A Comparison of EMCL Directives with IMM Simulation Data

Briefing Document

Robert Lewis

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This aerospace medicine clerkship project is under the direction of Dr. Sharmila Watkins and is in cooperation with Dr. Eric Kerstman and Dr. Ronak Shah.

The questions of the research project are:

1. What are the main drivers of evacuation and loss of crew life (LOCL) on three Design Reference Missions (DRMs): Near Earth Asteroid (NEA), Lunar Sortie and Lunar Outpost using an inexhaustible International Space Station medical kit

2. What are the treatment designations for these driving medical conditions as listed in Expedition Medical Condition List (EMCL)

3. Do the drivers make sense in the context of the given Design Reference Mission (DRM)

4. Do any EMCL treatment designations need re-assessing

The IMM simulations were run with the help of Millennia Foy. The number of trials run was 100,000. The outputs fell under four categories, best case (treated and untreated) and worst case (treated and untreated). Each of the DRMs were run with an exhaustible ISS resource kit and an inexhaustible ISS resource kit. Outputs were Crew Health Index (based on functional impairment rates), evacuation and LOCL.

Only evacuation and LOCL were evaluated for the three DRMs (NEA, Sortie, and Outpost). The top 15 medical conditions causing evacuation and LOCL were evaluated. It was hypothesized that the top 15 drivers of evacuation and loss of crew life in each Design Reference Mission (DRM) would have a "shall" treatment designation in the Expedition Medical Condition List (EMCL).

For evacuation and LOCL, the data was compiled as follows. The raw data was taken from the inexhaustible ISS resource scenario and showed conditions as either best or worst case. The number of occurrences per 100,000 trials for best and worst case scenarios for each medical condition were added together and then arranged from highest to lowest. The top 15 medical conditions were then chosen.

> For example, if evacuation due to appendicitis-worst case- occurred 16 times on NEA, then it was placed on the excel sheet. The evacuation due to appendicitis best case was

found and the occurrence number was added to the number of occurrences of worst case. This created a total number of evacuations due to appendicitis.

When the data was accumulated in this fashion, it gave the total number of evacuations, or LOCL, due to that medical condition.

In the excel spreadsheet the following was recorded:

- The medical condition
- The occurrence rate per 100,000 trials
- The expedition medical condition list's treatment designation for that specific medical condition for that specific DRM
    - For example, wrist fracture in Lunar Outpost is "should" and for Lunar Sortie it is "not addressed"
    - Treatment designations: 2 for shall, 1 for should and 0 for not addressed
- n missions per event. This provided perspective and relevance to the occurrence rate. This was done by dividing the total number of trials, 100,000 in this case, by the occurrence rate.

Also, pie graphs containing the top 15 medical conditions and their occurrence rates were provided for evacuation and LOCL for each DRM.

The reason that only the inexhaustible ISS resource kit was used was because the simulations were run with version 3.5 of the IMM. No timeline exists for this version so all medical conditions that will occur in the mission occur on the same time point. When medical conditions occur simultaneously the condition with the highest incidence is treated first. Thus, when one uses an exhaustible medical kit, higher incidence conditions are treated preferentially. In general, most of the conditions that have a higher incidence are less severe; therefore one will see a skewing of data towards more severe conditions. It was considered prudent to report using an inexhaustible kit because the data would be more realistic.

In future projects, it would be ideal to examine the drivers of CHI in these DRMs as they may give drivers that are wholly different from conditions causing evacuation and LOCL. Also, using an optimized medical kit instead of an inexhaustible medical kit may yield more realistic results.

A Comparison of Expedition Medical Condition List Treatment Directives with Integrated Medical Model Simulation Data

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Clerkship Research Question

1. What are the main drivers of evacuation and loss of crew life (LOCL) on Near Earth Asteroid (NEA), Lunar Sortie and Lunar Outpost DRMs
    1. Using an inexhaustible International Space Station medical kit
2. What are the treatment designations for these conditions as listed in Expedition Medical Condition List (EMCL)
3. Do the drivers make sense in the context of the given Design Reference Mission (DRM)

Hypothesis

* It was expected that the top 15 drivers of evacuation and loss of crew life in each Design Reference Mission (DRM) would have a "shall" treatment designation in the Expedition Medical Condition List (EMCL)

Agenda

- Introduction to EMCL
- Introduction to IMM
- Data from IMM
  - Significance pertaining to EMCL
- Conditions needing further evaluation
  - EMCL treatment designations
  - IMM simulation protocols
- Future directions

Exploration Medical Condition List (EMCL)

- List of 86 medical conditions
  - Purpose: To identify medical conditions encountered by crewmembers on a specific mission and to identify which conditions are concerning and require treatment.
    - Also used to identify gaps in knowledge and/or technology

Exploration Medical Condition List (EMCL)

* Created using information from:
  * International Space Station (ISS) Integrated Medical Group (IMG) Medical Checklist (JSC-48522),
  * Flight Data File Medical Checklist (JSC-48031),
  * In-flight medical incidence data in the Lifetime Surveillance of Astronaut Health (LSAH) repository
  * National Aeronautics and Space Administration (NASA) flight surgeon subject matter expertise

Exploration Medical Condition List (EMCL)

- Each condition is given a treatment marker
  - Shall: The condition must be addressed by the medical system
  - Should: If resources are available, it is desirable for the condition to be addressed by the medical system
  - Not addressed: The condition will not be treated by the medical system
    - A condition was listed as "not addressed" if it is:
      - highly unlikely to occur
      - is expected to be engineered out or
      - limitations in medical training/hardware/consumables preclude its treatment.

Exploration Medical Condition List (EMCL)

- Limitations of EMCL:
  - No definitive data and insight into decision making process by creators
  - No condition severity scale
  - Evidence behind decisions were not graded on a quality
  - Over/under treatment of certain conditions
    - No ability to test amount of supplies needed
  - Hard to quantify importance of treatment of certain medical conditions
    - Difficult to assess overall risk to mission and crew

Integrated Medical Model (IMM)

* Developed as a risk assessment and evidence based decision support tool
  * Provides a quantified output necessary for objective evaluation of medical needs on an expedition
    * Multiple types of expedition simulations available
* Inputs:
  * Historical spaceflight data
  * Terrestrial analog data
  * Subject Matter Experts (SMEs)

Integrated Medical Model (IMM)

- Outputs:
  - Crew Health Index (CHI)
    - Assesses time lost during mission due to medical issues
    - Based on functional impairment
  - Evacuation
    - Probability of termination of mission due to a medical issue
    - Is considered if any of following 3 criteria are met:
      1. potential LOCL
      2. potential significant permanent impairment
      3. potential intractable pain
  - Loss of Crew Life (LOCL)
    - Probability of a medical issue leading to loss of a crewmember

Integrated Medical Model (IMM)

* Output Determinations:
  * Each medical condition has four variables
    * **Best case** and **worst case** scenario
      * With an accompanying:
        * functional impairment rate
        * Evacuation rate
        * LOCL rate
        * Treatment efficacy rate
    * Treatment using an International Space Station (ISS) medical kit (**exhaustible**)
    * Treatment using an International Space Station (ISS) medical kit (**inexhaustible**)

Clinical Findings Form (CliFF) Template

	Clinical Phase I -		Clinical Phase II -		Clinical Phase III -		
	Diagnosis & Initial Treatment[1]		*On-going Treatment / Convalescence*[2]		*Recovered / Mission End State*[3]		
	FI*	Duration	FI*	Duration	FI*	EVAC**	LOCL**
	(%)	(hrs)	(%)	(hrs)	(%)	(%)	(%)
ISS-based Treatment (best case scenario: 75%)	100	0.5	3-51	24 - 72	0	0	0
ISS-based Treatment (worst case scenario: 25%)	100	1.5	32 - 74	48 - 168	0 - 74	100	34 - 100
Untreated Best Case	N/A	N/A	32 - 74	24 - 72	0 - 51	0 - 100	0
Untreated Worst Case	N/A	N/A	60 - 93	48 - 168	60 - 93	100	100

Constraints on Medical Equipment

- Finite limits on volume and mass of equipment needed to support the crew's health
  - Medical equipment space competes with
    - Redundancy of engineering systems
    - Extra foodstuffs
    - Excess medical supplies
  - Medical training preflight is very limited

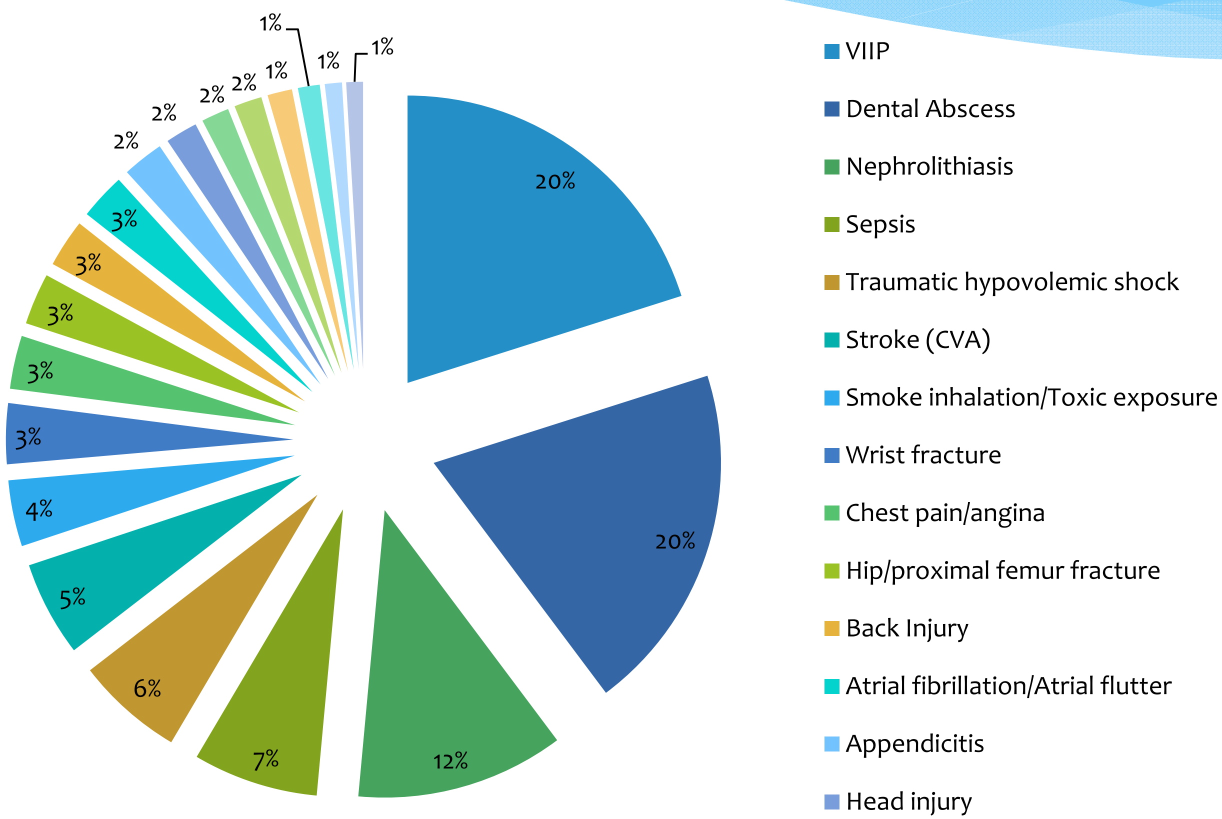
Design Reference Missions (DRMs)

