SENSITIVITY ANALYSIS OF THE INTEGRATED MEDICAL MODEL FOR ISS PROGRAMS

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• Consider data for 100 medical conditions from the Integrated Medical Evidence Database (iMED)
• Simulate medical event occurrences over large number of missions via Monte Carlo methodology
• For each medical condition:

   Incidence Rate → Time to occurrence → Best Case or Worst Case? → Treated or Untreated? → FI, duration, EVAC, LOCL
• Best practices with computer modeling includes establishing the robustness of the model

• Robustness is the determination of how thoroughly the sensitivities of the model results to the variables and parameters of the model are known

• Infers an understanding of the sensitivity of the real-world system to potential changes in the variables and parameters of the system
  – Assuming the imitated system behaves like the real-world system

• Understanding the relative importance of variables and parameters, along with the relative ability to affect those variables and parameters, improves decision making
Sensitivity Analysis Methodology

- Saltelli: “Sensitivity Analysis is the study of how variation in the output of a model can be apportioned, qualitatively or quantitatively, to different sources of variation (input) and how the given model depends upon the information fed into it.”

- **Partial Rank Correlation Coefficient (PRCC) Analysis**
  - Provides the linear relationships between two variables (one input parameter and one output parameter) when all linear effects of other variables are removed after rank transformation
  - Rank Transformation: transforms non-linear monotonic relations to linear

- **SRRC – Description goes here**
  - Standardized regression-based coefficients measure the sensitivity of each input on each output, adjusted for all the other inputs
  - Rank Transformation: transforms non-linear monotonic relations to linear
Contributing versus a sensitive parameter

• **KEEP IN MIND** the difference between an influential condition and a sensitive condition
  – Many conditions contribute substantially to the mean output of the model
    • Low sensitivity may indicate a “DC-signal effect” over the range of model application and parameter variance
    • Example: VIIP and EVAC
  – Parameter variance affecting model output (magnitude and variance) indicates a sensitive parameter
Using IMM for ISS missions

- IMM Provides probabilistic analysis of 100 medical condition occurrences and impact to mission outcomes
- Context: 32 person-missions representing ISS person-missions of NASA astronauts Expedition 14 and later; also used in RWS validation
- Output:
  - Total Medical Events
  - Crew Health Index (crew available time – time lost due to medical events)
  - Evacuation
  - Loss of crew life

\[
CHI = \left(1 - \frac{QTL}{L}\right) \times 100\%
\]
Total Medical Events

Sensitivity Estimates - Treated Timeline TME


- Incidence Dist: 'BETA', 'GAMMA'

- PRCC: -0.6, -0.4, -0.2, 0.0, 0.2, 0.4, 0.6
- SRRC: -0.6, -0.4, -0.2, 0.0, 0.2, 0.4, 0.6
Crew Health Index

Sensitivity Estimates - Treated Timeline CHI

Condition
- VIIP-SA
- SKIN LACERATION
- 'NEPHROLITHIASIS'
- STROKE/CEREBROVASCUL.
- DENTAL-ABSCESS
- SMOKE INHALATION
- SLEEP DISORDER
- 'SEIZURES'
- 'SEPSIS'
- TRAUMATIC HYPOVOLEMIC.
- HIP/PROXIMAL FEMUR FRA.
- DENTAL CARIES
- 'SEPIS'
- SMALL BOWEL OBSTRUCT.
- ATRIAL FIBRILLATION/ATRIAL.
- ANGINA/MYOCARDIAL INFAR.
- HEAD INJURY
- RETINAL DETACHMENT
- 'SKIN RASH'
- 'APPENDICITIS'
- CHEST INJURY

Incidence Dist
- 'BETA'
- 'FIXED'
- 'GAMMA'
- 'LOGNORMAL'

