

The Effect of Heroic Medical Care on Mission Medical Outcomes

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We will not discuss off-label use and/or investigational use in this presentation

Study Objective

- A catastrophic medical event depletes medical resources.
- What happens to the rest of the mission's medical outcomes after such an event?
- Use Probabilistic Risk Assessment (PRA) to see if we can find out.

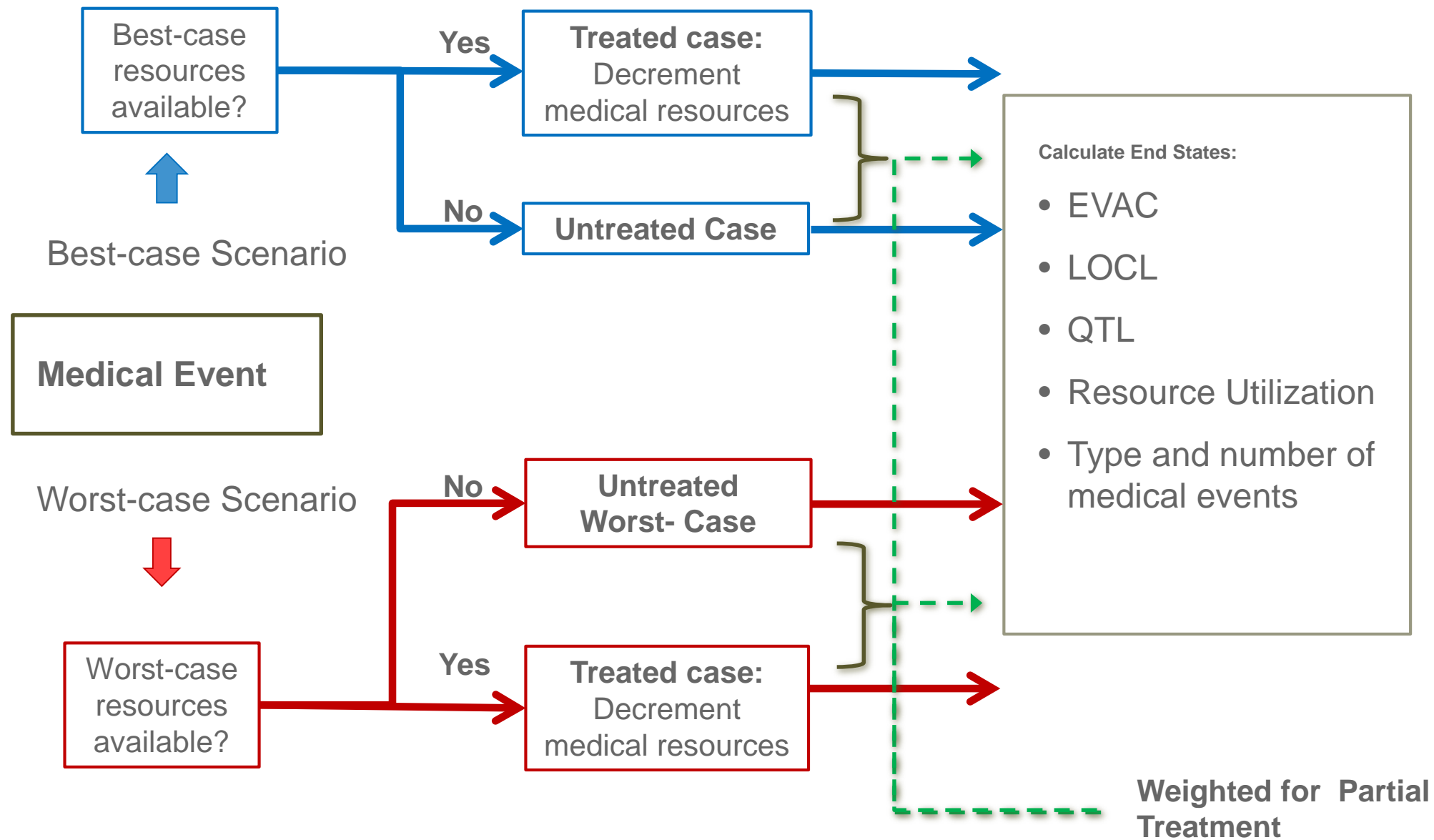
What is the Integrated Medical Model?