* Near Earth Asteroid (NEA): 3 crewmembers (2 males, 1 female), 395 days total, 30 days on surface, 30 EVAs/crewmember, EVA every day
* Lunar Sortie: 4 crewmembers (3 males, 1 female), 14 days on surface, 4 EVAs/crewmember
* Lunar Outpost: 4 crewmembers (3 males, 1 female), 6 months on surface, 90 EVAs/crewmember

Simulation Data

NEA Evacuation Drivers

Inexhaustible ISS resources



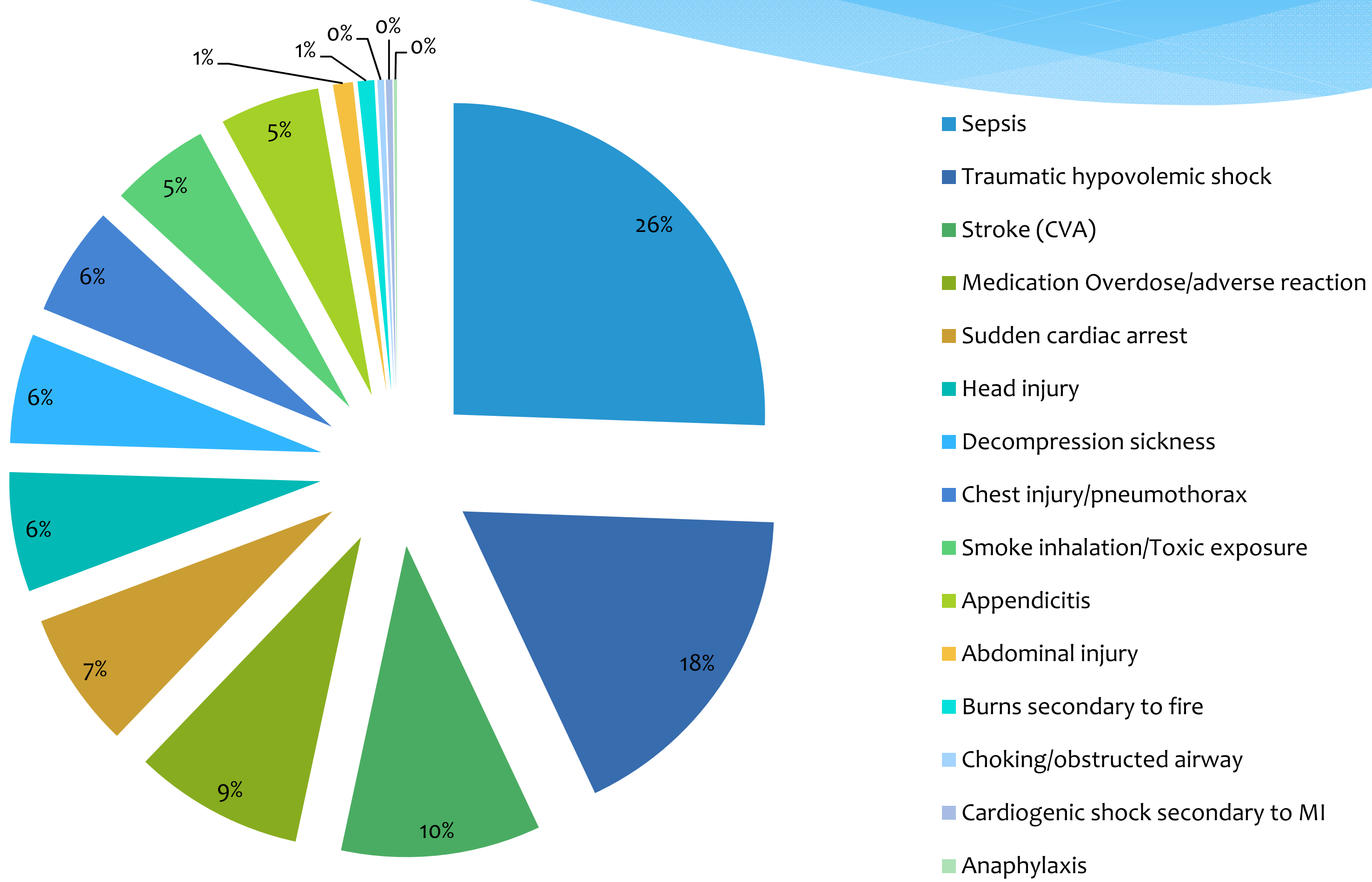
NEA Evacuation Drivers

Inexhaustible ISS resources

Medical condition	Occurrence rate per 100k trials	EMCL	n (1 event per n missions)
VIIP	797	2	125
Dental Abscess	780	2	128
Nephrolithiasis	464	2	215
Sepsis	279	2	358
Traumatic hypovolemic shock	240	**0**	416
Stroke (CVA)	212	**1**	471
Smoke inhalation/Toxic exposure	148	2	675
Wrist fracture	135	**1**	740
Chest pain/angina	119	**1**	840
Hip/proximal femur fracture	115	**0**	869
Back Injury	107	2	934
Atrial fibrillation/Atrial flutter	103	2	970
Appendicitis	92	2	1086
Head injury	72	**0**	1388
Decompression sickness	62	2	1612

NEA LOCL Drivers

Inexhaustible ISS resources



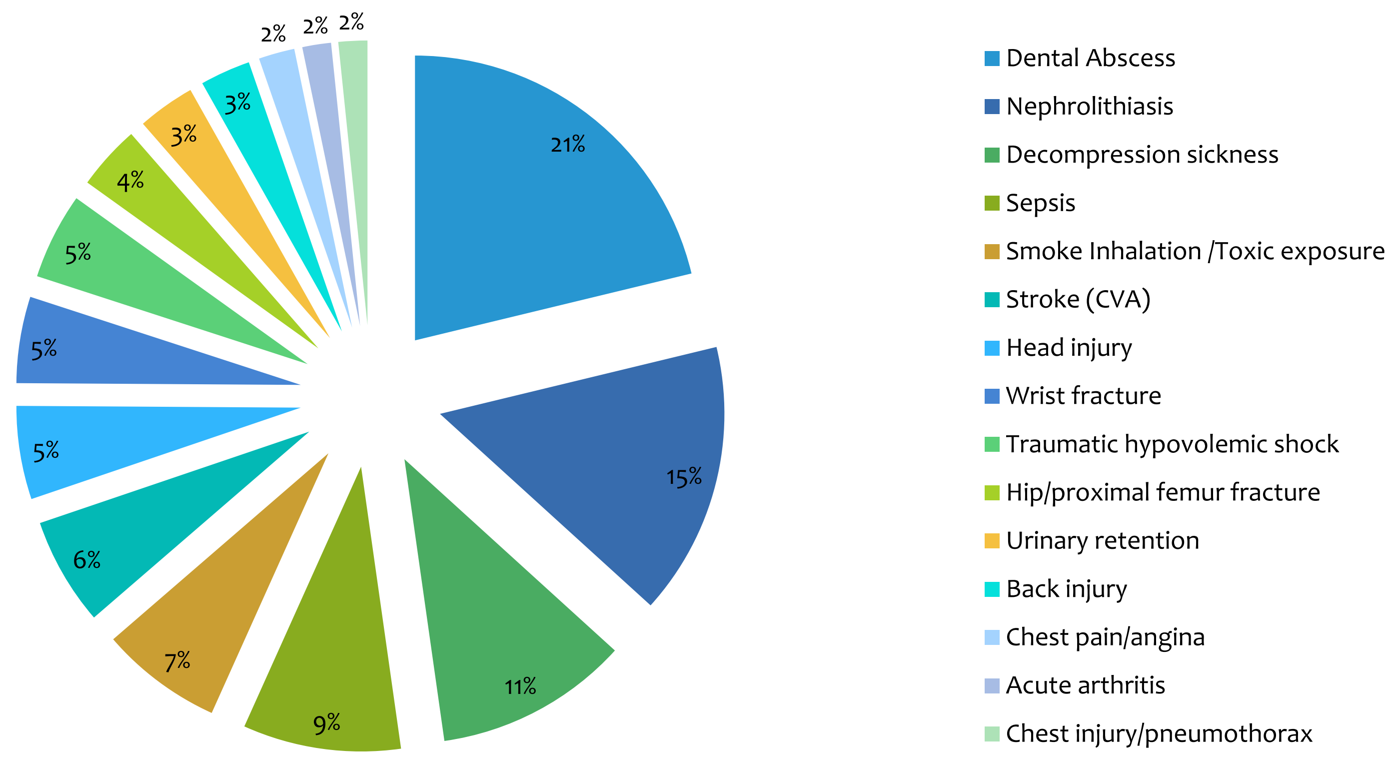
NEA LOCL Drivers

Inexhaustible ISS resources

Medical condition	Occurrence rate per 100k trials	EMCL	n (1 event per n missions)
Sepsis	148	2	675
Traumatic hypovolemic shock	101	**0**	990
Stroke (CVA)	60	**1**	1666
Medication Overdose/adverse reaction	51	2	1960
Sudden cardiac arrest	41	**1**	2439
Head injury	36	**0**	2777
Decompression sickness	33	2	3030
Chest injury/pneumothorax	33	**1**	3030
Smoke inhalation/Toxic exposure	30	2	3333
Appendicitis	30	2	3333
Abdominal injury	6	**1**	16666
Burns secondary to fire	5	2	20000
Choking/obstructed airway	2	2	50000
Cardiogenic shock secondary to MI	2	**0**	50000
Anaphylaxis	1	2	100000

