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MEDICINE IN SPACE: HOW TO PERFORM SURGERY IN ZERO GRAVITY?

CREDITS

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How would surgeons save a life to a mission to Mars? The challenges of surgery beyond Earth.

INTRODUCTION

Space exploration has been pushing medicine beyond where ordinary healthcare may not be possible. On Earth, surgery requires stable gravity, specialized equipment and teams, and urgent access to emergency services, however, in space, these conditions are not applicable.

Microgravity explains how blood, movement, and medical procedures work, enhancing difficulties in surgery in confined aircrafts. As long-duration missions become more common, space medicine explores how life-saving surgery could be performed beyond Earth.

OBJECTIVE

The aim of this poster is to identify the challenges of microgravity and potential future solutions to surgery.

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CHALLENGE - SURGERY IN MICROGRAVITY



Microgravity is defined as the condition of objects appearing weightless, and these effects are witnessed in space^[1]. Performing surgery in space comes with challenges...

- floating blood & fluids - blood forms floating droplets that can contaminate equipment and increase infection risks; physiologic changes also occur complications include fluid redistribution & diuresis, bone demineralization, and immune system alterations^[2]
- patient & surgeon movement - without gravity, the patient and surgeon will float; even applying pressure with surgical instrument could push them away
- limited equipment & delayed support - spacecrafts have limits on weight, storage, power supply, and sterile equipment, so astronauts cannot access extra tools when complications occur; a space mission experiences around 20-minute delays, so surgeons on Earth cannot assist with emergency surgeries on space
- radiation exposure - space radiation causes DNA damage, increased risk of cancer, and reduced motility^[3]

HOW COULD SURGERY WORK IN SPACE?

- Robotic Telesurgery is where the surgeon guides a robot arm to perform an operation, making it a teleoperated system. The aim is to improve overall quality in surgery e.g. motion scaling, adaptive tremor filtering, automated following of organ movement, and automated suturing^[4]. All these precise movements will greatly reduce the risk of accidents.
- Sealed surgical chambers would help prevent the floating fluids when performing surgery. The suction systems implemented in these enclosures help to contain the fluids. It also aids in maintaining a sterile environment and preventing cross contamination^[5]. Even though negative pressure chambers are included in these chambers, it is important to include restraint systems to avoid the patient floating away from the surgeon. These could include straps & harnesses, magnetic boots, and adjustable operating tables. Future missions could also enforce 3D printing in space as these will be long-duration missions in alienated environments^[6]. This will prove useful for 3D printed surgical tools, replacement equipment, and custom medical devices.
- AI-assisted medicine can help reduce communication delays. AI can monitor vital signs, suggest diagnoses, and guide procedures. Future spacecraft may carry AI systems capable of supporting medical decisions when contact with Earth is delayed. Otherwise, for missions closer to Earth, telemedicine can be utilized, where specialists on Earth assist astronauts remotely or live imaging is transmitted in order for experts to guide them through procedures.

CONCLUSION

Although performing surgery in zero gravity presents challenges e.g. floating bodily fluids, communication delays, radiation exposure, technological advances e.g. robotic telesurgery and AI may support astronauts to safely undergo surgical procedures in future space missions. The future of surgery may not be in hospitals alone – one day, it may extend far beyond Earth. As space exploration continues to expand, innovations developed for space medicine could improve healthcare on Earth.

EARTH V.S. SPACE SURGERY

Surgery on Earth relies on gravity, specialist equipment, and immediate medical support. In space, problems, such as, microgravity and limited resources require new approaches to patient care and surgical treatment.

BEFORE SURGERY...	
EARTH	SPACE
a full medical assessment is undertaken	there are limited diagnostic tools available
scanning equipment e.g. CT, MRI available	there is only portable ultrasound
time for a specialist consultation	delayed communication with Earth

DURING SURGERY...	
EARTH	SPACE
gravity keeps surgeon stable & blood drains naturally	surgeon must be restrained & blood floats in droplets
a full operating team is available	small crew with limited expertise
a sterile theater with abundant of medical supplies	confined spacecraft environment with limited supplies

AFTER SURGERY...	
EARTH	SPACE
access to rehabilitation services	limited rehabilitation options
variety of medications available	restricted medical supplies
emergency treatment can be performed if necessary	evacuation is not possible in case of emergency

RISKS UNIQUE TO SPACE...

Space flight can cause various physiological changes to the human body. Understanding these effects are essential as space missions become more common.

- fluid redistribution (reduced fluid volume in extremities due to lack of gravity^[7])
- loss of bone density (approximately 1-2% per month^[7])
- muscle atrophy (20-30% depending on mission duration^[7])
- space motion sickness caused by neurovestibular effects^[7]
- immune dysregulation (results in reactivation of dormant viruses^[7])
- psychosocial effects - fatigue, isolation, sleep debt^[7]

FUTURE POSSIBILITIES...

Countermeasures must be implemented to aid an astronaut's journey in all stages of their spaceflight. With the rise of technology, spacecrafts may integrate various improvement in space medicine. Remedies, such as, exercise targeted to each space risk, have been executed to minimize these physiologic changes.

Future space operating rooms in spacecrafts may include...

- autonomous surgical robots
- AI powered medical assistances
- 3D printed medical equipment
- virtual reality surgical training

These comparisons reinforce the difficulty and complexity of space surgery than on Earth due to diverse restrictions. Although space surgery presents various medical challenges, such as, physiological changes, innovations, such as, robotic surgery and artificial intelligence allow future astronauts to overcome these challenges and support long-duration space missions.