

Probabilistic Assessment of Sex-Dependent Medical Risk During Spaceflight

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Disclosure Information

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Quantifying Risk

- Differences between males and females create different medical risks
- These differences may effect medical outcomes and mission success
- The Integrated Medical Model (IMM) was used to quantify these risks

Sex Differences Examples

System	Male	Female
Cardiovascular	Predisposition to cardiovascular events (e.g. stroke ⁶ , MI ¹²)	Higher rates of orthostatic intolerance post flight ³
Genitourinary	Prostatitis ^{2,17}	Urinary tract conditions ^{7,17}
Musculoskeletal	Higher rates of musculoskeletal injury on ISS ¹⁹	Osteoarthritis, joint issues ¹⁵
Behavioral	Higher responses with anger, noncooperation, and conflict in psychosocial isolation ⁷	Higher rates of depression and anxiety ³

Study Objective

- Assess medical risk differences between men and women in a space flight environment
- Assess impact of those differences on mission outcomes
- Determine effect of those risks on different mission types/lengths
- Identify ways to mitigate risks

What is the Integrated Medical Model?

- Probabilistic Risk Assessment (PRA) using Monte Carlo methodology
- Used to assess mission risk due to in-flight medical events
- Considers relevant preexisting medical conditions
- User defined Design Reference Missions (DRM) (e.g. crew, duration, EVA, etc.)
- Considers outcomes for 100 medical conditions that have or may occur in-flight

Incidence data from spaceflight medical events, and analog and general populations