Lunar Sortie Evacuation Drivers

Inexhaustible ISS resources



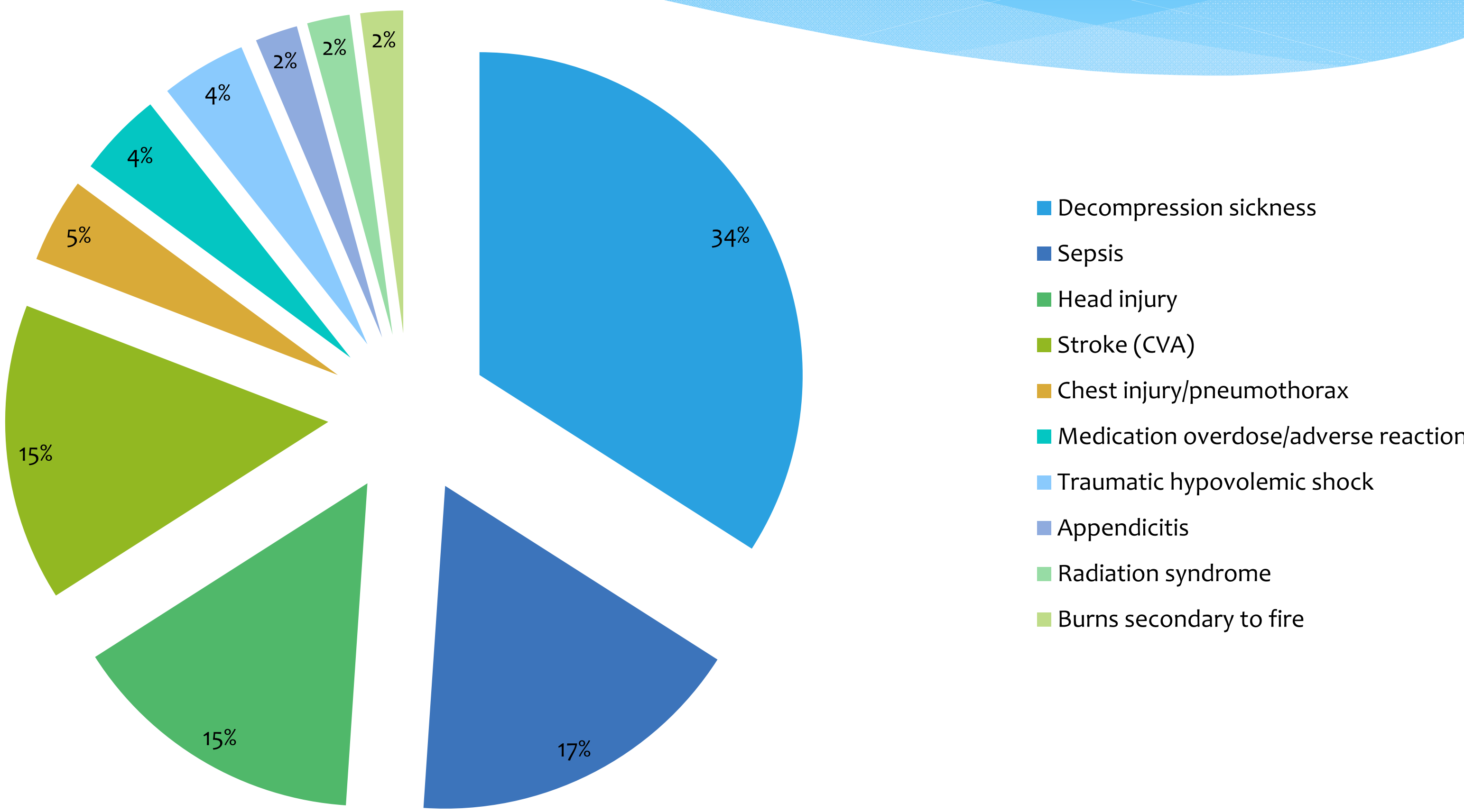
Lunar Sortie Evacuation Drivers

Inexhaustible ISS resources

Medical condition	Occurrence rate per 100k trials	EMCL	n (1 event per n missions)
Dental Abscess	52	2	1923
Nephrolithiasis	38	2	2631
Decompression sickness	27	2	3703
Sepsis	22	2	4545
Smoke Inhalation /Toxic exposure	17	2	5882
Stroke (CVA)	15	**0**	6666
Head injury	13	**0**	7692
Wrist fracture	12	**0**	8333
Traumatic hypovolemic shock	12	**0**	8333
Hip/proximal femur fracture	9	**0**	11111
Urinary retention	8	2	12500
Back injury	7	2	14285
Chest pain/angina	5	**0**	20000
Acute arthritis	4	--	25000
Chest injury/pneumothorax	4	**0**	25000

Lunar Sortie LOCL Drivers

Inexhaustible ISS resources



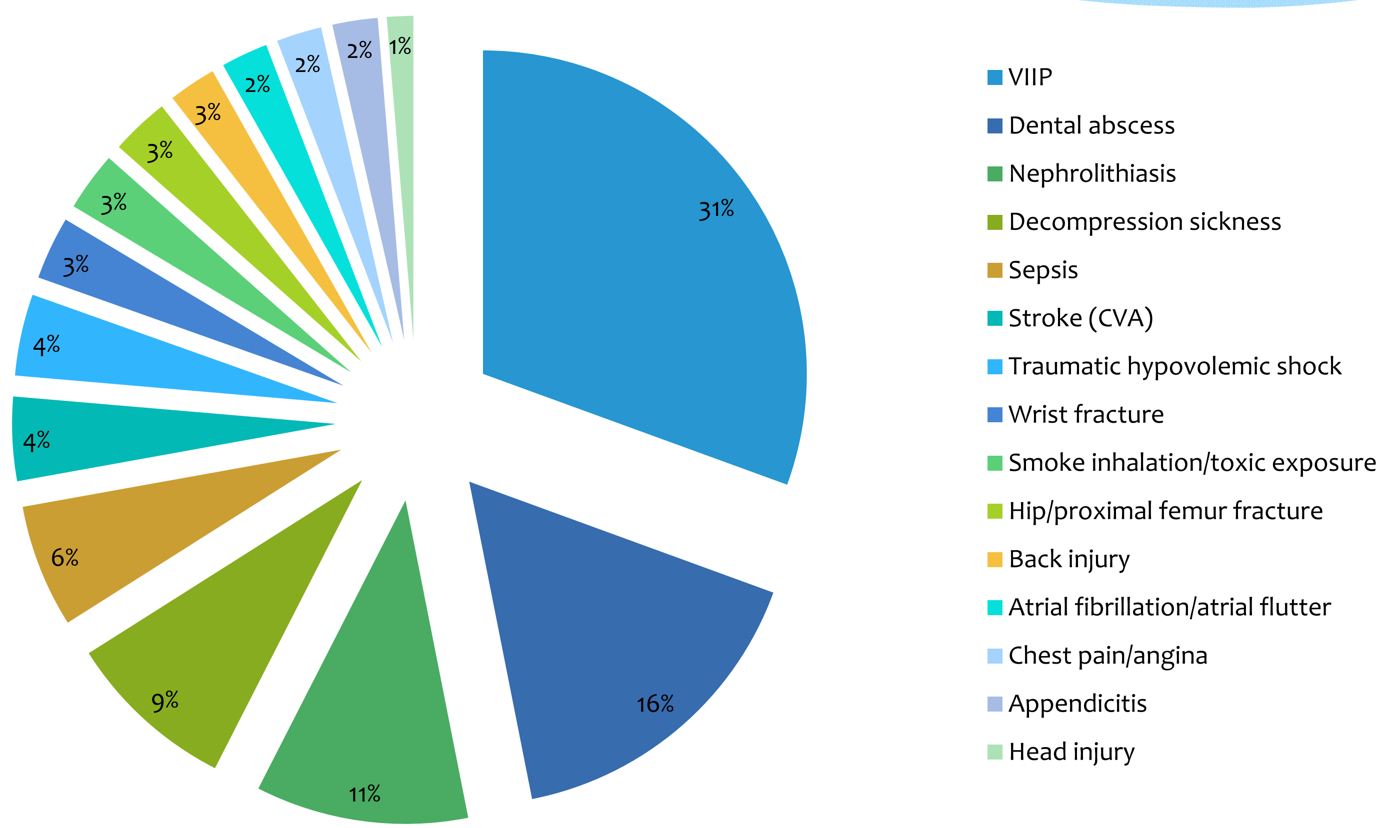
Lunar Sortie LOCL Drivers

Inexhaustible ISS resources

Medical condition	Occurrence rate per 100k trials	EMCL	n (1 event per n missions)
Decompression sickness	16	2	6250
Sepsis	8	2	12500
Head injury	7	**0**	14285
Stroke (CVA)	7	**0**	14285
Chest injury/pneumothorax	2	**0**	50000
Medication overdose/adverse reaction	2	2	50000
Traumatic hypovolemic shock	2	**0**	50000
Appendicitis	1	2	100000
Radiation syndrome	1	2	100000
Burns secondary to fire	1	2	100000