- PRA model using Monte Carlo methodology
- Used to assess mission risk due to in-flight medical events
- User defined Design Reference Missions (DRM) (crew, duration, EVA, etc.)
- Considers outcomes for 100 medical conditions that have or may occur in-flight
- 100,000 trials conducted per DRM

Model Outputs

- **Total Medical Events (TME)**
- **Crew Health Index (CHI)** - 0 to 100%, complete impairment to normal function
- Need for **Evacuation (EVAC)** occurs if...
 - Risk of LOCL (needs advanced care to survive)
 - Risk for significant permanent impairment
 - Risk of intractable pain
- **Loss of Crew Life (LOCL)** means that the clinical scenario resulted in death
- **Influential conditions**, those that had significant contribution to outcomes
- **Medical Resources** consumed

IMM Methodology



Study Design Reference Missions (DRM)

- 4 crew members on a 540 day simulated Mars mission
- 5 DRMs
 - *DRM 1 – Control – no catastrophic event*
 - DRM 2 to 5, A catastrophic medical event occurs ...
 - *DRM 2 – Day 1 of 540 (100% of mission remaining)*
 - *DRM 3 – Day 135 of 540 (75%)*
 - *DRM 4 – Day 270 of 540 (50%)*
 - *DRM 5 – Day 405 of 540 (25%)*
- Baselined to the ISS medical kit **without** resupply

Study Design Reference Missions (DRM)

	Sex	CAC	Crowns	Contacts	Prior Abdominal Surgery	CATASTROPHIC EVENT
Crew 1	Male	Yes	Yes	No	No	No
Crew 2	Female	No	No	Yes	Yes	Yes*
Crew 3	Male	No	Yes	No	No	No
Crew 4	Female	No	No	Yes	No	No

* No catastrophic event for control

Catastrophic Medical Event

- **Urinary Obstruction → Urinary Tract Infection → Sepsis**
- Maximum resources used (worst case scenario +) (example below)
- Crew member recovers after prolonged treatment

Resource	Best Case	Worst Case	Dosage Type	Best Case per Day	Worst Case per Day
Adrenaline (Epinephrine 1:10000) 10mL	0	2	per day	0	2
Ambu bag and mask	0	1	event	0	0
Blood Oximeter	1	1	event	0	0
Blood Pressure /ECG Monitor	1	1	event	0	0
BZK wipes	6	8	event	0	0
CMRS	1	1	event	0	0
Ertapenem 1gm	1	3	per day	1	1
Foam electrodes	5	5	event	0	0