20 of 100 conditions have sex-dependent outcomes

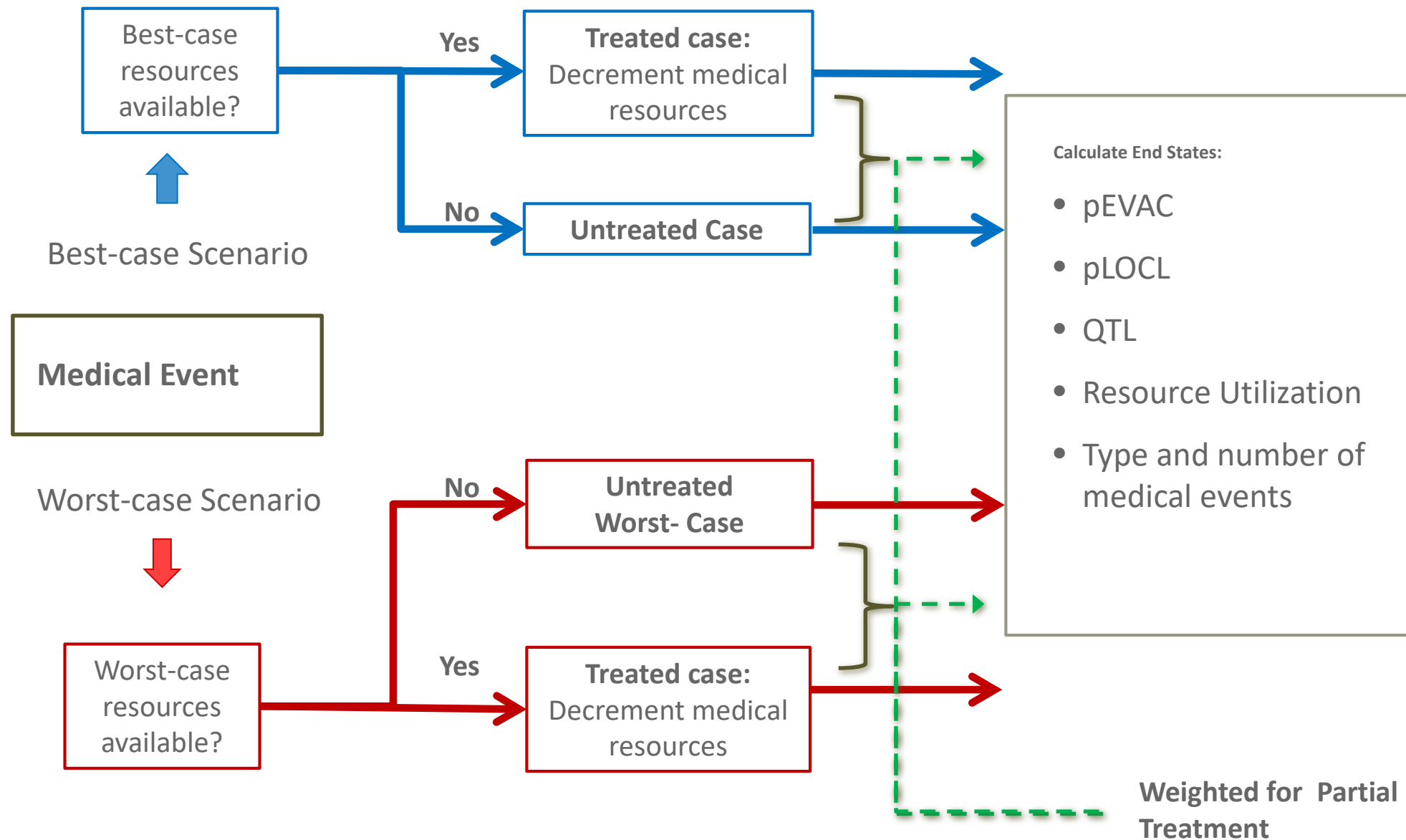
IMM Sex-Dependent Medical Conditions

Male Predominant	Female Predominant
Acute Prostatitis (male only)	Abnormal Uterine Bleeding (female only)
Acute Compartment Syndrome	Urinary Incontinence (female only)
Angina/MI	Vaginal Yeast Infection (female only)
Atrial Fibrillation/Flutter	Acute Arthritis
Cardiogenic Shock Secondary to MI	Acute Cholecystitis
Hip/Proximal Femur Fracture	Acute Glaucoma
Lumbar Spine Fracture	Anxiety
Retinal Detachment	Depression
Cerebral Vascular Accident	Lower Extremity Stress Fracture
	Urinary Retention
	<i>Urinary Tract Infection</i>