Lunar Outpost Evacuation Drivers

Inexhaustible ISS resources



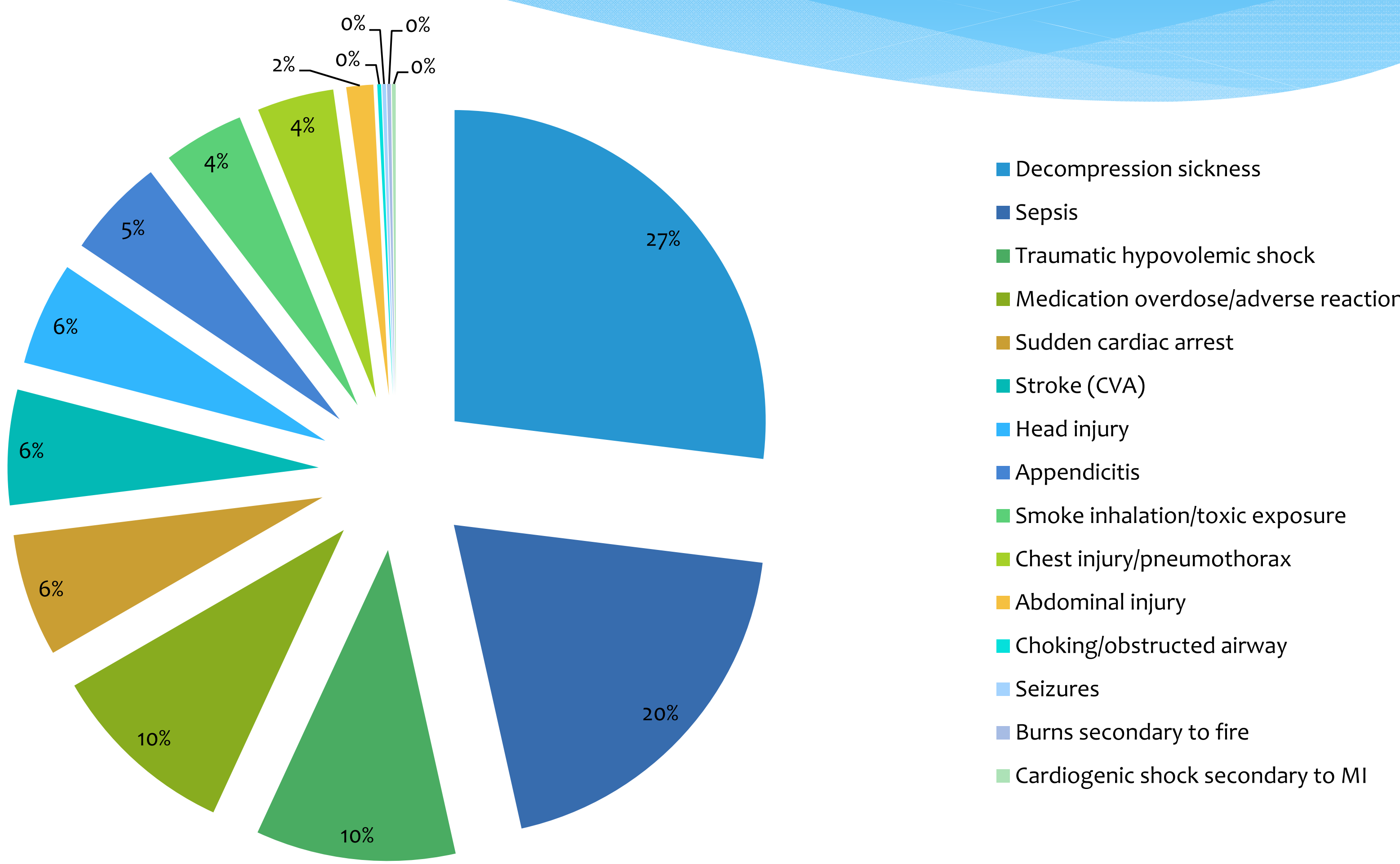
Lunar Outpost Evacuation Drivers

Inexhaustible ISS resources

Medical condition	Occurrence rate per 100k trials	EMCL	n (1 event per n missions)
VIIP	1028	2	97
Dental abscess	549	2	182
Nephrolithiasis	357	2	280
Decompression sickness	286	2	349
Sepsis	207	2	483
Stroke (CVA)	141	**1**	709
Traumatic hypovolemic shock	137	**0**	729
Wrist fracture	106	**1**	943
Smoke inhalation/toxic exposure	99	2	1010
Hip/proximal femur fracture	98	**0**	1020
Back injury	80	2	1250
Atrial fibrillation/atrial flutter	79	2	1265
Chest pain/angina	76	**1**	1315
Appendicitis	76	2	1315
Head injury	44	**0**	2272

Lunar Outpost LOCL Drivers

Inexhaustible ISS resources



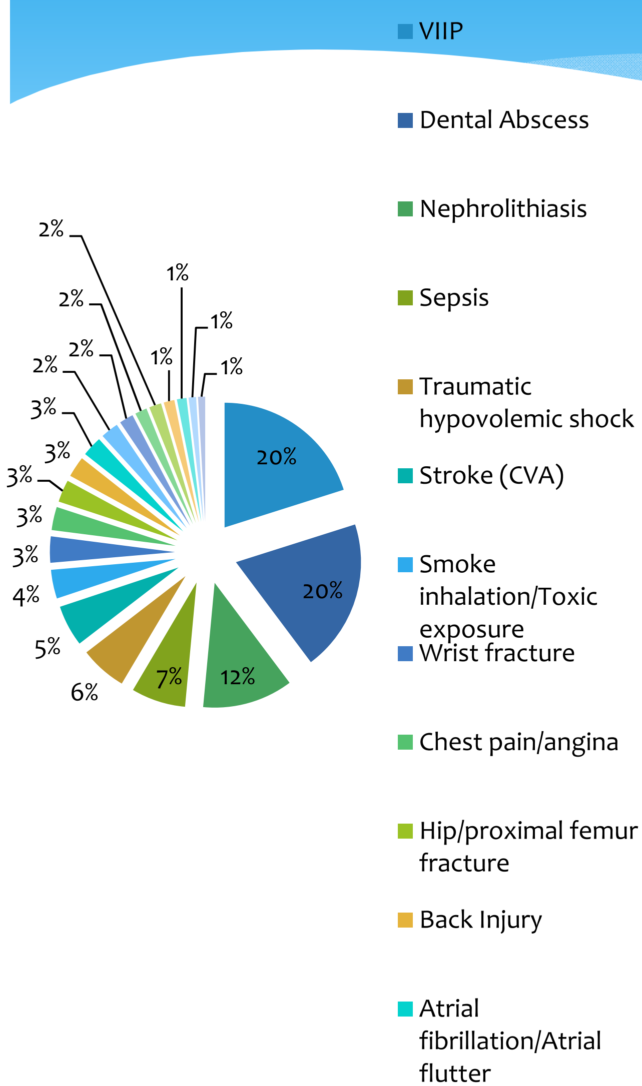
Lunar Outpost LOCL Drivers

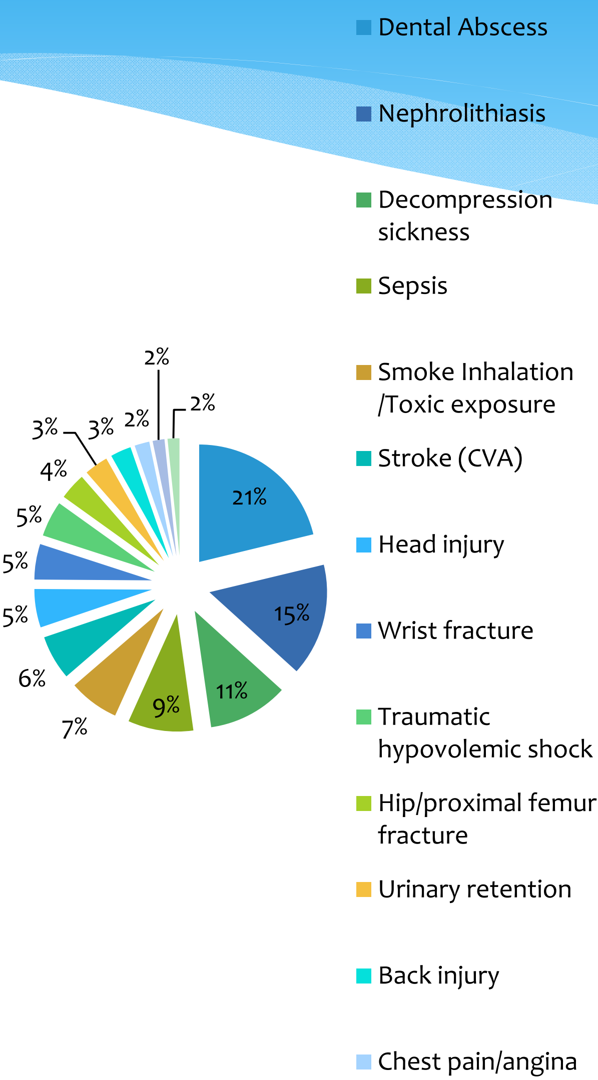
Inexhaustible ISS resources

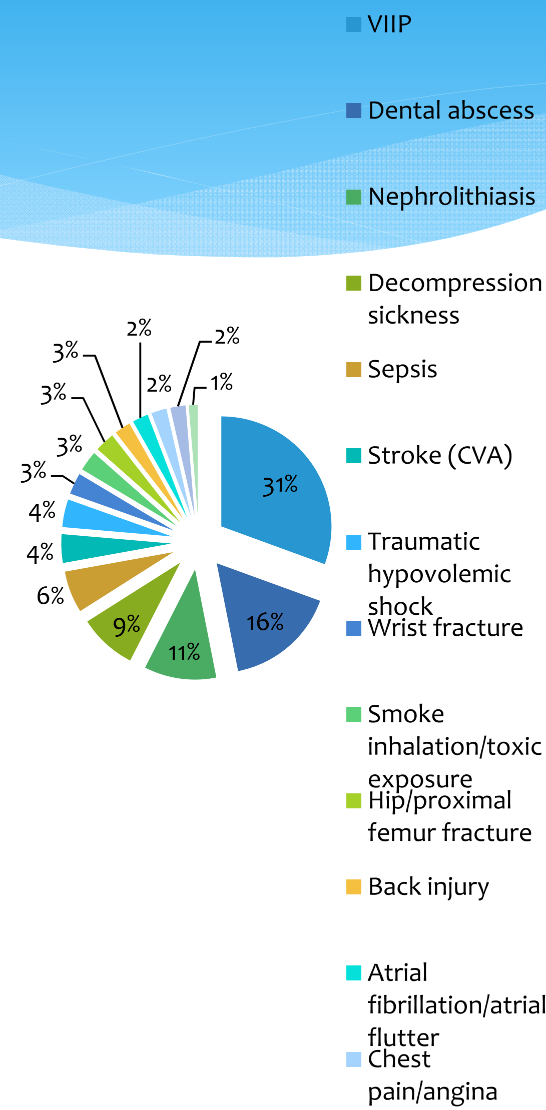
Medical condition	Occurrence rate per 100k trials	EMCL	n (1 event per n missions)
Decompression sickness	135	2	740
Sepsis	98	2	1020
Traumatic hypovolemic shock	52	**0**	1923
Medication overdose/adverse reaction	49	2	2040
Sudden cardiac arrest	32	**1**	3125
Stroke (CVA)	30	**1**	3333
Head injury	27	**0**	3703
Appendicitis	26	2	3846
Smoke inhalation/toxic exposure	21	2	4761
Chest injury/pneumothorax	20	**1**	5000
Abdominal injury	7	**0**	14285
Choking/obstructed airway	1	2	100000
Seizures	1	2	100000
Burns secondary to fire	1	2	100000
Cardiogenic shock secondary to MI	1	**0**	100000