Catastrophic Medical Event

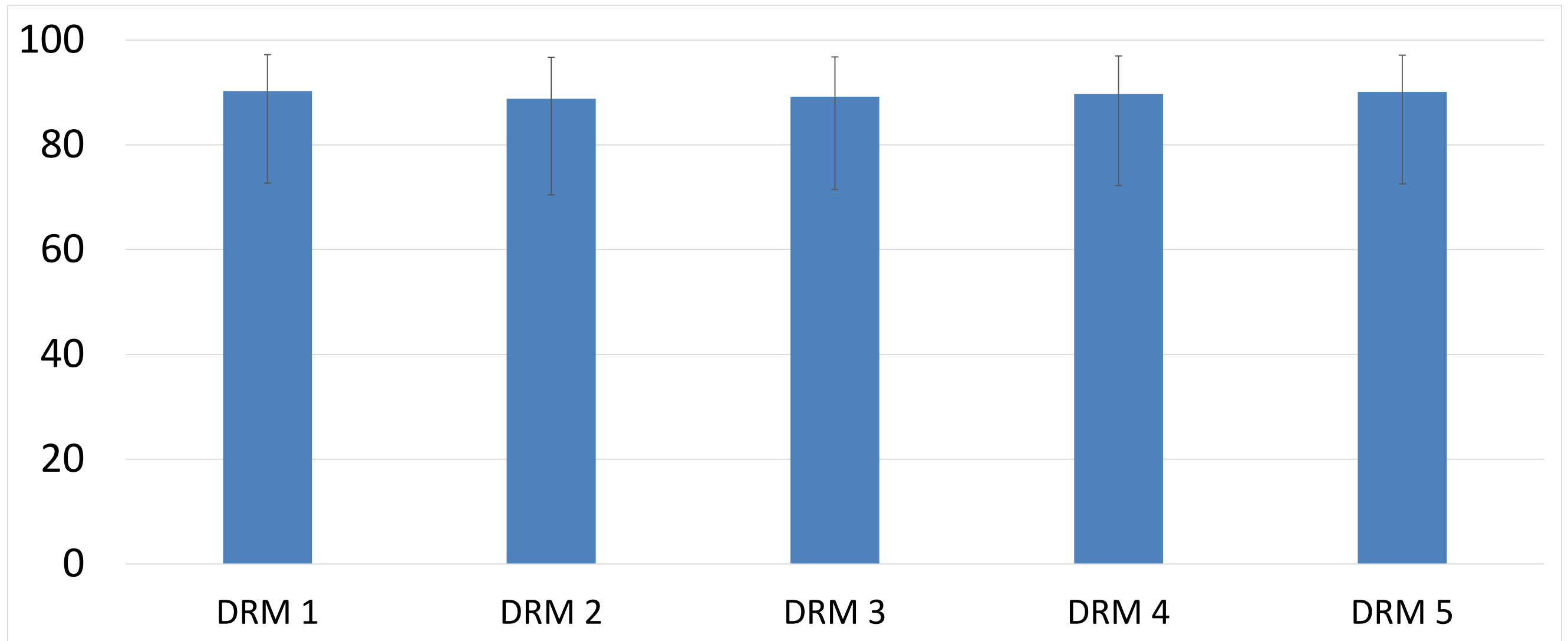
- **Urinary Obstruction → Urinary Tract Infection → Sepsis**
- Maximum resources used (worst case scenario +) (example below)
- Crew member recovers after prolonged treatment

Resource	Worst Case	Heroic Measures	Heroic Rationale
Adrenaline (Epinephrine 1:10000) 10mL	2	All	WC hypotension would require all available
Ambu bag and mask	1	n/c	nonconsumable
Bactrim DS	0	20 of 40	10 day course, would end up switching to something else if not working and had no culture to guide.
Blood Oximeter	1	n/c	nonconsumable
Blood Pressure /ECG Monitor	1	n/c	nonconsumable
BZK wipes	8	30 of 60	would use a lot of these
CMRS	1	n/c	nonconsumable
Cotton swabs	1	4 of 6	run at least 4 urine tests, intial and repeats with treatment
Ertapenem 1gm	3	All	use all for non-response to other antibiotics
Foam electrodes	5	8 of 20	accounts for loss and reapplication of electrodes
Gauze pads (4x4)	8	25 of 50	would use a lot but not all
ILMA cue card	1	n/c	nonconsumable

Results Summary

- Total Medical Events (TME) the same across all DRMs, ~180 (same rate of events)
- CHI unaffected
- The earlier the event occurs in the mission timeline...
 - Fewer resources are available to treat subsequent medical events
 - EVAC and LOCL increase
 - More events are partially treated

