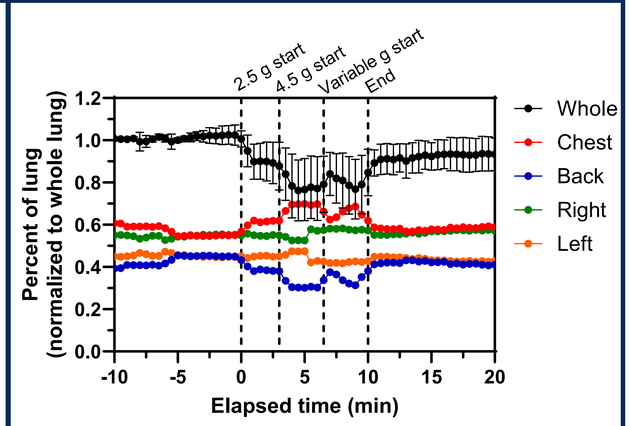

Figure 9. The effects of acceleration of ventilation within the whole chest (black) and different regions (colors) normalized to percent change compared to baseline.

CONCLUSION

- Sustained G_x acceleration in a live swine model altered positive-pressure ventilation. PIP increased and delivered TV that decreased with higher G_x. EIT confirmed altered regional redistribution during G-loading. This study provides initial in vivo data on ventilation mechanics during sustained acceleration relevant to medical evacuation platforms.

DISCLAIMER

Corresponding Author: Major Craig Nowadly, MD; craig.d.nowadly.mil@health.mil