IMAGING MODALITIES RELEVANT TO INTRACRANIAL PRESSURE ASSESSMENT IN ASTRONAUTS

Ashot E. Sargsyan¹, Larry A. Kramer², Douglas R. Hamilton¹, Jennifer Fogarty³, JD Polk³

1. Space Medicine, Wyle Integrated Science and Engineering, Houston, TX, USA.
2. University of Texas Health Sciences Center at Houston.
3. Space Life Sciences Directorate, NASA Lyndon B. Johnson Space Center, Houston, TX, USA.
I have no financial relationships to disclose.

I will not discuss off-label use and/or investigational use in my presentation.
Learning Objectives

1: To review the morphological changes in orbit structures caused by elevated ICP, and their imaging representation.

2: To learn about the similarities and differences between MRI and sonographic imaging of the eye and orbit.

3: To learn about the role of MRI and sonography in the noninvasive assessment of intracranial pressure in aerospace medicine, and the added benefits from their combined interpretation.
Introduction

- Intracranial pressure (ICP) elevation has been inferred or documented in a number of space crewmembers.
- Recent advances in noninvasive imaging technology offer new possibilities for ICP assessment.
- No standards or applicable evidence-based guidelines/criteria are available for immediate use.
- NASA and its ISS partners adopted a battery of occupational health monitoring tests including:
  - Magnetic resonance imaging (MRI) pre- and postflight;
  - High-definition sonography of the orbital structures in all mission phases including during flight.
- We hypothesize that joint consideration of data from the two techniques has the potential to improve quality and continuity of crewmember monitoring and care.
Macroscopic Anatomical Substrate

Image Source: Orbital Pathology by David Youssem
Neuroradiology department of the Johns Hopkins Hospital in Baltimore
http://www.radiologyassistant.nl
Microscopic Anatomical Substrate
Methods

- Identification of redundant parameters in MR and sonographic data sets
- Comparisons of MR and sonographic measurements of the optic nerve and optic nerve sheath
- Comparison of posterior globe curvature measurements from MR and sonographic images
- Assessment of the potential of image “fusion” between MR and sonography
# Methods

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>US</th>
<th>MRI</th>
<th>FORMAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior chamber survey</td>
<td>X</td>
<td></td>
<td>free text based on entire image set</td>
</tr>
<tr>
<td>Posterior chamber survey</td>
<td>X</td>
<td></td>
<td>free text based on entire image set</td>
</tr>
<tr>
<td>Antero-posterior Diameter</td>
<td>X</td>
<td></td>
<td>numerical</td>
</tr>
<tr>
<td>Papilledema/Disc Edema</td>
<td>X</td>
<td>X</td>
<td>semi-quantitative: 0-3</td>
</tr>
<tr>
<td>Globe flattening</td>
<td>X</td>
<td>X</td>
<td>semi-quantitative: 0-3</td>
</tr>
<tr>
<td>Optic Nerve Sheath Diameter</td>
<td>X</td>
<td>X</td>
<td>within 3-5 mm from retina; numerical</td>
</tr>
<tr>
<td>Characterization of optic nerve sheath structure</td>
<td>X</td>
<td></td>
<td>free text based on entire image set</td>
</tr>
<tr>
<td>Optic Nerve Diameter</td>
<td>X</td>
<td>X</td>
<td>within 3-5 mm from retina; numerical</td>
</tr>
<tr>
<td>Optic Sheath-Nerve Ratio</td>
<td>X</td>
<td>X</td>
<td>calculated, numerical, unitless</td>
</tr>
<tr>
<td>ON tortuosity</td>
<td>X</td>
<td>X</td>
<td>semi-quantitative: 0-3</td>
</tr>
<tr>
<td>ON sheath hypoechoogenicity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ON T2-hyperintensity</td>
<td></td>
<td>X</td>
<td>semi-quantitative: 0-3</td>
</tr>
<tr>
<td>Survey of intracranial CSF spaces</td>
<td>X</td>
<td></td>
<td>free text based on entire image set</td>
</tr>
<tr>
<td>Characterization of sella turcica and pituitary</td>
<td>X</td>
<td></td>
<td>free text based on entire image set</td>
</tr>
<tr>
<td>Assessment of CSF production rate</td>
<td></td>
<td>X</td>
<td>numerical</td>
</tr>
<tr>
<td>Characterization of CSF flow through the Sylvian aqueduct</td>
<td>X</td>
<td></td>
<td>numerical</td>
</tr>
<tr>
<td>Other Notes: Compared with: [dates]</td>
<td></td>
<td></td>
<td>free text</td>
</tr>
<tr>
<td>IMPRESSION:</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Optic Nerve Characterization
ONS Structure
Papilledema
Retina

Posterior Sclera

Posterior Pole Thickening
Dr. Hamilton's Nonlinear Jacobian Analysis to Regress to a Circle on an MRI and Ultrasound

**Step 1 - Digitize Anterior Orbit**

**Step 2 – Calculate Best Circle and Center**
Center = $(2.12, 1.38)$
Radius = 1.20

**Step 3 – Digitize Posterior Orbit**

**Step 4 – Calculate Best Circle and Center**
Center = $(1.55, 2.67)$
Radius = 2.18
Calculate Best Circle and Center
Center = (-0.737, 19.38)
Radius = 18.189

Calculate Best Circle and Center
Center = (1.148, 2.146)
Radius = 1.131

Calculate Best Circle and Center
Center = (-0.737, 19.38)
Radius = 18.189
Posterior segment
Real-time - maneuvers
Results and Conclusion

- MRI and sonography are tomographic methods, however images obtained by the two modalities are based on different physical phenomena and use different acquisition principles.
- Consideration of the images acquired by these two modalities allows cross-validating findings related to the volume and fluid content of the ON subarachnoid space, shape of the globe, and other anatomical features of the orbit.
- Each of the imaging modalities also has unique advantages, making them complementary techniques.