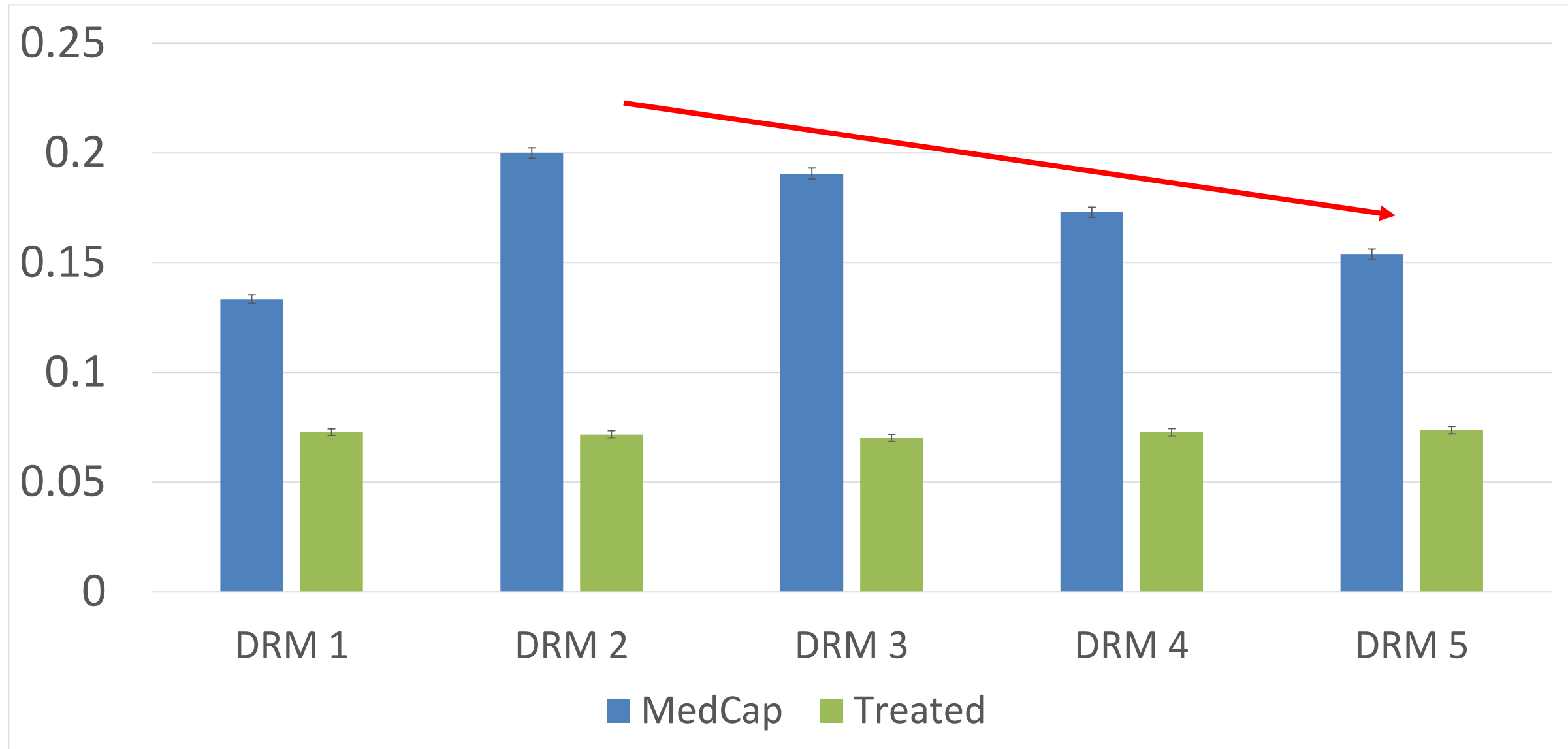
Crew Health Index (%)



Probability of One or More EVAC and LOCL

Catastrophic Event	EVAC			LOCL		
	Probability	95% CI		Probability	95% CI	
None (control)	0.1333	0.1314	0.1354	0.0095	0.0088	0.0100
Day 1	0.2000	0.1975	0.2024	0.0139	0.0132	0.0147
Day 135	0.1904	0.1881	0.1932	0.0131	0.0125	0.0139
Day 270	0.1731	0.1707	0.1753	0.0119	0.0113	0.0126
Day 405	0.1539	0.1516	0.1562	0.0109	0.0102	0.0115

Probability of EVAC (0 – 1)