NEA, Sortie, Outpost Evac

Inexhaustible ISS resources

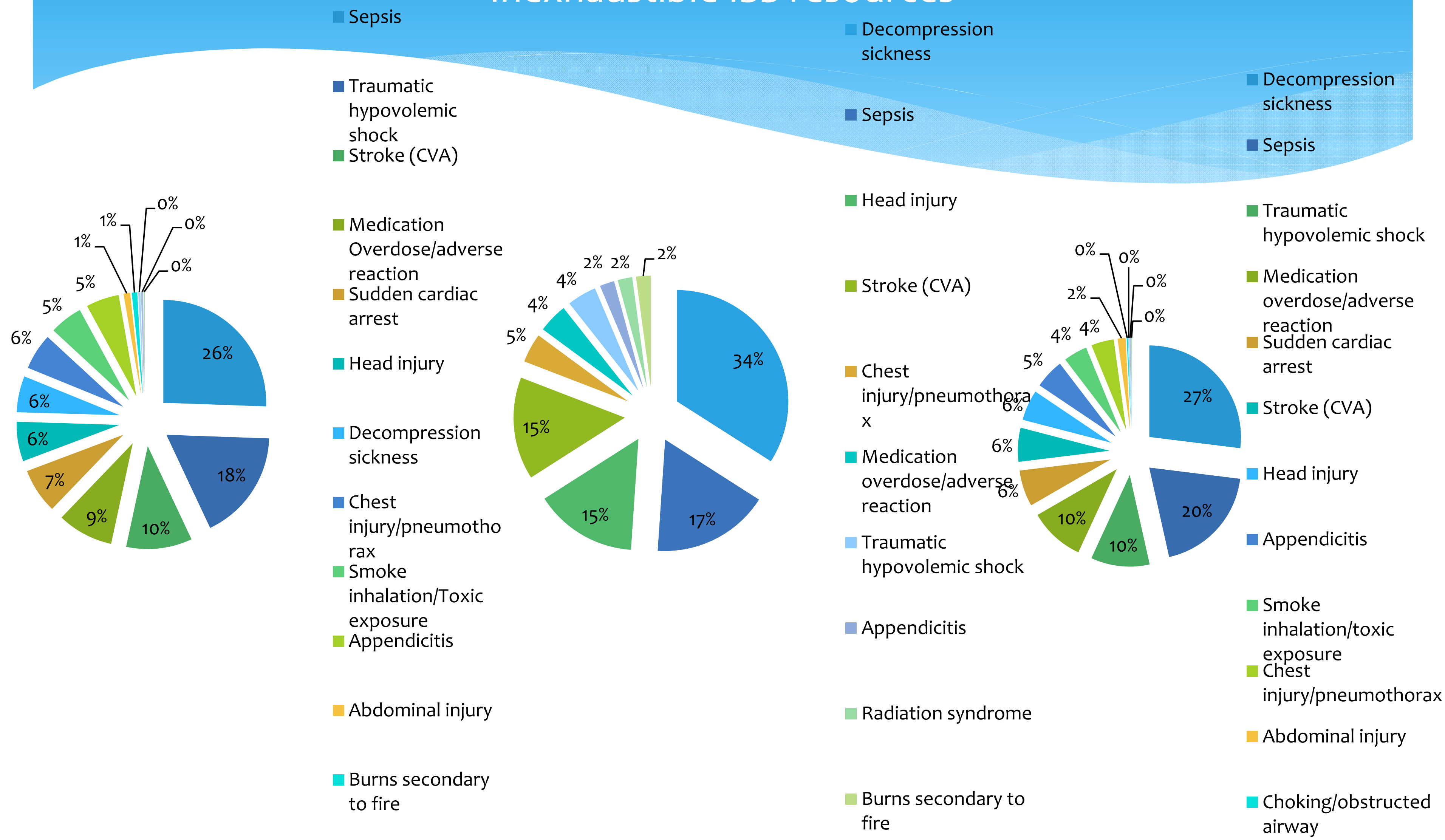






NEA, Sortie, Outpost LOCL

Inexhaustible ISS resources



Disparities between EMCL and IMM drivers

* Items listed as “Should”:
  * Abdominal injury
  * Chest injury/pneumothorax
  * Chest pain/angina
  * Stroke
  * Sudden cardiac arrest
  * Upper extremity fracture (wrist fracture)

* Items listed as “Not addressed“:
  * Cardiogenic Shock
  * Head Injury
  * Hip/Lower Extremity Fracture
  * Hypovolemic Shock
  * Neurogenic Shock

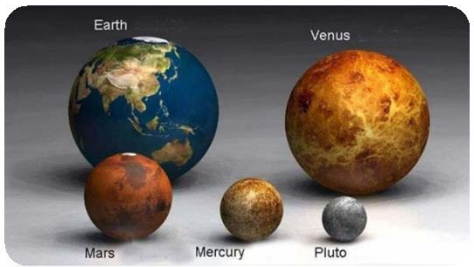
Future Directions

1. Reassess certain EMCL conditions
   * Wrist fracture, sudden cardiac arrest, stroke
   * Abdominal injury, chest injury/pneumothorax, head injury
2. Run IMM with protocols to refuse allocation of resources for "not addressed" conditions and compare rates of LOCL and evacuation to previous data
3. Examine drivers of CHI
4. Re-examine DRMs

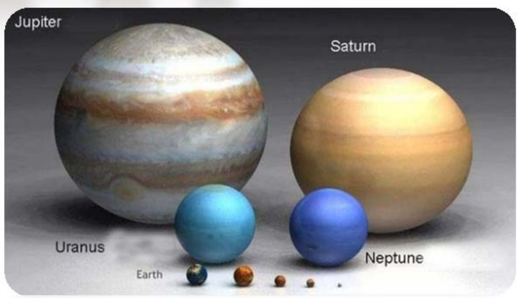
Thank you

- Special thanks to
  - Dr. Watkins
  - Dr. Kerstman
  - Dr. Shah

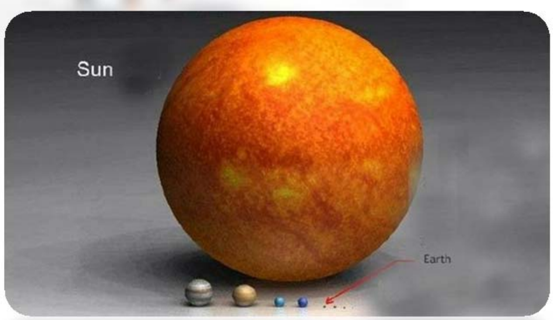
Questions?



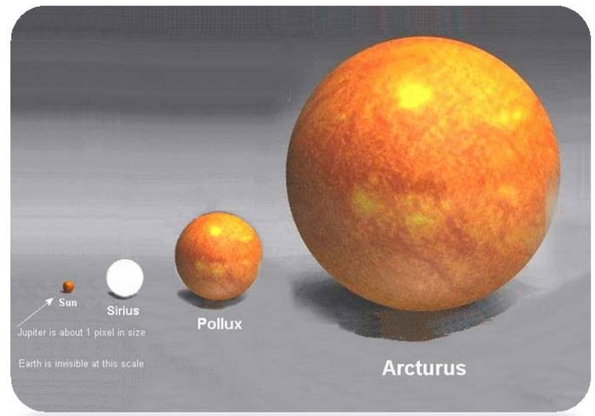
Earth
Venus
Mars
Mercury
Pluto



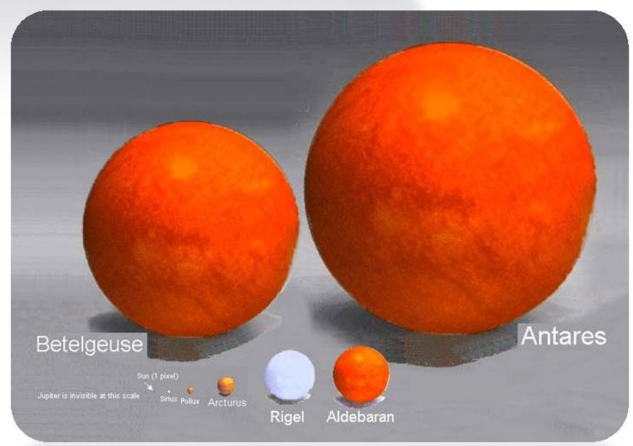
Jupiter
Saturn
Uranus
Neptune
Earth



Sun
Earth

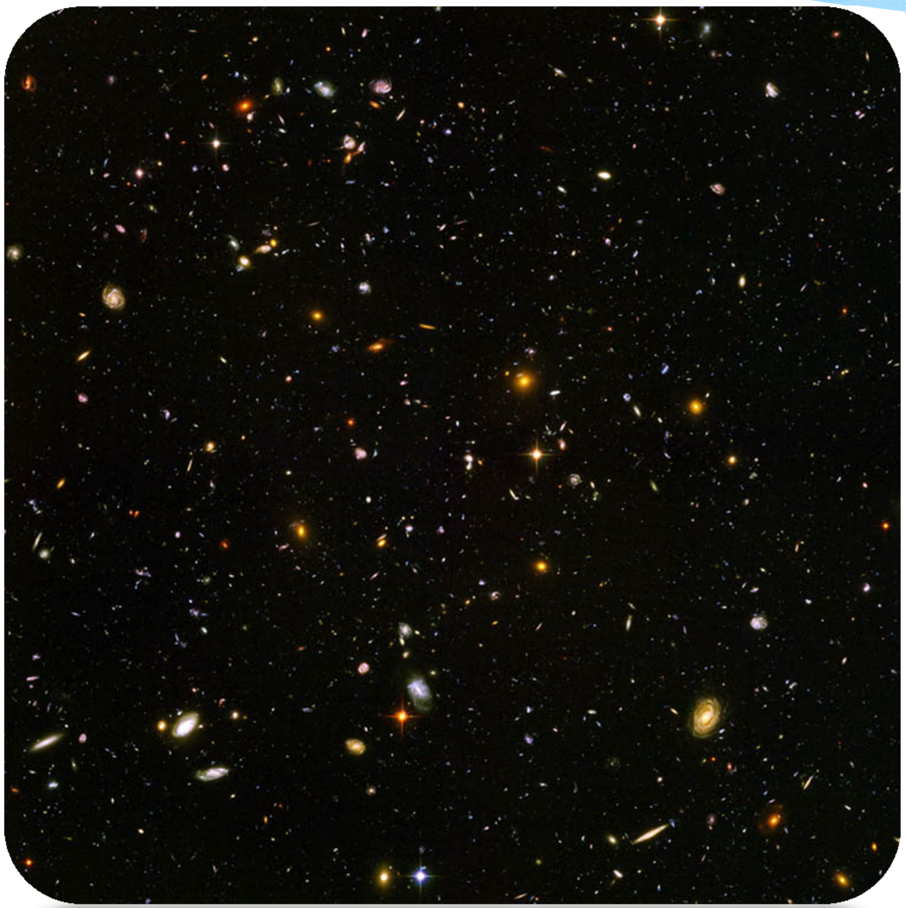


Sun
Sirius
Pollux
Jupiter is about 1 pixel in size
Earth is invisible at this scale
Arcturus



Betelgeuse
Antares
Arcturus
Rigel
Aldebaran

Backup Slides



Hip Fx

- **Hip fx: Example of technologic improvement may mitigate risk plus difficulty in treatment**
- model incidence: females **0.000112259,** SD **0.00039585,** males **0.00041818**, and **SD 0.00130529**
- technology may edit out risk: more form-fitting spacesuits, may reduce fracture incidence by improving an astronaut's agility with better field of view and by diminished mass.
- No practical differences in fracture risk emerged in comparing our lunar short and long missions

Wrist Fx

- **Wrist Fx: Reassessment suggested, most common type of fracture in this environment and terrestrially and 75% chance of successful treatment with casting: there is a gap looking at casting techniques in microgravity**
- Wrist fracture: The fracture probability mean was estimated at 6.47e-6 person-days and the standard deviation is 3.57e-5 [Myers, 2010]Our conversion to person-years is Mean **0.00236 ---** based on terrestrial data and spaceflight MSK injury rate and location data
- 16% and 25% of wrist fractures require surgical treatment looking at Swenson 2010 and Earnshaw 2002---- nonsurgical treatment-casting-is sufficient and takes 4-6 weeks.

