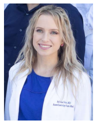
LIMITATIONS AND FEASIBILITY OF MINIATURE X-RAY DEVICES IN SPACE ENVIRONMENTS



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FEASIBILITY OF MINIATURE X-RAY DEVICES IN SPACE ENVIRONMENTS

As space exploration advances toward long-duration missions, reliable medical diagnostic tools become increasingly critical.

CHALLENGES IN OPERATIONALIZATION

One of the primary challenges with miniature XR devices is the ability to achieve specific anatomical views, particularly in the confined and weightless conditions of a spacecraft. Operators may struggle to acquire diagnostic-quality images when space is limited for proper patient positioning and for the volume of the imaging device. Since ambient radiation and detector limitations may further degrade image quality, flexibility of the operating procedures of these devices will be critical for their success in space applications. Training in the skills necessary to acquire diagnostic-quality scans may be a barrier for non-clinician crewmembers. The curriculum developed for crew medical officers (CMOs) will require simplification and adaptation to fit into the highly truncated pre-flight training period. Therefore, hands-on familiarization and simulation, both pre-flight and just-in-time training during missions, will be crucial to ensuring the crew can operate the devices in real-life situations. The ability to adjust acquisition parameters must be simplified or made automatic through exam selections on equipment user interfaces, and subject and operator positioning should be assisted with laser guidance and pictorial guides.

Mini X-ray devices can provide unique diagnostic/treatment capabilities if included as a resource for spaceflight

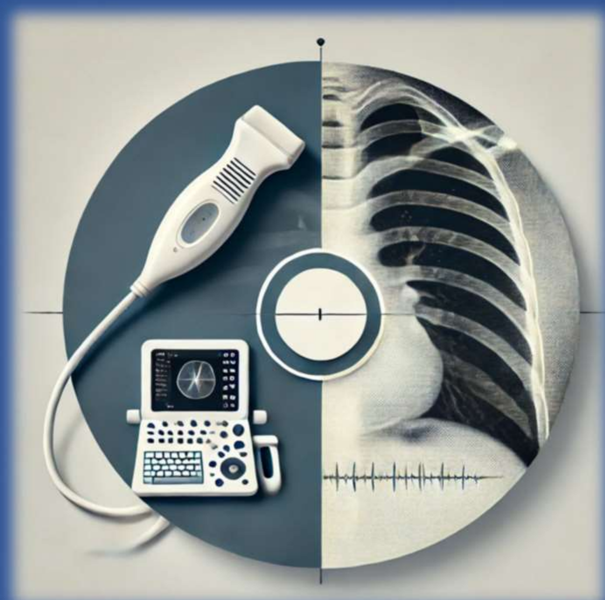

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Image: OpenAI, 2024, "Venn Diagram of Ultrasound and XR"

POTENTIAL FOR CDSS OR AI-ASSISTED CDSS

Clinical decision support systems (CDSS) and AI-assisted CDSS could provide real-time feedback on image quality and interpretation, helping to mitigate the risks of human error during space missions. Integrating procedural guidance tools, such as augmented reality, will support crewmembers in accurately positioning patients and obtaining high-quality images. However, the success of such systems will depend on the development of robust training datasets, integration with spaceflight-rated hardware, and the medical system.

FEASIBILITY OF GROUND INTERPRETATION AND DATA TRANSMISSION

Reliance on ground-based interpretation may prove difficult for acute care during exploration class-missions due to delays in transmission with increasing distance from Earth or complete communication blackout periods. In such instances where immediate interpretation for clinical intervention is required, crew must be able to interpret the images independently or utilize AI-based assistance to do so. File sizes for XR exams can be large if numerous images are acquired and bandwidth constraints may limit data transmissions for both radiological and ultrasound exams.

FUTURE WORK

The possibility of combining miniature XR with other imaging modalities, such as ultrasound devices, is also under investigation. While miniature XR technology holds potential for extraterrestrial medical systems, there are significant challenges to overcome. Training, integration of AI tools, dedicated exam protocols for microgravity, and improved data transmission systems will be key to realizing the full benefits of miniature XR technology in space.