Model Outputs

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

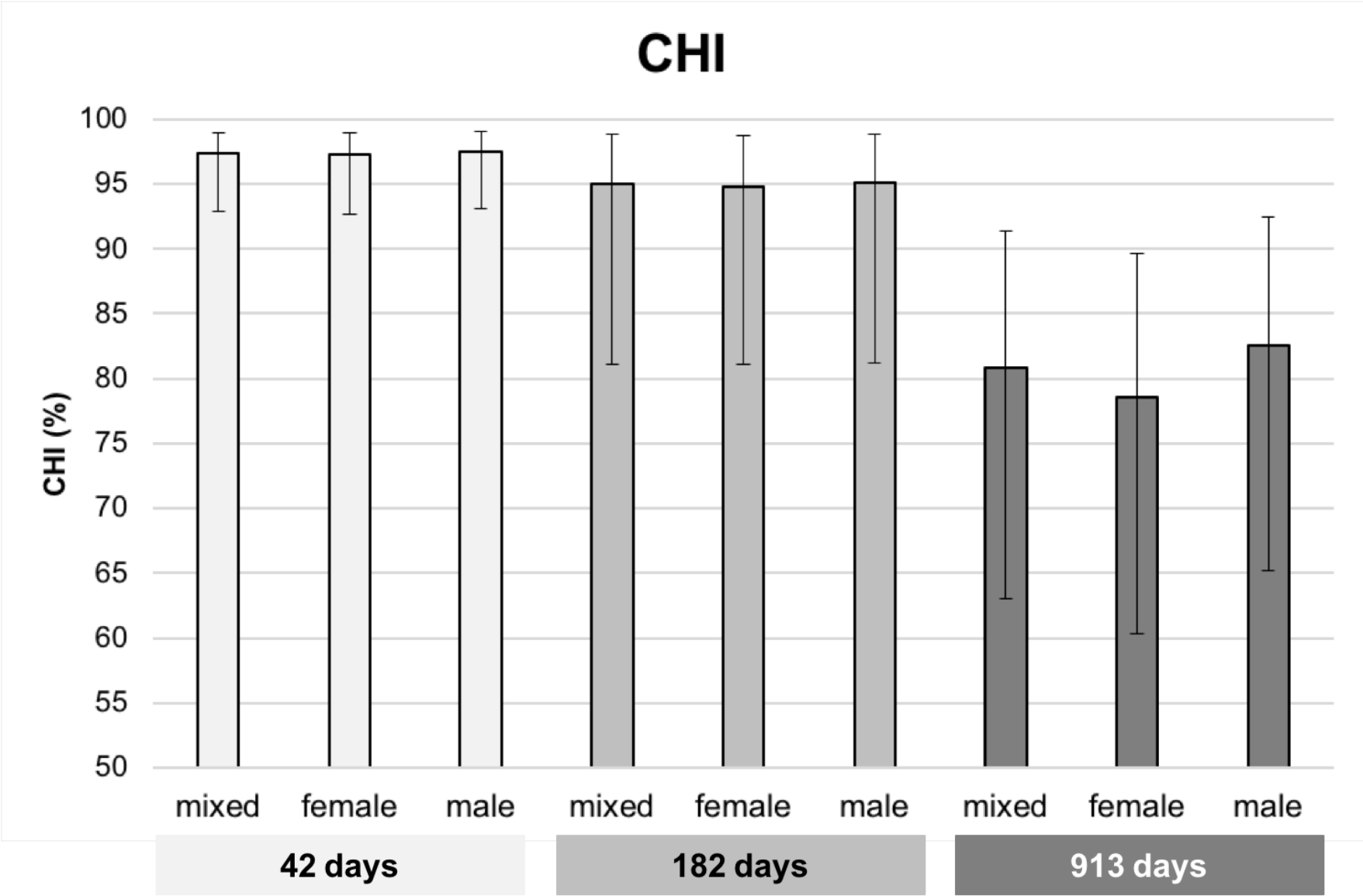
IMM Methodology



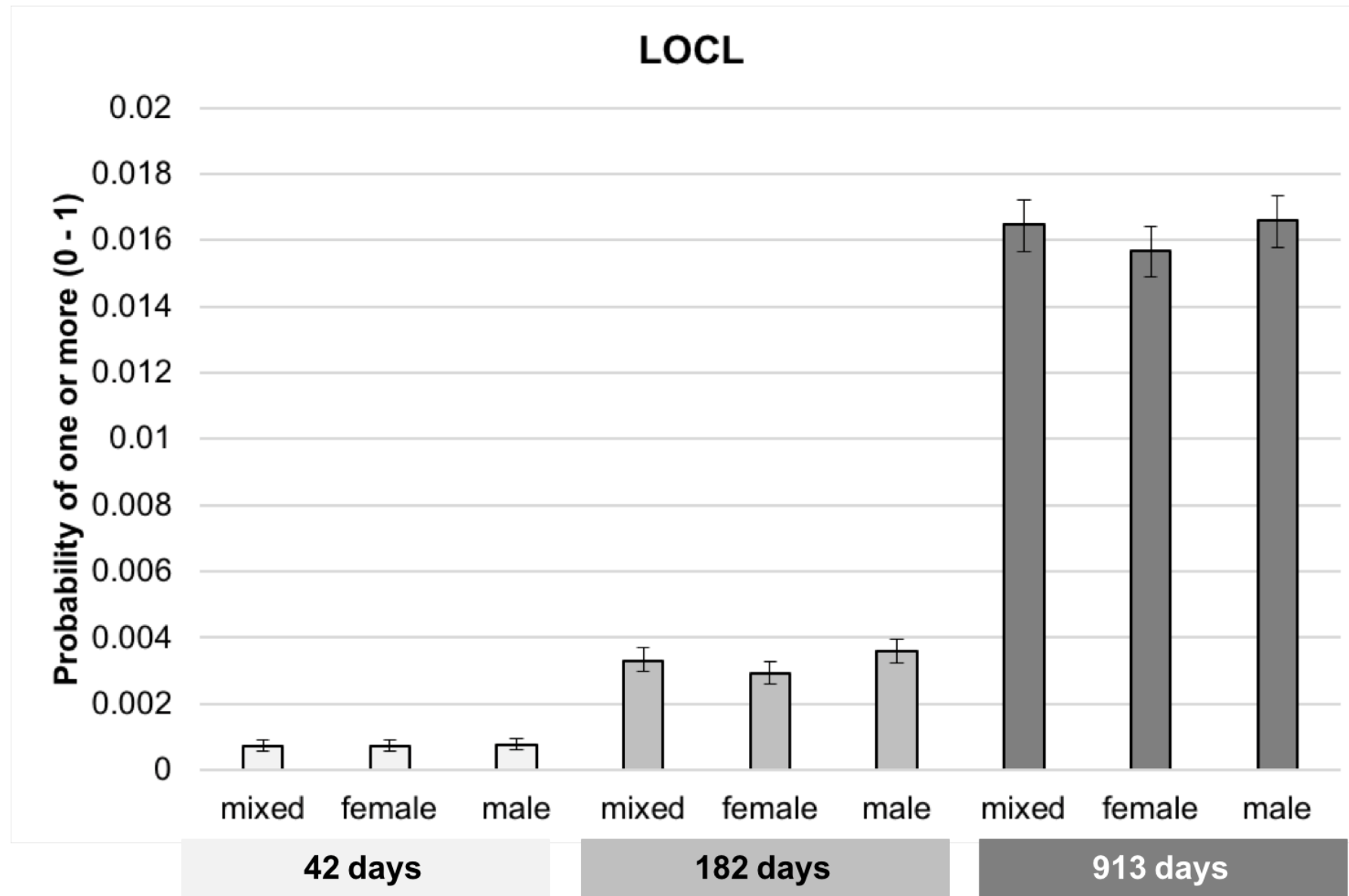
Study Design Reference Missions (DRM)

- 4 crew members in each DRM
- Three different crews → *mixed sex, all female, all male,*
- Three *different mission lengths*
 - Lunar sortie (42 days)
 - International Space Station (ISS) mission (182 days)
 - Mars mission (913 days)
- 9 total studies performed
- Inventory of medical supplies from the ISS med kit **with and without** the possibility of resupply

