Estimating the Risk of Renal Stone Events during Long-Duration Spaceflight

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Disclosures

No financial relationships

Off-label use and/or investigational use of drugs or other treatments will not be discussed
Potential Renal Stone Outcomes

• Infection
• Obstruction
• Incapacitation
• Mission failure
• Evacuation
• Long-term disability
• Death
Space Flight Risk Factors

- Fluid shifts in microgravity
- Bone demineralization
- Decreased thirst and fluid intake
- Concentrated urine
- Calcium excretion

Current ISS Medical Standards

Renal stone is a disqualifying medical condition for long duration space flight

- Presence or history of urinary calculus
- Requires a medical waiver
History of Renal Stones in Space Flight

• U.S. Space Program
  • 14 renal stone events among 12 astronauts as of 2008
  • 4 events prior to space flight (no association)
  • 10 events within 2 years postflight

• Russian Space Program
  • 3 renal stone events postflight
  • 1 renal stone event inflight
**Inflight Renal Stone Event**

- Acute abdominal pain in a cosmonaut on 11/11/82 on Salyut 7 (6 months into a 7 month mission)
- Initially diagnosed as appendicitis
- Caused severe pain and significantly impacted the inflight timeline
- Resolved on-orbit with apparent passing of the stone spontaneously over a period of days
- No medical evacuation
- Mission was completed
Renal Stone Epidemiology

- Lifetime prevalence 10% male, 5% female
- 3.7 % to 4.6% of commercial aviation pilots between 2000 – 2007*
- Similar to astronaut prevalence

# Asymptomatic Stones

<table>
<thead>
<tr>
<th>Size (mm)</th>
<th>Stone Free</th>
<th>Progression</th>
<th>Intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 5</td>
<td>28%</td>
<td>40.4%</td>
<td>5.3%</td>
</tr>
<tr>
<td>5 - 10</td>
<td>4.8%</td>
<td>52.4%</td>
<td>9.5%</td>
</tr>
<tr>
<td>&gt; 10</td>
<td>0%</td>
<td>71.4%</td>
<td>14.3%</td>
</tr>
</tbody>
</table>

Size vs. Spontaneous Passage

# Medical Risk Matrix – Long-Duration Missions (ISS)
## MDC-1

<table>
<thead>
<tr>
<th>Class 1 Medical Event</th>
<th>Class 2 Medical Event</th>
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<tr>
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<td>Acute medical crisis beyond ISS medical resource capabilities</td>
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<td>Can handle within designated timeline</td>
<td>May cause failure to meet mission objectives</td>
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<td>Emergency evacuation</td>
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### Renal Stone Risk

<table>
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<tr>
<th>Likelihood</th>
<th>Low risk – acceptable for MDC 1 disposition (long duration)</th>
<th>Moderate risk – Further consideration required for an MDC 1 disposition</th>
<th>High risk – unsuitable for MDC 1 disposition</th>
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<tr>
<td>Likely ≥2%&lt;5%</td>
<td><img src="Green" alt="Green" /></td>
<td><img src="Yellow" alt="Yellow" /></td>
<td><img src="Red" alt="Red" /></td>
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<tr>
<td>Possible ≥1%&lt;2%</td>
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### MSMB Risk-based Decision Analysis

- **Green**: Low risk – acceptable for MDC 1 disposition (long duration)
- **Yellow**: Moderate risk – Further consideration required for an MDC 1 disposition
- **Red**: High risk – unsuitable for MDC 1 disposition
Integrated Medical Model (IMM)

- IMM Background
  - Software model used to simulate human space flight missions
  - Simulates medical events during space flight missions
  - Estimates the impact of these medical events on crew health and mission success
  - Outputs include estimates of crew health, probability of medical evacuation, and probability of medical loss of crew life
  - Optimization routines can be used to design medical systems which maximize crew health and probability of mission success
**IMM Conceptual Model**

**Inputs**
- Medical Conditions & Incidence Data
- Crew Profile
- Mission Profile & Constraints
- Potential Crew Impairments
- Potential Mission End States
- In-flight Medical Resources

**Outputs**
- Medical Condition Occurrences
- Crew Impairments
- Clinical End States
- Mission End States
- Resource Utilization
- Optimized Medical System
## Medical Risk Matrix – Long-Duration Missions (ISS) MDC-1

### Astronaut with no history of stones

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### Likelihood

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### MSMB Risk-based Decision Analysis

- **Low risk** – acceptable for MDC 1 disposition (long duration)
- **Moderate risk** – Further consideration required for an MDC 1 disposition
- **High risk** – unsuitable for MDC 1 disposition
IMM Analysis

Six month ISS mission with 6 crew
- with all crew meeting current med standards

• Evacuation
  1. Visual Impairment
  2. Dental Abscess
  3. Kidney Stone
  4. Sepsis
  5. Smoke Inhalation
Three Scenarios

1. No history of stone
2. History of stone
3. Current stone
Hypothetical Case #1

• 38 year old female Astronaut
• No stone history
• No findings on imaging
• Will launch in 2 months to the ISS
• For a 6 month mission

Risk of developing first stone?
Hypothetical Case #2

• 45 year old male Cosmonaut
• History of symptomatic 5 mm stone
• Treated with lithotripsy, resolved
• Will launch in 2 months to the ISS
• For a 6 month mission

Risk of developing a new stone?
Hypothetical Case #3

- 42 year old male Astronaut
- 2 mm calcification in renal parenchyma
- Asymptomatic
- Will launch in 2 months to the ISS for a 6 month mission

Risk of becoming symptomatic?
Risk Quantification

• IMM can provide renal stone risk estimates that can be used to assist
  • Crew medical certification decisions
  • Medical resource allocation
  • Crew medical training
Renal Stone Issues

Renal stones are a low likelihood but high consequence event

• What are acceptable waiver criteria?
• Can renal stone events be prevented?
• How do we monitor for stone formation pre-flight and in-flight?
• How do we manage in-flight stones?
Future Work

• Improved risk assessment
• Prevention
• Close monitoring and early detection
• Improved treatments
• Creation of a NASA Renal Stone Clinical Practice Guideline