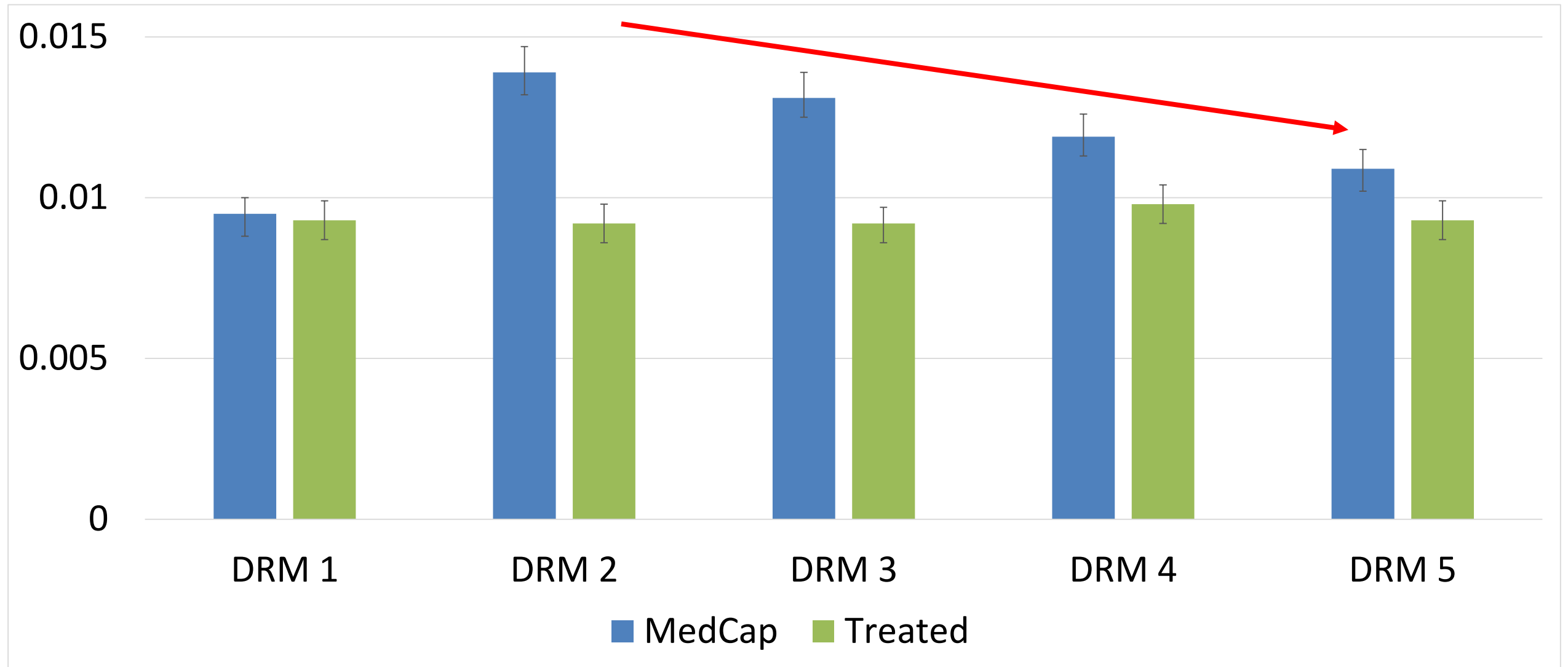
Control – EVAC, Top Ten Influential Conditions

Scenario	Treated	Medical Condition	# Events	Contribution (%)	Cumulative (%)
BEST	PARTIAL	EYE CHEMICAL BURN	3272	23.10	23.10
WORST	PARTIAL	URINARY TRACT INFECTION	1127	7.96	31.05
WORST	TREATED	SANS	936	6.61	37.66
WORST	PARTIAL	EYE CHEMICAL BURN	516	3.64	41.30
WORST	TREATED	SMOKE INHALATION	478	3.37	44.68
WORST	PARTIAL	NEPHROLITHIASIS	478	3.37	48.05
WORST	TREATED	NEPHROLITHIASIS	453	3.20	51.25
WORST	TREATED	SEPSIS	410	2.89	54.14
WORST	PARTIAL	BACK SPRAIN/STRAIN	406	2.87	57.01
WORST	TREATED	WRIST FRACTURE	306	2.16	59.17

CE Day1 – EVAC, Top Ten Influential Conditions

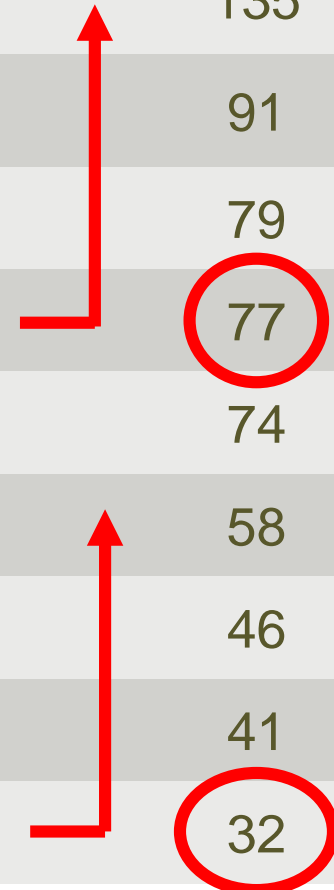
Scenario	Treated	Medical Condition	# Events	Cumulative (%)	Cumulative (%)
BEST	PARTIAL	EYE CHEMICAL BURN	3747	22.82	22.82
WORST	PARTIAL	URINARY TRACT INFECTION	1657	10.09	32.91
WORST	TREATED	SANS	1012	6.16	39.07
WORST	PARTIAL	BACK SPRAIN/STRAIN	629	3.83	42.90
WORST	PARTIAL	EYE CHEMICAL BURN	601	3.66	46.56
WORST	PARTIAL	NEPHROLITHIASIS	476	2.90	49.46
BEST	PARTIAL	FINGER DISLOCATION	455	2.77	52.23
WORST	TREATED	NEPHROLITHIASIS	391	2.38	54.61
WORST	TREATED	SMOKE INHALATION	323	1.97	56.57
WORST	TREATED	SEPSIS	304	1.85	58.42