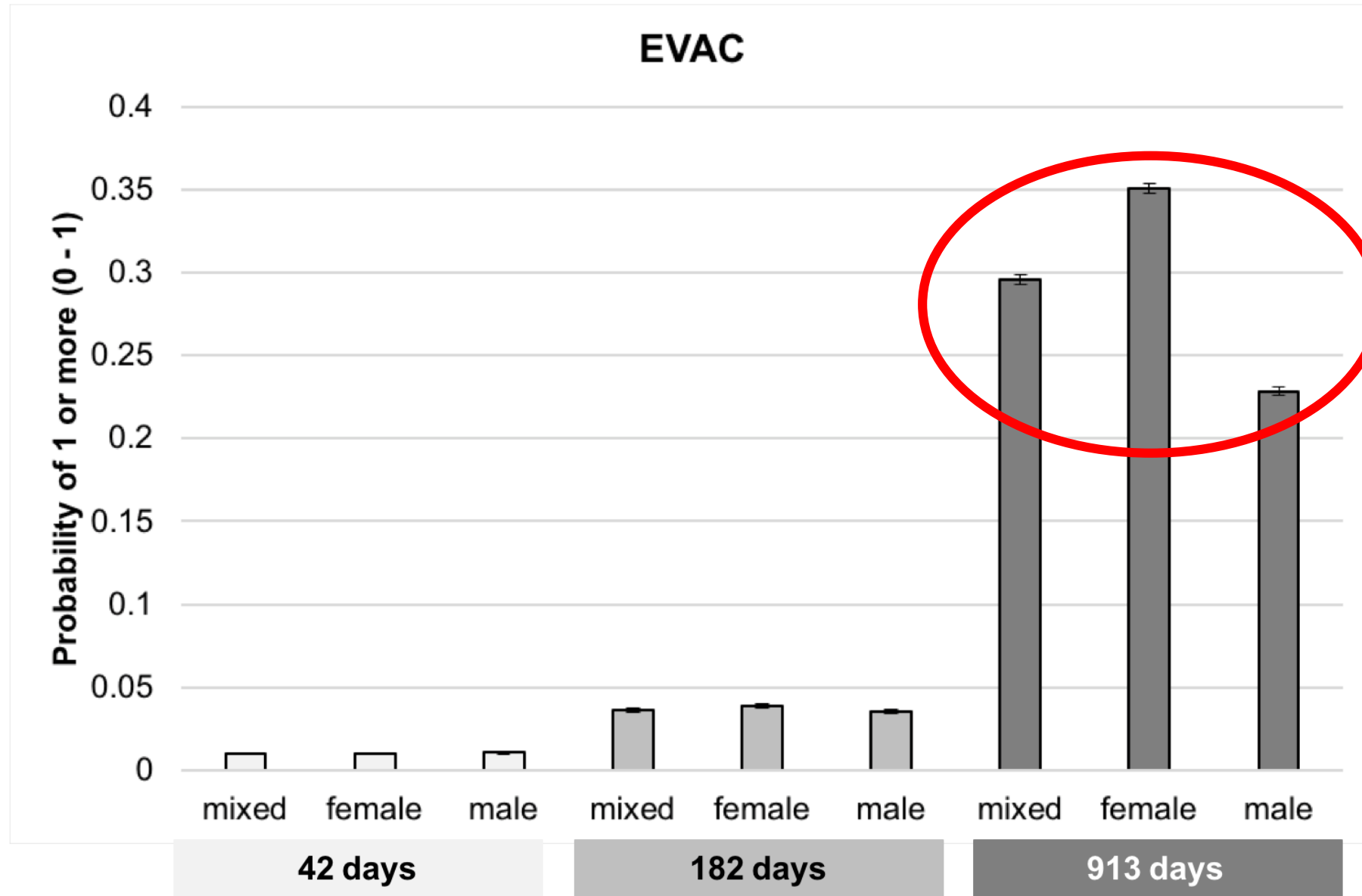
CHI - No resupply



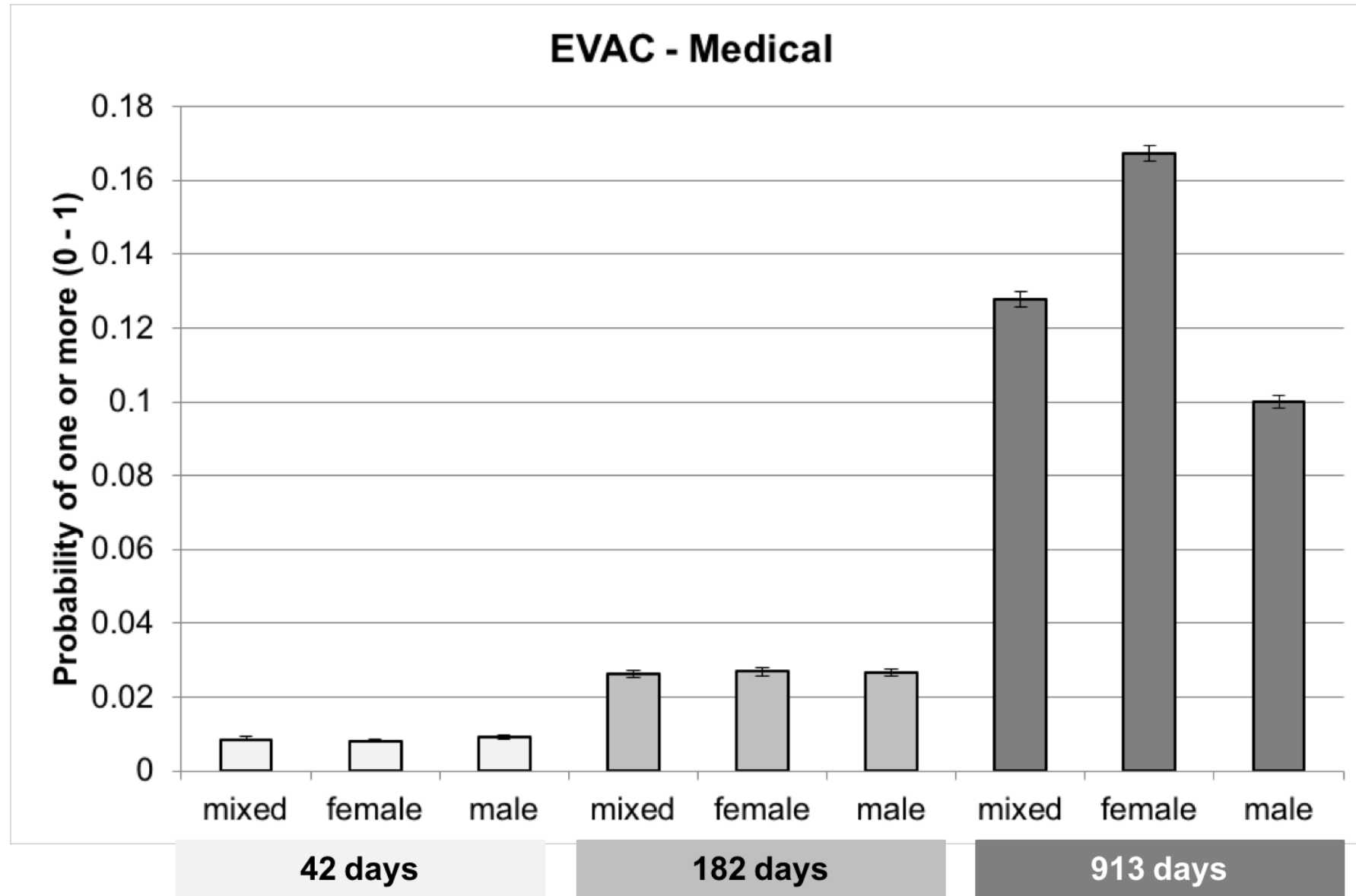
pLOCL - No resupply



pEVAC - No Resupply



pEVAC Medical - No Resupply



pEVAC (No Resupply): Female Influential Conditions

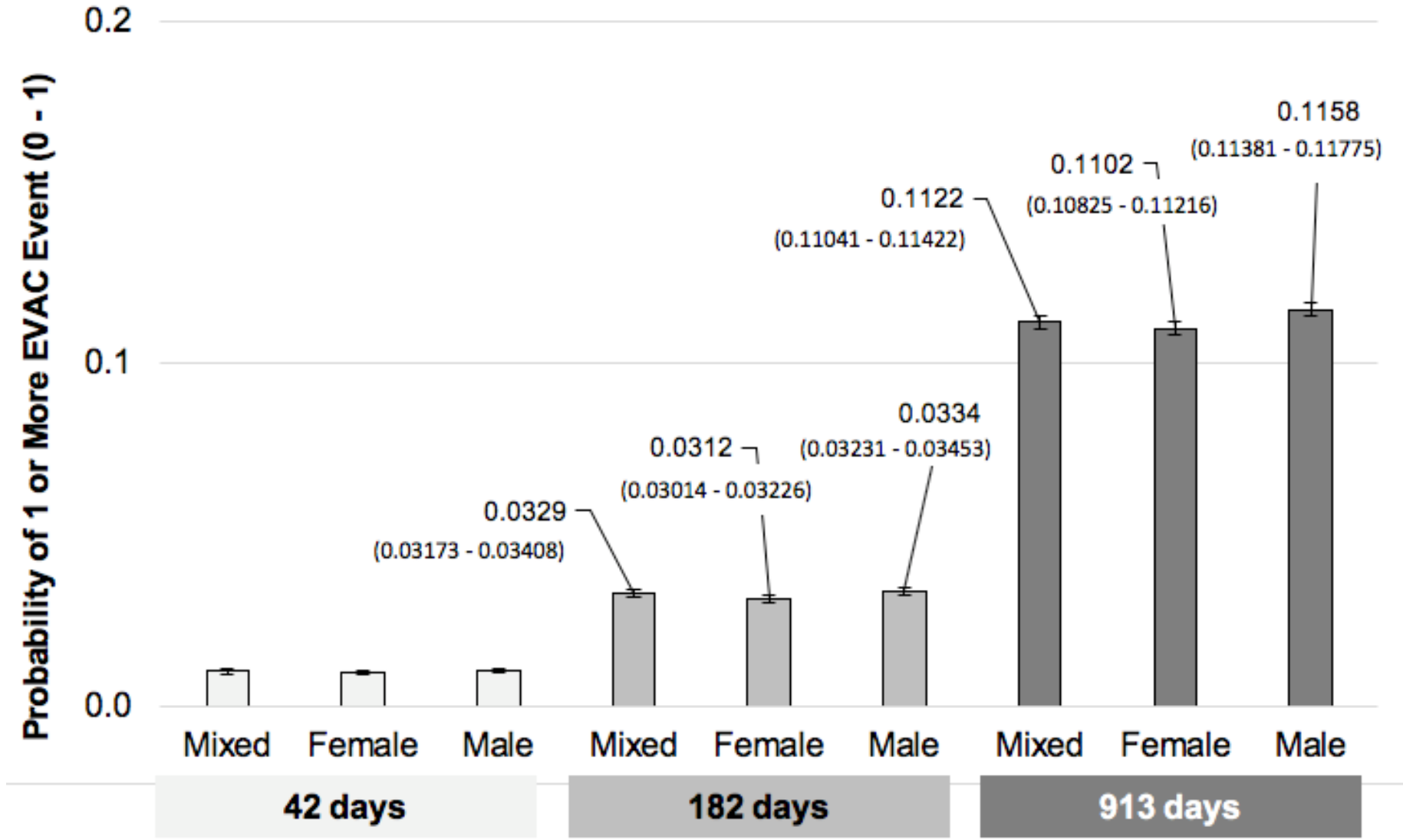
All Female						
Rank	Case	Treated	Condition	Events	Contribution (%)	Cumulative (%)
1	BEST	PARTIAL	EYE CHEMICAL BURN	11702	28.45	28.45
2	WORST	PARTIAL	URINARY TRACT INFECTION	7710	18.74	47.19
3	WORST	PARTIAL	BACK SPRAIN/STRAIN	2088	5.08	52.27
4	WORST	PARTIAL	EYE CHEMICAL BURN	1877	4.56	56.83
5	BEST	PARTIAL	FINGER DISLOCATION	1527	3.71	60.54
6	WORST	PARTIAL	NEPHROLITHIASIS	1124	2.73	63.28
7	WORST	TREATED	SANS	1026	2.49	65.77
8	WORST	TREATED	SMOKE INHALATION	668	1.62	67.39
9	WORST	PARTIAL	EYE INFECTION	617	1.50	68.89
10	WORST	PARTIAL	LE STRESS FRACTURE	534	1.30	70.19