Shock

- **Cardiogenic/Neurogenic/Hypovolemic Shock: high mortality rates, underlying cause difficult to treat, hypovolemic shock is a spectrum- difficult to characterize it into one mortality rate**
- Traumatic Hypovolemic Shock for our model is estimated as 0.000641 events/person-year considering that in our model, the incidence of Septic Shock (Sepsis) = 0.0024 events/person-year , the incidence of Cardiogenic Shock = 0.00000529 events/person-year, and the incidence of Neurogenic Shock = 0.00000498 events/person-year.
- 5-10% of patients with MI experience cardiogenic shock
- probability of death for patients hospitalized with cardiogenic shock was 74%

VIIP

- **VIIP:**
- best case scenario rate: visual acuity changes and or papilledema grades 0-2
- Worst case scenario rate: visual acuity changes and or papilledema grades 3 or above
- Percentage of worst case/best case used case reports and inflight data: 1 case is considered worst case out of 15 pts reporting vision changes, thus 7% is worst case and 93% is best case
- IMM reflects that there is no treatment, Functional impairment and evac rates in Best case treated and untreated is same, worst case treated and untreated have the same evac and FI rates
- Best case scenarios do not cause evac, only 21% of worst case scenarios cause evac

DCS

- **DCS:**
- based on Conkin's model that used the Hypobaric DCS databank which took 79,000 altitude exposures from 1942 to 1992. Had 0.011 incidence of Type II DCS. Risk to astronauts of Type II DCS lies between the Confidence interval of 0.00016 and 0.00196. NASA however uses Cuff Classification, Class 1 thru 4. 4 being central neurologic signs.
- There have been over 300 EVAs, 14 on lunar surface, and no reports of DCS.
- Prevention: 3 prebreathe protocols: 1. Exercise prebreath, 4 hour in suit prebreath and campout prebreathe.
- Best case is Cuff 1-2: occurs 97-100%
- Worst case is Cuff 3-4, occurring 0 to 3% using upper boundary of confidence interval laid out by Conkin of 0.00196, the risk of serious DCS is no greater than 0.03 or about 15 times greater than Conkins worst case estimate (0.00196)

Dental Abscess

- **Dental abscesses:**
- -looked at submariner and LSAH data, Rate: 0.023
- Dental problem probability in Skylab was 0.92% for 3 man 28 day mission, no problems occurred. Apollo showed dental emergency is 1 event in 9000 man days, dental discomfort is 1 in 1500 man days. Submarine officers greater than 30 years old had 1.4 per 100 person years, using that data, 36.3 per 100 person years
- 0-42% are worst case and require care in addition to antibiotics

Summary of other conditions

* **Stroke---push for better imaging because the incidence rates are worrisome:: near infrared imaging promising**
* **Abdominal injury/chest injury pnemo/head injury** are Conditions that are on a spectrum of severity, we need protocols for what we are going to treat and what we would give palliation for, would like to consider at least splitting up these conditions into severe and mild if there is analog data to go along with it
* **Sudden cardiac arrest: High incidence in LOCL data, easy treatment, may consider reassessment**

Disparities between EMCL and IMM drivers

* Items causing evacuation that are not designated “Shall”:
  * Abdominal injury
  * Acute chest pain/angina
  * Chest injury/pneumothorax
  * Head Injury
  * Hip/proximal femur fracture
  * Hypovolemic shock
  * Stroke
  * Wrist Fracture

Disparities between EMCL and IMM drivers

- Items causing LOCL that are not designated "Shall":
  - Abdominal injury
  - Chest injury/pneumothorax
  - Head injury/TBI
  - Hypovolemic shock
  - Neurogenic Shock
  - Stroke
  - Sudden cardiac arrest

Disparities between EMCL and IMM drivers

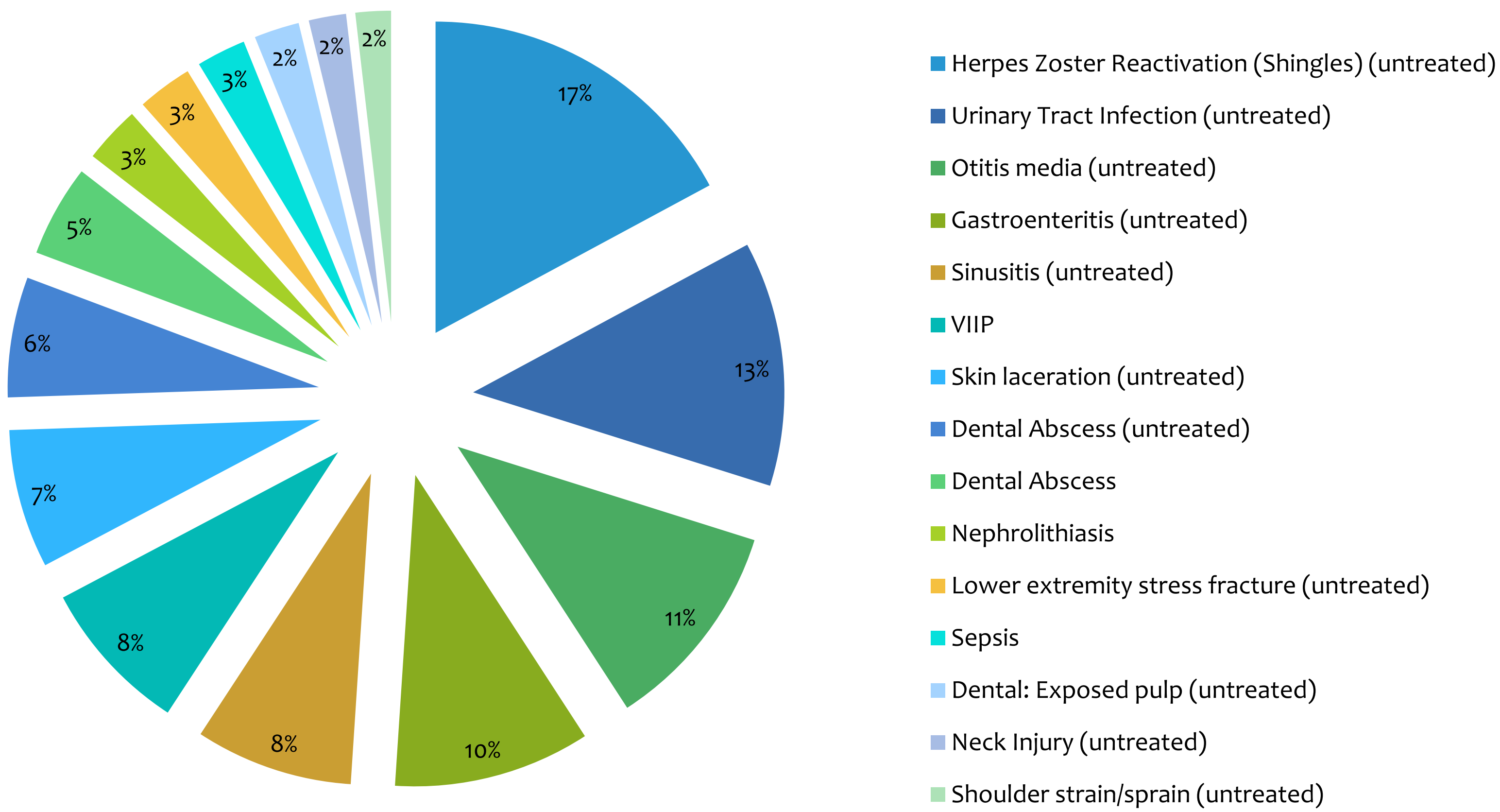
Items on Evac that are not Shall	Probability of EVAC with best case scenario and treatment	Probability of EVAC with best case scenario and no treatment	Probability of EVAC with worst case scenario and treatment	Probability of EVAC with worst case scenario and no treatment
Abdominal injury**	0	50	100	100
Acute chest pain/angina	50	100	100	100
Chest injury/pneumothorax	0	50	50	100
Head Injury	0	50	100	100
Hip/proximal femur fracture	0	100	100	100
Hypovolemic shock	100	100	100	100
Neurogenic shock**	50	100	100	100
Stroke	50	100	100	100
Sudden Cardiac Death**	100	50	0	0
Wrist Fracture	0	100	100	100

Disparities between EMCL and IMM drivers

Items on LOCL that are not Shall	Probability of LOCL with best case scenario and treatment	Probability of LOCL with best case scenario and no treatment	Probability of LOCL with worst case scenario and treatment	Probability of LOCL with worst case scenario and no treatment
Abdominal injury	0	0	67	100
Chest injury/pneumothorax	0	0	59	100
Head injury/TBI	0	0	50	100
Hypovolemic shock	0	50	100	100
Neurogenic Shock	0	50	50	100
Stroke	0	0	50	100
Sudden cardiac arrest	0	50	100	100

