Nasal Congestion on the International Space Station

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Disclosure Information

• No financial relationships to disclose

• The views expressed in this presentation are those of the author(s) and do not necessarily reflect the official policy or position of the National Aeronautics and Space Agency (NASA).

• This work was NOT prepared as part of my official duties as a military service member, and in no way is representative of Naval Medical Center Portsmouth, or the U.S. Navy.
Incidence

- 55% of crewmembers report use of medications for congestion

Incidence

- Immunological related health events for 21 flight years

<table>
<thead>
<tr>
<th>Medical Conditions / Clinical Symptoms</th>
<th>Total Events</th>
<th>Events / Flight Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allergic reaction (hypersensitivity)</td>
<td>2</td>
<td>0.1</td>
</tr>
<tr>
<td>Prolonged congestion, rhinitis, sneezing</td>
<td>20</td>
<td>1.0</td>
</tr>
<tr>
<td>Herpes viruses (cold sores)</td>
<td>6</td>
<td>0.3</td>
</tr>
<tr>
<td>Ear related: pain, congestion, itchiness</td>
<td>6</td>
<td>0.3</td>
</tr>
<tr>
<td>Pharyngitis (sore throat)</td>
<td>1</td>
<td>0.1</td>
</tr>
<tr>
<td>Skin infection (including pus forming wounds on wrist, finger, feet)</td>
<td>6</td>
<td>0.3</td>
</tr>
<tr>
<td>Skin rash/hypersensitivity (including skin conditions such as tinea versicolor, dermatitis, rosacea)</td>
<td>23</td>
<td>1.1</td>
</tr>
<tr>
<td>Urinary tract infection</td>
<td>2</td>
<td>0.1</td>
</tr>
<tr>
<td>Infections and other (including conditions such as fever, aphthous ulcer, lymphadenitis)</td>
<td>4</td>
<td>0.2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>70</td>
<td><strong>3.4</strong></td>
</tr>
</tbody>
</table>

Why is this a concern?

- Uncomfortable/distracting
- Could contribute to poor sleep
- Prevent EVAs
- Decrease in taste
- Risk of ear/sinus infections
- Sign of underlying problems on ISS
Traditional Explanation

- Fluid shifts increase cerebral blood volume
  - Doesn’t explain why congestion complaints continue throughout mission
Study Goals

Examine the relationship between nasal congestion and:

- Complaints of headache
- Carbon dioxide levels
- Age of the ISS
CO₂ Background

• Original flight rules were based on U.S. Navy submarine data and NIOSH occupational limits.
• 1970’s data from U.S. subs indicated 1% (7.6 mm Hg) was relatively safe.
• Physiologic effects thought to be related to 1% CO₂ in subs:
  • Respiratory minute volume
  • Blood Ph
  • Electrolytes
  • Gastric acidity
  • Sleep disturbances
• Original flight rule for ISS set at 7.6 mm Hg


Messier AA, Heyder E, Schaefer KE. Effect of 90-Day Exposure to 1% CO₂ on Acid-Base Status of Blood. Naval Submarine Medical Research Lab, Groton, Ct. March, 02 1971.
Reported CO₂ symptoms:
- Headaches
- Fatigue
- Irritability
- Lethargy
- Decreased work performance
- Sleep difficulties

CO₂ related symptoms were anecdotally associated with large group gatherings like press conferences.

These symptoms seemed to improve when breathing 100% O₂ for EVAs.

CO$_2$ Hypothesis

- **CO$_2$** is a potent **vasodilator**
  - Mediated through decreases in pH which act extracellularly to relax blood vessels and increase blood flow

- **Microgravity** alters venous outflow in the head and neck
  - Increases **blood volume in the head and neck**
Methods

• Data gathered on USOS Astronauts that flew on ISS March 14, 2001- February 16, 2018

• Complaints of congestion gathered from PMCs and SMOTs

• CO₂ data drawn from Main Constituent Analyzer
  • Missing data addressed mathematically by multiple imputation

• First 7 days of flight excluded to control for confounding variables
  • Fluid shifts occur in first week
  • Arriving vehicles have different CO₂ levels compared to ISS

PMC (Private Medical Conference)
SMOT (Space Medicine Operations Team)
Statistical Analysis