pEVAC (No Resupply): Male Influential Conditions

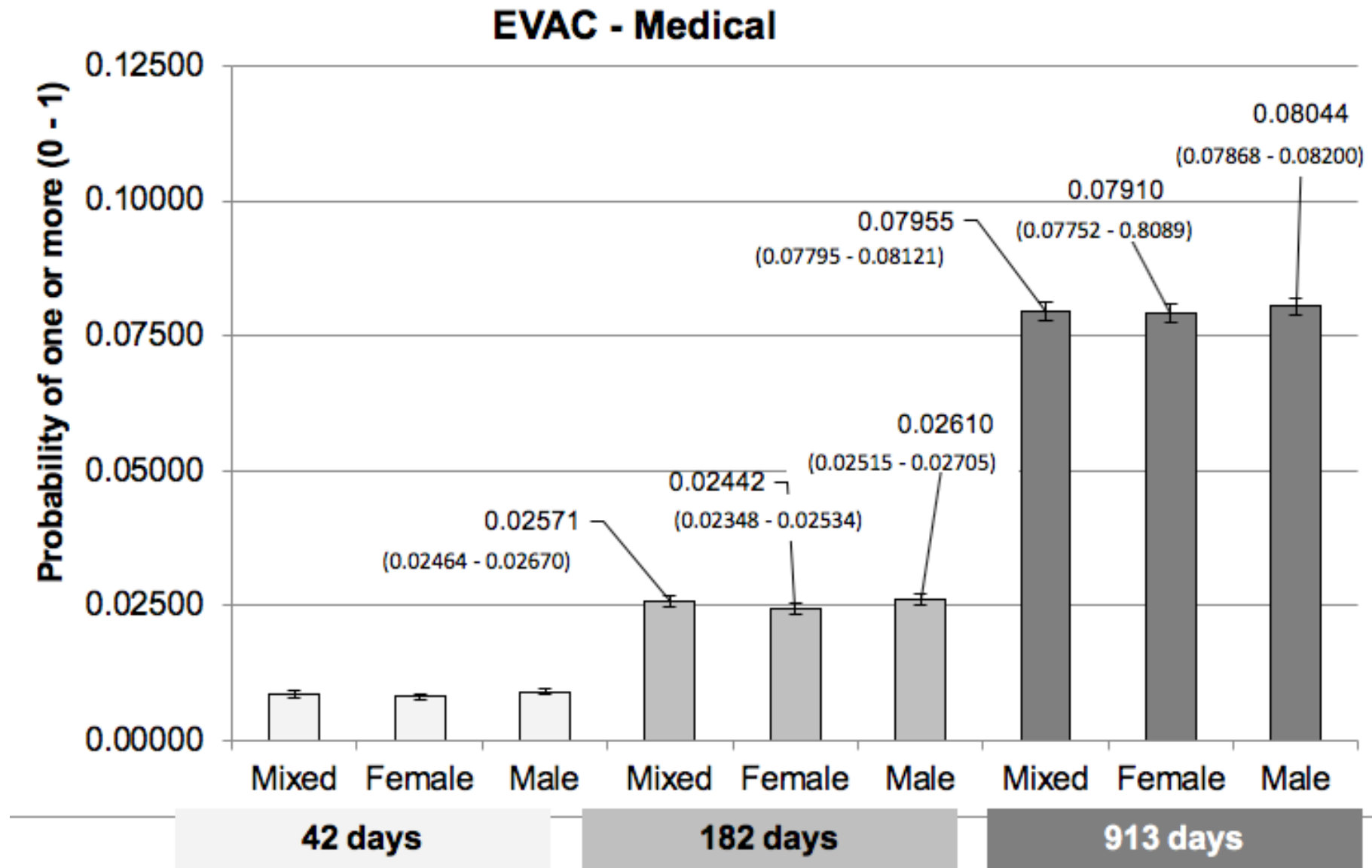
All Male						
Rank	Case	Treated	Condition	Events	Contribution (%)	Cumulative (%)
1	BEST	PARTIAL	EYE CHEMICAL BURN	4072	16.08	16.08
2	WORST	PARTIAL	BACK SPRAIN/STRAIN	2033	8.03	24.10
3	BEST	PARTIAL	FINGER DISLOCATION	1603	6.33	30.43
4	WORST	TREATED	SANS	1022	4.03	34.47
5	WORST	PARTIAL	EYE CHEMICAL BURN	925	3.65	38.12
6	WORST	PARTIAL	NEPHROLITHIASIS	811	3.20	41.32
7	WORST	TREATED	NEPHROLITHIASIS	689	2.72	44.04
8	WORST	TREATED	SMOKE INHALATION	674	2.66	46.70
9	WORST	PARTIAL	EYE INFECTION	659	2.60	49.30
10	WORST	PARTIAL	DENTAL ABSCESS	482	1.90	51.21