NEA Evacuation Drivers

Worst case, exhaustible ISS resources



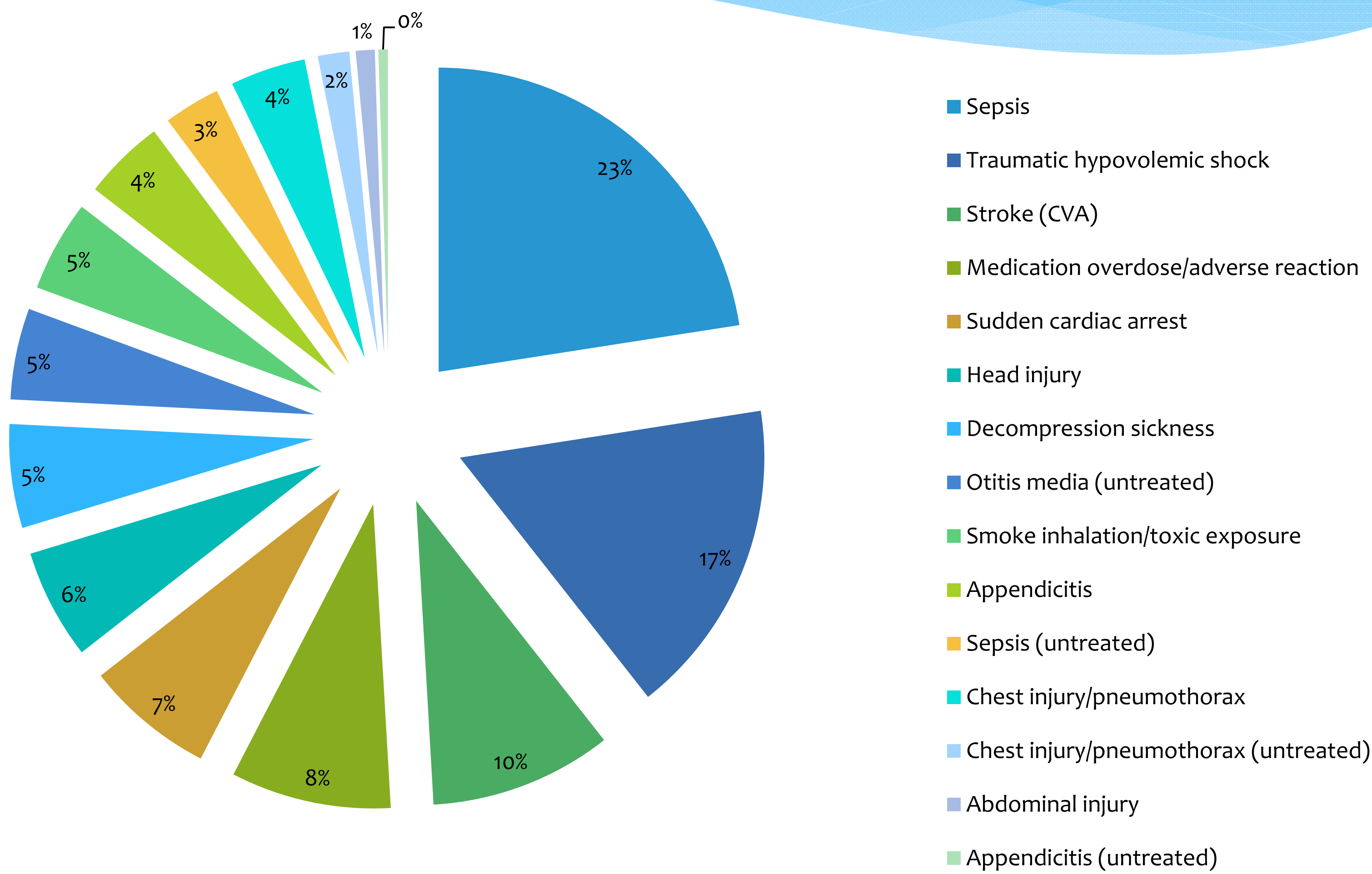
NEA Evacuation Drivers

Worst case, exhaustible ISS resources

Medical condition	Number in trial	Occurrence rate per 100k trials	Probability of EVAC
Herpes Zoster Reactivation (Shingles) (untreated)	1	1700	**100**
Urinary Tract Infection (untreated)	2	1260	**50**
Otitis media (untreated)	3	1089	**50**
Gastroenteritis (untreated)	4	1013	**50**
Sinusitis (untreated)	5	812	**50**
VIIP	6	797	**11**
Skin laceration (untreated)	7	715	**50**
Dental Abscess (untreated)	8	619	**100**
Dental Abscess	9	473	**50**
Nephrolithiasis	10	293	**100**
Lower extremity stress fracture (untreated)	11	284	**50**
Sepsis	12	255	**100**
Dental: Exposed pulp (untreated)	13	233	**100**
Neck Injury (untreated)	14	192	**50**
Shoulder strain/sprain (untreated)	15	183	**50**

NEA LOCL Drivers

Worst case, exhaustible ISS resources



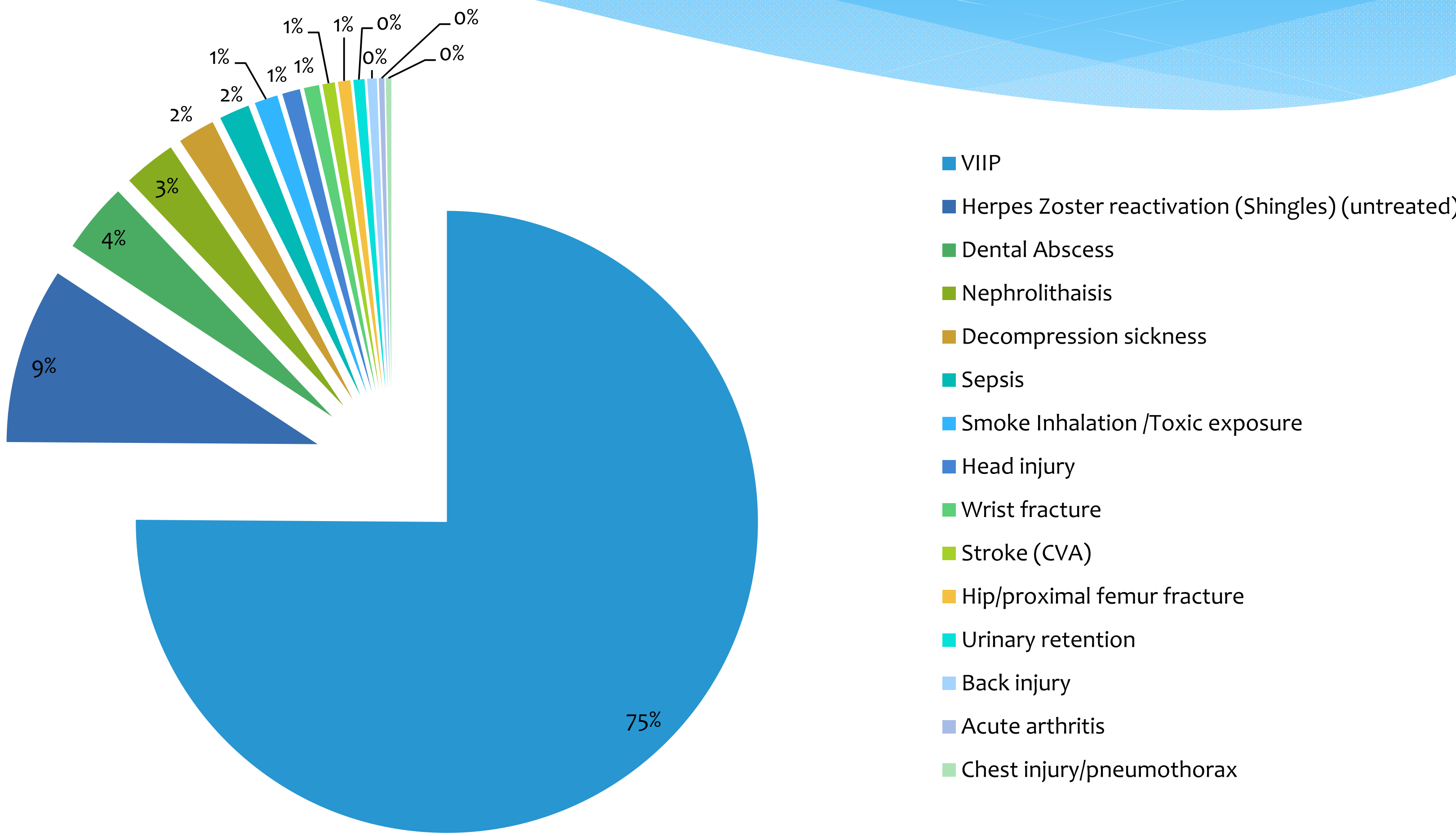
NEA LOCL Drivers

Worst case, exhaustible ISS resources

Medical condition	Number in trial	Occurrence rate per 100k trials	Probability of LOCL
Sepsis	1	135	**50**
Traumatic hypovolemic shock	2	101	**100**
Stroke (CVA)	3	58	**50**
Medication overdose/adverse reaction	4	51	**50**
Sudden cardiac arrest	5	41	**100**
Head injury	6	35	**50**
Decompression sickness	7	33	**3**
Otitis media (untreated)	8	29	**1**
Smoke inhalation/toxic exposure	9	29	**6**
Appendicitis	10	26	**50**
Sepsis (untreated)	11	18	**100**
Chest injury/pneumothorax	12	24	**50**
Chest injury/pneumothorax (untreated)	13	10	**100**
Abdominal injury	14	6	**67**
Appendicitis (untreated)	15	3	**50**

Lunar Sortie Evacuation Drivers

Worst case, exhaustible ISS resources



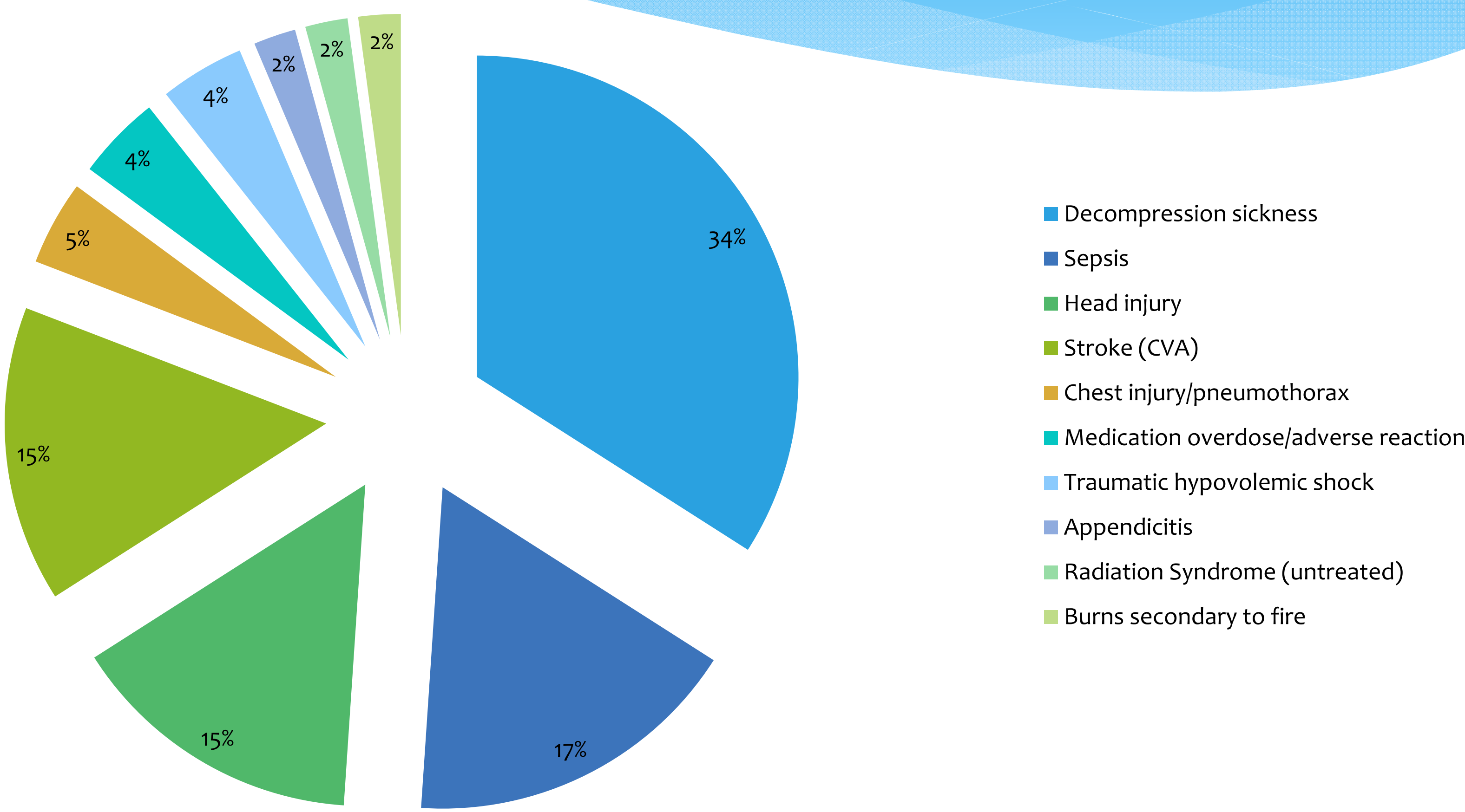
Lunar Sortie Evacuation Drivers

Worst case, exhaustible ISS resources

Medical condition	Number in trial	Occurrence rate per 100k trials	Probability of EVAC
VIIP	1	1050	**11**
Herpes Zoster reactivation (Shingles) (untreated)	2	128	**100**
Dental Abscess	3	51	**50**
Nephrolithiasis	4	38	**100**
Decompression sickness	5	27	**5**
Sepsis	6	22	**100**
Smoke Inhalation /Toxic exposure	7	17	**29**
Head injury	8	13	**100**
Wrist fracture	9	11	**100**
Stroke (CVA)	10	9	**100**
Hip/proximal femur fracture	11	9	**100**
Urinary retention	12	8	**1**
Back injury	13	7	**2**
Acute arthritis	14	4	**19**
Chest injury/pneumothorax	15	4	**50**