PRCC

SRRC
Consideration of Evacuation
Loss of Crew Life

Sensitivity Estimates - Treated Timeline LOCL

Condition

TRAUMATIC HYPOVOLEMIC.. 'SEPSIS'
CHEST INJURY'
HEAD INJURY'
STROKE/CEREBROVASCUL..
SUDDEN CARDIAC ARREST'
CARDIOGENIC SHOCK SEC..
'APPENDICITIS'
ABDOMINAL INJURY'
TOXIC EXPOSURE/AMMONI..
SMOKE INHALATION'
NEUROGENIC SHOCK'
MEDICATION OVERDOSE/A..
ELBOW SPRAIN/STRAIN'
'DEPRESSION'
SLEEP DISORDER'
HIP SPRAIN/STRAIN'
SMALL BOWEL OBSTRUCTI..
HEADACHE-SA'
SKIN ABRASION'

-0.6  -0.4  -0.2  0.0  0.2  0.4  0.6
PRCC

Condition

TRAUMATIC HYPOVOLEMIC..
'SEPSIS'
CHEST INJURY'
HEAD INJURY'
STROKE/CEREBROVASCUL..
SUDDEN CARDIAC ARREST'
CARDIOGENIC SHOCK SEC..
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ELBOW SPRAIN/STRAIN'
'DEPRESSION'
SLEEP DISORDER'
HIP SPRAIN/STRAIN'
SMALL BOWEL OBSTRUCTI..
SKIN ABRASION'
HEADACHE-SA'

-0.6  -0.4  -0.2  0.0  0.2  0.4  0.6
SRRC
Conclusions

• Successfully implemented a rigorous quantification of model sensitivity to parameter uncertainty
  – Differs from and augments influential conditions estimate currently used by IMM

• Many sensitive conditions in the CHI, EVAC, and LOCL cases do not appear in the sensitivity estimates of the total number of medical events
  – these conditions having a low incidence rate, so the effect on TME is minimal
  – have a large effect such as prolonged impairment, evacuation, or death
Thank you!

Questions?
Backup - Untreated Total Medical Events

Sensitivity Estimates - Untreated Timeline TME

Condition
- SLEEP DISORDER
- SKIN RASH
- SKIN ABRASION
- EYE IRRITATION/ABRASION
- HEADACHE-LATE
- DIARRHEA
- RESPIRATORY INFECTION
- BACK SPRAIN/STRAIN
- BAROTRAUMA/EAR SINUS...
- SHOULDER SPRAIN/STRAIN
- HEADACHE-CO2 INDUCED
- NASAL CONGESTION-SA
- BACKPAIN-SA
- INSOMNIA-SA
- HEADACHE-SA
- VIBR-SA
- URINARY TRACT INFECTION
- SKIN INFECTION
- SPACE MOTION SICKNESS...
- ELBOW SPRAIN/STRAIN

Incidence Dist
- 'BETA'
- 'GAMMA'
Untreated Crew Health Index

Sensitivity Estimates - Untreated Timeline CHI

Condition
- EYE CHEMICAL BURN
- URINARY RETENTION SA
- VIMEP-SA
- SLEEP DISORDER
- DECOMPRESSION SICKNESS
- EYE IRRITATION/ABRAISON
- DENTAL-ABCESS
- SKIN LACERATION
- DENTAL-EXPOSED PULP
- FINGER DISLOCATION
- PARESTHESIAS SECONDARY
- SKIN RASH
- BURNS SECONDARY TO FL.
- NEPHROLITHIASIS
- SMOKE INHALATION
- PHARYNGITIS
- SKIN ABRasion
- DENTAL CARIES
- EYE INFECTION
- SEPSIS

Incidence Dist
- BETA
- FIXED
- GAMMA
- LOGNORMAL
Untreated Consideration of Evacuation

Sensitivity Estimates - Untreated Timeline EVAC

<table>
<thead>
<tr>
<th>Condition</th>
<th>Incidence Dist</th>
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<tbody>
<tr>
<td><strong>EYE CHEMICAL BURN</strong></td>
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PRCC SRRC