- Logistic regression mixed-effects model approach
- Subject-specific random effects to addressed repeated observations of the same individuals
- Robust standard errors to address possible heteroscedasticity (model miss-specification)
- Multiple imputation used to address missing CO2 values
- Completed in SAS 9.4
- The following equation models the relationship between variables examined and the log odds where $p$ represents the probability of reporting congestion

$$\log \left( \frac{p}{1 - p} \right) = \beta_0 + \beta_1 \times Age_{ISS} + \beta_2 \times CO_2$$
## Demographics

- \( N = 79 \)  Exp: 2-53

<table>
<thead>
<tr>
<th>Variables</th>
<th>Mean ± Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males, (%)</td>
<td>82.3</td>
</tr>
<tr>
<td>Females, (%)</td>
<td>17.7</td>
</tr>
<tr>
<td>Age at Launch, yr</td>
<td>( 47.3 ± 4.8 )</td>
</tr>
<tr>
<td>Mission duration, d</td>
<td>( 162.4 ± 40.2 )</td>
</tr>
<tr>
<td>Number of observations per crewmember</td>
<td>( 40.0 ± 17.2 )</td>
</tr>
</tbody>
</table>
Headache vs Congestion

(Predicted probability)
$\text{CO}_2$ over time
CO$_2$ vs. Congestion
(Predicted probability)

Probability of Congestion for 15 year old ISS

p = 0.1582
Age of ISS vs. Probability of Congestion

p = .0024
Potential Consequence of Aging: Physical Dust Particles

- Microgravity= floating dust
- Most ISS dust particles are large enough that they are trapped in the upper airways and nose.
- >100 microns
- Composition:
  - Dead skin
  - Hair
  - Nail clippings
  - Food particles
  - Paper
  - Plastic
  - Clothing lint
  - Other granular debris

HEPA ISS filters are designed to remove 99.7% of particles greater than .3 microns

https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20170008803.pdf

Potential Consequence of Aging: Microorganisms

• 2007: Analysis of dust collected from ISS HEPA filters by PCR returned results that included 39 species of molds, higher levels than found in most US homes.

• 2014: Risk of an astronaut reporting a medical event tripled if microbial counts were above the established limits


Potential Consequence of Aging: Rodents

- 2009: Lab mice flown to the ISS for experiments
- Research has found that up to 30% of people working with lab animals will develop an allergic response within the first year
- Did not see spike in congestion in 2009
Potential Consequence of Aging: Toxic Contaminants

- Off-Gassing of materials
  - (formaldehyde, halocarbons)
- Anticorrosives in fluid lines
  - (cadmium, nickel)
- Waste Management Systems
  - (Urea, sulfuric acid)

- Sensitive monitoring systems on board ISS have demonstrated that trace contaminants have decreased with age of station
Study Limitations

• CO₂ exposures vary throughout missions
  • Exercise
  • Social and work related gatherings
  • Working behind racks or in engineering spaces
  • EVAs: 100% O₂ and decreased pressure

• Ventilation needed to lower CO₂, however also reduce particles
• PMCs only once a week
• Individual variability in symptoms
Conclusion

• Congestion is a common ISS medical complaint
• Congestion has impacts to health and performance
  • Poor Sleep
  • Sinus Infections
  • Prevents EVAs
  • Distracting/discomfort
• Cephalic fluid shift common explanation, yet complaints continue after adaptation period
• Headaches are associated with congestion in ISS crew members
• Elevated CO2 levels may lead to congestion
• The older the ISS, the higher the predicted probability of congestion
• ISS mold levels reported higher than most US homes
• Risk of an astronaut reporting a medical event tripled if microbial counts were above the established limits
References


• Messier AA, Heyder E, Schaefer KE. Effect of 90-Day Exposure to 1% CO2 on Acid-Base Status of Blood. Naval Submarine Medical Research Lab, Groton, Ct. March, 02 1971.

• Hagar, R. Submarine Atmosphere Control and Monitoring Brief for the COT Committee. Presentation at the First Meeting on Emergency and Continuous Exposure Guidance Levels for Selected Submarine Contaminants, January 23, 2003, Washington, DC.