But...

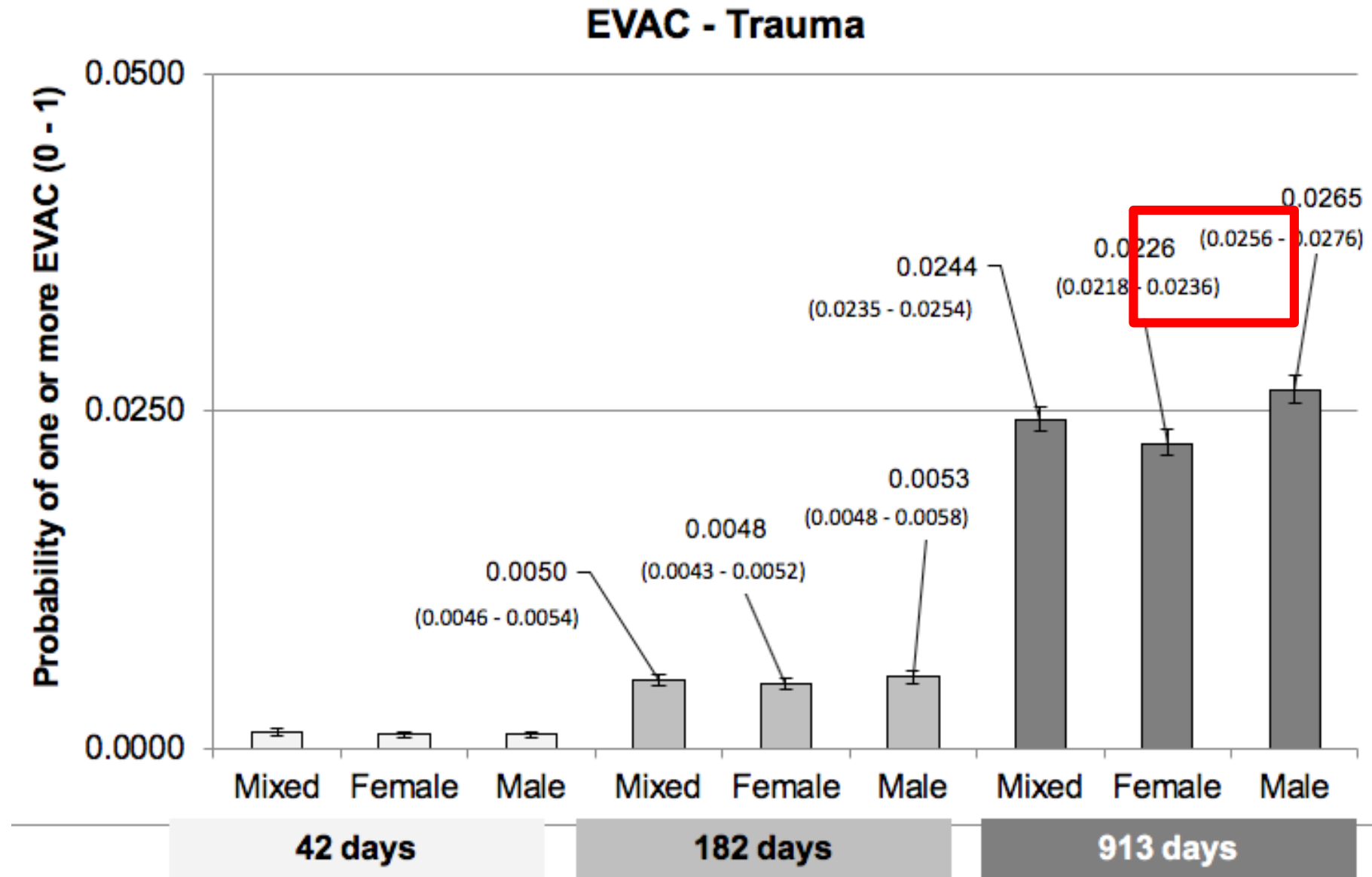
pEVAC - With Resupply



pEVAC Medical – With Resupply



pEVAC Trauma – With Resupply



pEVAC (With Resupply): Female Influential Conditions

All Female						
Rank	Scenario	Treated	Condition	Events	Contribution (%)	Cumulative (%)
1	WORST	TREATED	NEPHROLITHIASIS	1490	12.95	12.95
2	WORST	TREATED	SANS	1074	9.33	22.28
3	WORST	TREATED	DENTAL ABSCESS	924	8.03	30.31
4	WORST	TREATED	SEPSIS	770	6.69	37.00
5	WORST	TREATED	SMOKE INHALATION	726	6.31	43.31
6	BEST	TREATED	SMALL BOWEL OBSTRUCTION	519	4.51	47.82
7	WORST	TREATED	WRIST FRACTURE	441	3.83	51.66
8	WORST	TREATED	BACK SPRAIN/STRAIN	336	2.92	54.58
9	WORST	TREATED	URINARY TRACT INFECTION	305	2.65	57.23
10	WORST	TREATED	HEAD INJURY	249	2.16	59.39
11	BEST	TREATED	CEREBROVASCULAR ACCIDENT	245	2.13	61.52
12	WORST	TREATED	TRAUMATIC HYPOVOLEMIC SHOCK	236	2.05	63.57
13	BEST	TREATED	SEIZURES	236	2.05	65.62
14	WORST	TREATED	CEREBROVASCULAR ACCIDENT	221	1.92	67.54
15	BEST	TREATED	ANGINA /MYOCARDIAL INFARCTION	190	1.65	69.19



pEVAC (With Resupply): Male Influential Conditions

All Male						
Rank	Scenario	Treated	Condition	Events	Contribution (%)	Cumulative (%)
1	WORST	TREATED	NEPHROLITHIASIS	1507	12.45	12.45
2	WORST	TREATED	SANS	1058	8.74	21.18
3	WORST	TREATED	DENTAL ABSCESS	803	6.63	27.82
4	WORST	TREATED	SEPSIS	794	6.56	34.37
5	WORST	TREATED	SMOKE INHALATION	734	6.06	40.44
6	BEST	TREATED	SMALL BOWEL OBSTRUCTION	497	4.10	44.54
7	WORST	TREATED	WRIST FRACTURE	463	3.82	48.36
8	WORST	TREATED	HIP/PROXIMAL FEMUR FRACTURE	383	3.16	51.53
9	WORST	TREATED	CEREBROVASCULAR ACCIDENT	340	2.81	54.34
10	WORST	TREATED	BACK SPRAIN/STRAIN	326	2.69	57.03
11	BEST	TREATED	CEREBROVASCULAR ACCIDENT	323	2.67	59.70
12	BEST	TREATED	ANGINA/MYOCARDIAL INFARCTION	290	2.40	62.09
