MUSCULOSKELETAL-INDUCED NUCLEATION IN ALTITUDE DECOMPRESSION SICKNESS

NW Pollock¹, MJ Natoli¹, J Conkin², JH Wessel III³, ML Gernhardt⁴

¹ Center for Hyperbaric Medicine and Environmental Physiology, Duke University Medical Center, Durham, NC 27710; ² University Space Research Association, 3600 Bay Area Blvd, Houston, TX 77058; ³ Wyle Integrated Science and Engineering Group, 1290 Hercules, Houston, TX 77058; ⁴ NASA Johnson Space Center, 2100 NASA Parkway, Houston, TX 77058
INTRODUCTION

- Musculoskeletal activity has the potential to both improve and compromise decompression safety
  - enhancing inert gas elimination during oxygen breathing
  - promoting bubble nuclei formation and gas phase separation
- Timing, pattern and intensity of exercise and the level of tissue supersaturation may be critical to the net effect
  - understanding mechanisms may help quantify risk
- NASA Prebreathe Reduction Program (PRP) studies
  - combined oxygen prebreathe and exercise followed by low pressure (4.3 psi) microgravity simulation
  - produced two operational protocols used for EVA
    - CEVIS and ISLE
- Current study investigates the influence of ambulation exercise on bubble formation and risk of DCS
CEVIS PROTOCOL
(not to scale)

<table>
<thead>
<tr>
<th>PRP Phase II</th>
<th>100</th>
<th>50</th>
<th>20</th>
<th>10</th>
<th>30</th>
<th>5</th>
<th>35</th>
<th>30</th>
<th>240</th>
<th>10</th>
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</thead>
<tbody>
<tr>
<td>Time (min)</td>
<td></td>
<td></td>
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<table>
<thead>
<tr>
<th>Pressure (psi)</th>
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<tbody>
<tr>
<td>14.7</td>
</tr>
<tr>
<td>10.2</td>
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<tr>
<td>9.6</td>
</tr>
<tr>
<td>4.3</td>
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<tr>
<th>Activity</th>
<th>Non-Ambul.</th>
<th>Exercise</th>
<th>Non-Ambulatory</th>
<th>Exercise</th>
<th>Non-Ambulatory</th>
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<tr>
<th>Breathe Mix</th>
<th>Air</th>
<th>Oxygen</th>
<th>Air</th>
<th>Oxygen</th>
</tr>
</thead>
</table>
METHODS

- 4 experiments replicate CEVIS protocol, each with exception
  - **Expt 1** – ambulation both preflight and at 4.3 psi
  - **Expt 2** – non-ambulatory preflight; ambulatory at 4.3 psi
  - **Expt 3** – ambulatory preflight; non-ambulatory at 4.3 psi
  - **Expt 4** – reverse heavy/light exercise order; non-ambulatory

- Decompression stress assessment
  - ultrasound during each of 14 epochs in 4 h 'spacewalk'
    - aural Doppler for right heart bubbles (Spencer grade 0-IV)
    - two-dimensional imaging for left heart bubbles (test termin.)
  - venous blood to assess microparticle response to deco stress

- Fisher Exact Tests (one-tailed) compare test/control groups

- Plan - 25-50 subjects per experiment
  - trials suspended with 70% confidence of DCS risk >15% or grade IV VGE risk >20%
EXERCISE STRATEGIES

Controlled walking

Suit simulator set up for multiple semi-recumbent intermittent light exercise simulating astronaut tasks
EVA SUIT SIMULATOR EXERCISES

- 6 exercises
  - sit-ups, arm pulls, full body pulls, torque wrenching, walking
- Subjects cycle through
  - specific exercises
  - Doppler/2-D echo monitoring
  - Rest break
- 4 minute intervals for each
  - pace guided by an automated task prompter
  - manual prompting if needed
ULTRASONIC ASSESSMENT

Doppler Bubble Detector

Transthoracic Echo (TTE)
BLOOD MICROPARTICLE ASSESSMENT

- MPs are 0.1-1.0 µm diameter cell membrane fragments – pro-inflammatory
- 5 mL blood samples drawn at 3 points – baseline – post-10.2 psi repress – post-4.3 psi repress
RESULTS

◆ 15 Experiment 1 trials complete
  – 11 male, 4 female
◆ Expt 1 vs. CEVIS
  – DCS greater
    ✷ 4/15 (27%) vs. 0/45 (0%), respectively (p=0.0001)
  – peak grade IV VGE frequency greater
    ✷ 4/15 (27%) vs. 3/45 (7%), respectively (p=0.0334)
  – cumulative grade IV VGE across all trial epochs not different
    ✷ 10/183 (5%) vs. 26/630 (4%), respectively (p=0.220)
  – microparticle data for 9/15 trials (4 with DCS outcomes)
    ✷ high variability not yet resolved statistically
◆ DSMB review allowed Expt 1 trials to continue
  – to improve statistical power of microparticle assessment
DISCUSSION

- Expt 1 trial results support thesis that decompression stress is increased by ambulation exercise
- Additional trials may improve the statistical power to evaluate the relationship between decompression stress and microparticle accumulation
- Future experiments will test decompression stress of
  - ambulation at altitude (supersaturated) vs. ambulation at ground level (undersaturated)
  - light exercise after heavy exercise induced nucleation

ACKNOWLEDGMENT

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