References


References


### Parameter Estimates (20 Imputations)

| Parameter | Estimate | Std Error | 95% Confidence Limits | DF | Minimum | Maximum | Theta0 | t for H0: Parameter=Theta0 | Pr > |t| | Slope |
|-----------|----------|-----------|-----------------------|----|---------|---------|--------|---------------------------|-------|-------|--------|
| intercept | -5.199262| 1.024179  | -7.20828 -3.19025     | 1463.7 | -5.93589| -4.56054| 0 | -5.08 < .0001              |       |       |        |
| ISS_age   | 0.220178 | 0.072509  | 0.07806 0.36229       | 139928 | 0.206039| 0.237137| 0 | 3.04 | .0024 |       | 1.246299 |
| avg_24hr  | 0.1885   | 0.132823  | -0.07424 0.45124      | 132.02 | 0.035206| 0.360732| 0 | 1.42 | 0.1582|       | 1.207437 |

### HA Estimate Standard DF t Value Pr > |t| Alpha Lower Upper Mean Standard Lower Upper diff lower diff upper
| HA   | Estimate | Standard | DF  | t Value | Pr > |t| | Alpha | Lower | Upper | Mean | Standard | Lower | Upper | diff lower | diff upper |
|------|----------|----------|-----|---------|-------|-------|--------|-------|-------|------|----------|-------|-------|-------------|-----------|
|      | Error    |          |     |         |       |       |        |       |       |      |          |       |       |             |           |
| No   | -2.5392  | 0.2823   | 2835 | -8.99 <.0001 | 0.05 | -3.0928 | -1.9855 | 0.07316 | 0.01914 | 0.04341 | 0.1207 | 0.02975  | 0.04754 |
| Yes  | -0.619   | 0.3469   | 2835 | -1.78 0.0745 | 0.05 | -1.2993 | 0.06123 | 0.35 | 0.07893 | 0.2143 | 0.5153 | 0.1357 | 0.1653 |
• No increase in complaints of congestion after publication of Law et al paper on correlation of headaches and CO₂.
Potential Causes: Microorganisms

- 2014: Risk of an astronaut reporting a medical event tripled if microbial counts were above the established limits.

Microbiology and Crew Medical Events on the International Space Station

Background
- The closed environment of the International Space Station (ISS) creates an ideal environment for microbial growth.
- Microbial counts and surfaces for microbial growth on ISS begun in 2005.
- Microbial counts are determined from samples collected and reported to ground. Samples are returned to the Microbiology Laboratory at JSC for bacterial and fungal identification.
- It is unknown if high microbial counts in the ISS environment are associated with in-flight medical events.

Purpose
To determine if an association exists between high air and surface microbial counts and in-flight medical events onboard the ISS from 2009 to 2012 (Expedition 1 to Expedition 12).

Design and Methods
Microbiology Sampling
- Air and surface samples were collected quarterly by crew members.
- Common areas were sampled: assumed that all crewmembers were exposed where sampling was done.
- Crewmembers reported a categorization based on the number of Colony Forming Units grown in samples.
- Samples are returned to earth for identification but this data was not used in the analysis.

In-flight Medical Events
- Sources of medical event information include: Electronic Medical Record and Private Medical Conferences.
- First 7 days of medical events were excluded from analysis due to potential confounding with Space Adaptation Syndrome.
- Only illness-related medical events were used in analysis.
- Medical events were analyzed by quarter on ISS to coincide with microbial sampling.

Analyses
- Descriptive analysis of medical events and microorganisms.
- Logistic regression models assessed relationships between high microbial counts and in-flight medical events.
- Medical events requiring remediation strategies were not included in the analysis.
- Odds ratios were calculated.
- Controlled for effects of crew member during each calendar quarter.
- Any astronaut who flew on more than one mission was treated as unique individuals in the analysis.

Characteristics of Sample
- 36 ISS Astronauts who flew at least one mission to ISS
- 5 crewmembers flew on 2 missions for an effective sample size of 41
- 8 women (2 repeat flyers); 28 men (3 repeat flyers)

Environmental Microbiology Data
- Microbial monitoring of the spacecraft environment for high bacteria and fungi levels.

Characteristics of Medical Events
- 79 in-flight medical events reported:
  - Skin reactions: rashes, vesicular, pruritic dermatitis, pruritic rash, and allergy symptoms; nasal stuffiness, sneezing, coughing, throat irritation, eye irritation
  - Cold-like symptoms
  - Headaches
  - Illness: nausea, vomiting, diarrhea, abdominal pain
  - Infections from cuts
  - 37 of 41 crewmembers reported at least one medical event during their mission

Logistic Regression Results

https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20140011758.pdf

Houston, TX