



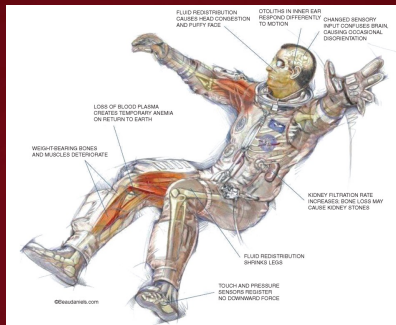
It's Just Rocket Surgery: Surgical Care and the Future of Human Space Flight



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INTRODUCTION:

The aeromedical community's understanding of the biomedical implications of spaceflight exposure has expanded tremendously in recent years.



Health effects of exposure to microgravity. *British Journal of Anaesthesia* 2017 119, i143-i153.

Nearly every physiologic system is impacted, and many effects have terrestrial parallels that are magnified in austere, resource-limited settings. Despite the significant need, there is a paucity of surgical research and understanding in this area.

The Space Surgery Association (SSA) is an international interdisciplinary organization with >250 members and an extensive collective expertise in Surgery, Anesthesiology, and Critical Care. The SSA seeks to advance current procedural capabilities inflight, in anticipation of upcoming exploration-class missions.

METHODS:

- In-depth PubMed literature review
- Over one hundred papers (1996-2022) pertaining to medical and surgical care in remote and resource-limited environments including space
- Identified the elements most critical for ensuring crew health and safety from a surgical perspective

1. Abdominal Injury	27. Chest Injury	54. Hearing Loss	81. Shoulder Dislocation
2. Abdominal Wall Hernia *	28. Choking/Obstructed Airway	55. Hemorrhoids *	82. Shoulder Sprain/Strain
3. Abnormal Uterine Bleeding *	29. Constipation (SA)	56. Herpes Zoster	83. Skin Abrasion
4. Acute Arthritis	30. Decompression Sickness	57. Hip Sprain/Strain	84. Skin Infection *
5. Acute Cholecystitis/ Biliary Colic	Secondary to EVA	58. Hip/Proximal Femur Fracture *	85. Skin Laceration *
6. Acute Compartment Syndrome *	31. Dental : Exposed Pulp *	59. Hypertension	86. Skin Rash
7. Acute Diverticulitis *	32. Dental : Caries	60. Indigestion	87. Small Bowel Obstruction *
8. Acute Glaucoma	33. Dental: Abscess *	61. Influenza	88. Smoke Inhalation
9. Acute Pancreatitis *	34. Dental: Avulsion (Tooth Loss)	62. Insomnia (SA)	89. Space Motion Sickness (SA)
10. Acute Prostatitis	35. Dental: Crown Loss *	63. Knee Sprain/Strain	90. Stroke (CVA)
11. Acute Radiation Syndrome	36. Dental: Filling Loss *	64. Late Insomnia	91. Sudden Cardiac Arrest
12. Acute Sinusitis	37. Dental: Toothache	65. Lower Extremity Stress Fracture	92. Toxic Exposure: Ammonia
13. Allergic Reaction (mild to moderate)	38. Depression	66. Lumbar Spine Fracture	93. Traumatic Hypovolemic Shock *
14. Altitude Sickness	39. Diarrhea	67. Medication Overdose / Reaction	94. Urinary Incontinence (SA)
15. Anginal/ Myocardial Infarction	40. Elbow Dislocation	68. Mouth Ulcer	95. Urinary Retention (SA)
16. Anaphylaxis	41. Elbow Sprain/Strain	69. Nasal Congestion (SA)	96. Urinary Tract Infection
17. Ankle Sprain/Strain	42. Eye Abrasion (foreign body)	70. Nephrolithiasis	97. Vaginal Yeast Infection
18. Anxiety	43. Eye Chemical Burn	71. Neurogenic Shock	98. VVIP - Visual Impairment/ Increased Intracranial Pressure
19. Appendicitis *	44. Eye Corneal Ulcer	72. Nose bleed (SA)	99. Wrist Fracture *
20. Atrial Fibrillation/ Flutter	45. Eye Infection	73. Nose bleed (SA)	100. Wrist Sprain/Strain
21. Back Injury	46. Eye Penetration (foreign body)	74. Otitis Externa	
22. Back Pain (SA)	47. Finger Dislocation	74. Otitis Media	
23. Barotrauma (sinus block)	48. Fingernail Delamination (EVA) *	75. Parosmia	
24. Behavioral Emergency	49. Gastroenteritis	76. Pharyngitis	
25. Burns secondary to Fire *	50. Head Injury	77. Respiratory Infection	
26. Cardiogenic Shock due to infarction	51. Headache (CO2 Induced)	78. Retinal Detachment	
	52. Headache (Late)	79. Seizures	
	53. Headache (SA)	80. Sepsis	

NASA's Integrated Medical Model outlines the 100 conditions most likely to develop inflight. At least 26/100 may need surgical/procedural intervention.

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RESULTS:

Prolonged spaceflight exposure has profound systemic physiologic effects, including, but not limited to:

- Pronounced cephalad fluid shifts
- Changes in central venous pressure, with stagnation and clot development in the jugular venous system
- Vision changes, with hyperopic shifts up to +1.75 diopters
- Immune system dysregulation, with greater propensity for bacterial infection and latent viral reactivation
- Rapid, clinically significant reductions in muscle volume and fiber area with unloading in weightlessness
- Increased incidence of nephrolithiasis and urinary retention

The surgical implications of these findings are poorly understood. Further dedicated study is necessary in order to define optimal preventative and therapeutic protocols that honor the extreme resource constraints of deep space while still ensuring that appropriate care is provided.

CONCLUSION:

The broader aeromedical community must design an innovative, collaborative plan for optimizing crew health and performance, with consideration given to the Surgical and Critical Care domains.