Lunar Sortie LOCL Drivers

Worst case, exhaustible ISS resources



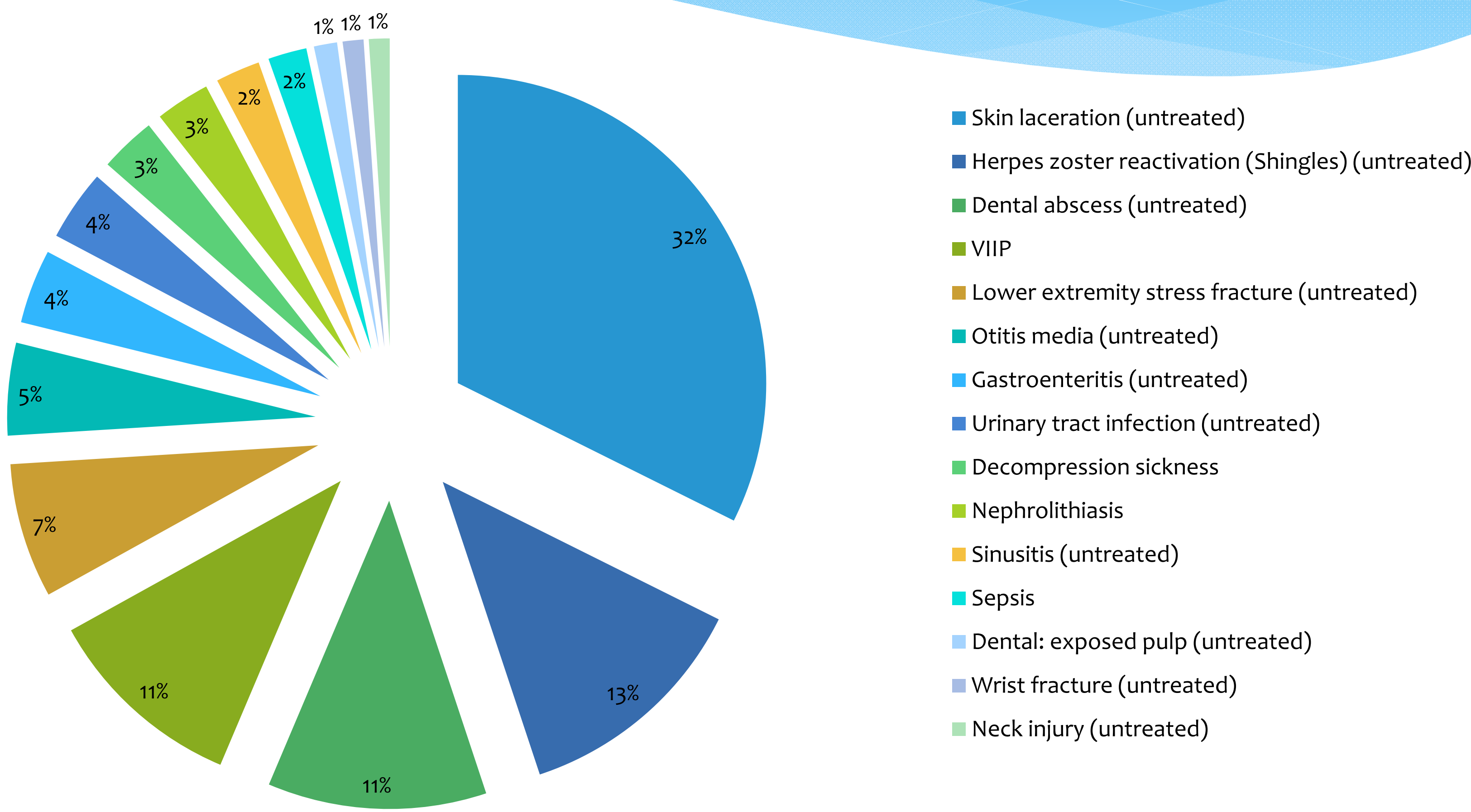
Lunar Sortie LOCL Drivers

Worst case, exhaustible ISS resources

Medical condition	Number in trial	Occurrence rate per 100k trials	Probability of LOCL
Decompression sickness	1	16	**3**
Sepsis	2	8	**50**
Head injury	3	7	**50**
Stroke (CVA)	4	7	**50**
Chest injury/pneumothorax	5	2	**50**
Medication overdose/adverse reaction	6	2	**50**
Traumatic hypovolemic shock	7	2	**100**
Appendicitis	8	1	**50**
Radiation Syndrome (untreated)	9	1	**100**
Burns secondary to fire	10	1	**50**

Lunar Outpost Evacuation Drivers

Worst case, exhaustible ISS resources



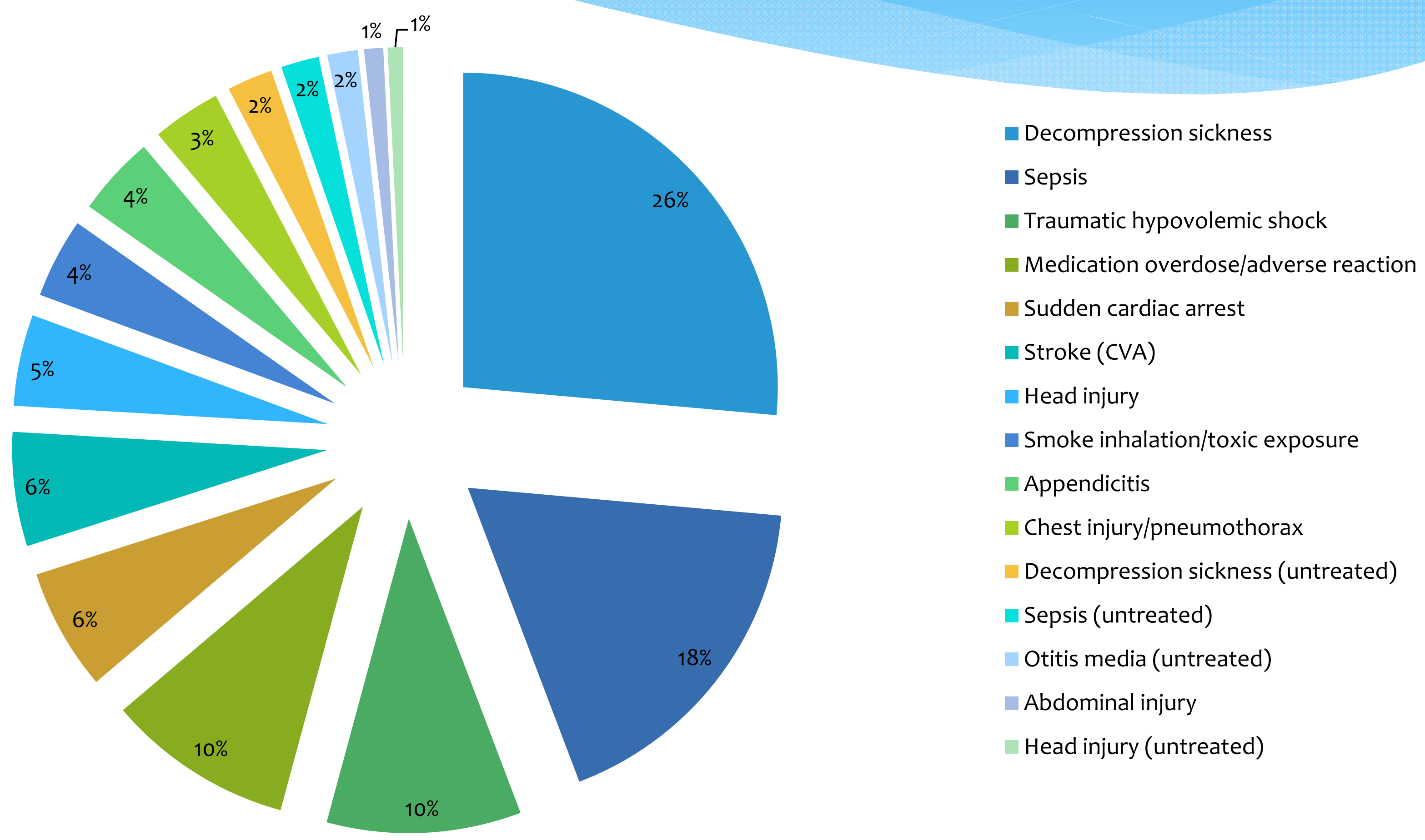
Lunar Outpost Evacuation Drivers

Worst case, exhaustible ISS resources

Medical condition	Number in trial	Occurrence rate per 100k trials	Probability of EVAC
Skin laceration (untreated)	1	3147	**50**
Herpes zoster reactivation (Shingles) (untreated)	2	1221	**100**
Dental abscess (untreated)	3	1116	**100**
VIIP	4	1028	**11**
Lower extremity stress fracture (untreated)	5	688	**50**
Otitis media (untreated)	6	471	**50**
Gastroenteritis (untreated)	7	378	**50**
Urinary tract infection (untreated)	8	361	**50**
Decompression sickness	9	286	**5**
Nephrolithiasis	10	278	**100**
Sinusitis (untreated)	11	227	**50**
Sepsis	12	197	**100**
Dental: exposed pulp (untreated)	13	118	**100**
Wrist fracture (untreated)	14	106	**100**
Neck injury (untreated)	15	105	**50**

Lunar Outpost LOCL Drivers

Worst case, exhaustible ISS resources



Lunar Outpost LOCL Drivers

Worst case, exhaustible ISS resources

Medical condition	Number in trial	Occurrence rate per 100k trials	Probability of LOCL
Decompression sickness	1	135	**3**
Sepsis	2	91	**50**
Traumatic hypovolemic shock	3	51	**100**
Medication overdose/adverse reaction	4	49	**50**
Sudden cardiac arrest	5	32	**100**
Stroke (CVA)	6	30	**50**
Head injury	7	24	**50**
Smoke inhalation/toxic exposure	8	21	**6**
Appendicitis	9	21	**50**
Chest injury/pneumothorax	10	18	**50**
Decompression sickness (untreated)	11	12	**50**
Sepsis (untreated)	12	10	**100**
Otitis media (untreated)	13	8	**1**
Abdominal injury	14	5	**67**
Head injury (untreated)	15	4	**100**