13	WORST	TREATED	TRAUMATIC HYPOVOLEMIC SHOCK	264	2.18	64.27
14	BEST	TREATED	ATRIAL FIBRILLATION/ FLUTTER	263	2.17	66.44
15	BEST	TREATED	SEIZURES	240	1.98	68.43

Discussion

- No differences in CHI or LOCL between sexes
- Partially-treated UTI drives higher female EVAC using the base ISS med kit
- Coronary and trauma risks for males are important for long missions
- Appropriate med kit design and prevention can mitigate sex-dependent risks
- Other conditions have sex-dependent risks which are not represented
- 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!

“All models are wrong. Some are useful.”

- George Box (1919 – 2013)

Back Up

Other Considerations: Landing/Postflight

- Orthostatic intolerance
- Landing impact trauma
- Neurosensory
 - Men: higher incidence of post-flight motion sickness
 - Women: higher incidence of post-flight vestibular instability symptoms

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 - Men: higher incidence of post-flight motion sickness
 - Women: higher incidence of post-flight vestibular instability symptoms

Other Considerations: Behavioral/Social

- Response to stress due to psychosocial isolation⁷
 - Women: more likely to be interpersonally supportive
 - Men: more often respond with anger, noncooperation and conflict
- Inconclusive studies in spaceflight and Antarctic groups as to ideal crew composition^{7,8,10,28}

Other Considerations: Malignancy

- Women have increased susceptibility to radiation induced cancer ⁹
- Antarctic winter-overs as analogue: multiple instances of cancer
- Large induction period for many cancers, but still possible for cancer to surface
 - Breast, lung, testicular carcinoma^{1,2}
- Evacuation unlikely

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