Probability of LOCL (0 – 1)



Control – LOCL, Top Ten Influential Conditions

Scenario	Treated	Medical Condition	# Events	Contribution (%)	Cumulative (%)
WORST	TREATED	SEPSIS	195	20.57	20.57
WORST	TREATED	TRAUMATIC HYPOVOLEMIC SHOCK	135	14.24	34.81
WORST	TREATED	MEDICATION ADVERSE REACTION	91	9.60	44.41
WORST	TREATED	CEREBROVASCULAR ACCIDENT	79	8.33	52.74
WORST	TREATED	SMOKE INHALATION	77	8.12	60.86
WORST	TREATED	HEAD INJURY	74	7.81	68.67
WORST	TREATED	CHEST INJURY	58	6.12	74.79
WORST	TREATED	TOXIC EXPOSURE (AMMONIA)	46	4.85	79.64
WORST	TREATED	APPENDICITIS	41	4.32	83.97
WORST	PARTIAL	SEPSIS	32	3.38	87.34



CE Day 1 – LOCL, Top Ten Influential Conditions

Scenario	Treated	Medical Condition	# Events	Contribution (%)	Cumulative (%)
WORST	PARTIAL	SMOKE INHALATION	302	21.62	21.62
WORST	PARTIAL	SEPSIS	275	19.69	41.30
WORST	PARTIAL	TRAUMATIC HYPOVOLEMIC SHOCK	135	9.66	50.97
WORST	PARTIAL	MEDICATION ADVERSE REACTION	96	6.87	57.84
WORST	PARTIAL	CEREBROVASCULAR ACCIDENT	86	6.16	63.99
WORST	PARTIAL	HEAD INJURY	80	5.73	69.72
BEST	PARTIAL	SEPSIS	78	5.58	75.30
WORST	PARTIAL	CHEST INJURY	75	5.37	80.67
WORST	PARTIAL	TOXIC EXPOSURE (AMMONIA)	54	3.87	84.54
WORST	PARTIAL	APPENDICITIS	53	3.79	88.33

Limitations

- Baselined to the International Space Station (ISS) environment
 - Uses the ISS medical kit
 - Some vagaries in the input data generate “interesting” results
- ➔ However, all biases inherent in the model are consistent across all DRMs
- The IMM is especially useful for comparing across multiple similar DRMs
 - The model and it’s input data are under continuing evolution

Discussion

- CHI unaffected
 - CHI maintained by things that were not depleted
- pEVAC and pLOCL increase → but not as much as you might expect
 - pEVAC from 0.1333 (control) to 0.2000 (CE day 1)
 - pLOCL from 0.0095 (control) to 0.0139 (CE day 1)
 - Depletion of resources increases risks for subsequent similar event
 - More events are partially treated

Conclusions

- ***Common things are common...*** and low consequence
 - All other factors held constant, crew will perform at a high level no matter what
- Fewer resources are available to treat future CATASTROPHIC medical events
 - But... ***Rare things are rare***, thus multiple catastrophic medical events are unlikely
- Impact of heroic care on subsequent outcomes is less than might be imagined

PRA is a useful tool to ask “what if...?”!

Disclaimer

These results are subject to the biases inherent in the model and should only be used by subject matter experts as one point of information among many.

Thank you for your attention.

“All models are wrong. Some are useful.”

- George Box (1919 – 2013)

