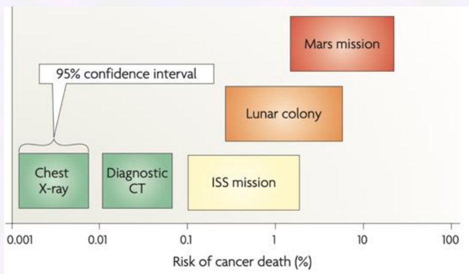
Exploring the Impact of Space Radiation on the Kidney: Houston, We May Have a Carcinogenesis Problem.

Harry Hughes – University College London Medical School

UCL

Introduction

Astronauts aboard the ISS are exposed to a level of radiation in a single day equivalent to a year on Earth. With the planned Lunar colony and the journey to Mars, outside of the Earth's magnetic field protection, there is a serious, growing risk of astronauts developing cancer years after the mission.

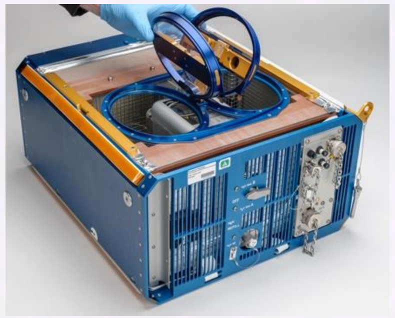


The kidney is highly sensitive to radiation and is often the primary organ at risk in clinical radiotherapy, yet it has been consistently overlooked in NASA's research into the risk of radiation carcinogenesis.

We hypothesised that exposure to space radiation may be associated with increased expression of biomarkers implicated in renal carcinogenesis.

Methodology

We used murine kidney tissue, and samples came from a spaceflight mission aboard the ISS (RR-10, 28 days) and from ground-based GCR simulations, which were both compared with ground control samples.



NASA's Rodent Habitat Module, which provided long-term housing for the mice during the RR-10 spaceflight mission.

We performed multi-omic analysis to determine if cancer pathways were overexpressed by analysing DISGENET and KEGG terms. We also searched this data to find a new biomarker for Galactic Cosmic Radiation (GCR) induced kidney carcinogenesis, which led us to RPS15A.

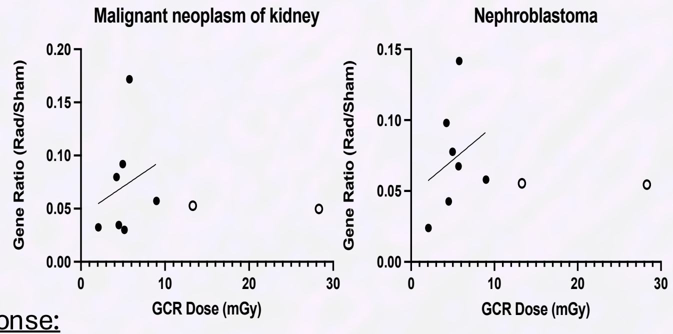
Then we performed immunohistochemistry on the tissue to visualize DNA damage marker expression and confirm the presence of the RPS15A biomarker *(RPS15A Tubular Staining Image Used as the Background)*

Results

Cancer pathways are activated and dose-response relationship:

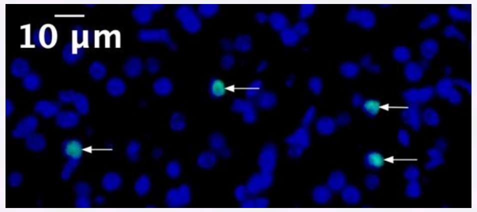
Multi-omic analysis showed that renal cancer pathways were significantly enriched, appearing in the top 3% of the 2000 disease pathways analysed.

For certain cancer pathways, a positive dose-response trend was observed across missions (higher dose = more cancer pathway activation). This suggests that greater GCR exposure may correlate with more cancer related molecular change.

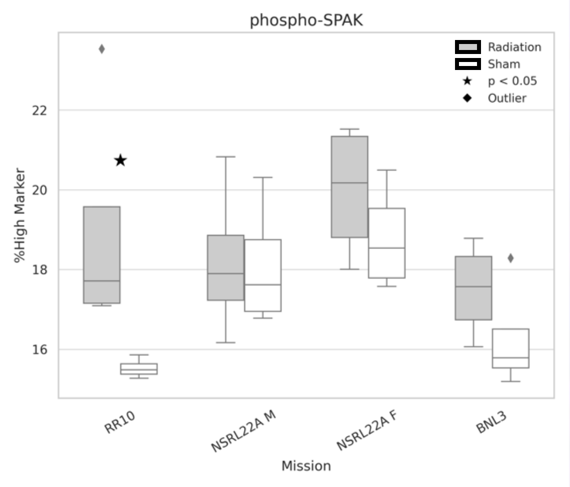


Tissue damage markers reveal focal response:

Imaging revealed focal DNA damage hotspots on the kidney, visible as distinct clusters of the DNA damage marker γH2AX. GCR is made up of high energy, large particles that deal a lot of damage to the specific area they hit, which this damage pattern aligns with.

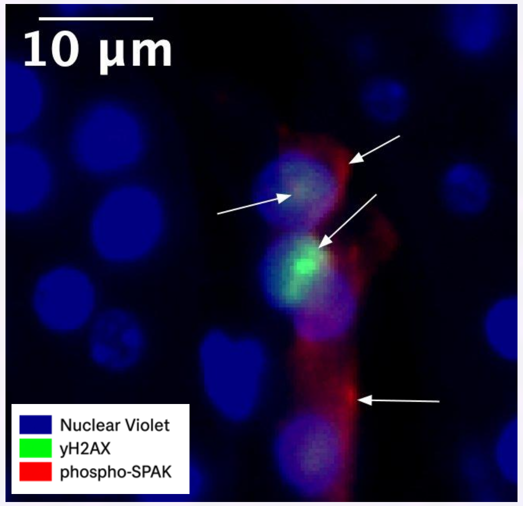


White arrows indicate marker signal.



Quantitative analysis showed a significant increase in phospho-SPAK (a DNA damage-linked kinase) in the RR-10 mission (the actual spaceflight mission), confirming a direct effect of the space environment. (%High refers to the percentage of cells exceeding a set damage threshold.)

The markers also revealed a co-localisation event between γH2AX and phospho-SPAK, indicating that DNA damage is triggering this repair response in the same renal cell structures.



White arrows indicate marker signal.

Conclusions

Molecular evidence indicates the kidney is vulnerable to GCR-induced cancer risk.

This study provides early evidence that space radiation may drive molecular changes linked to kidney cancer risk.

The kidney should be present in NASA's organ specific risk frameworks, especially for long-duration missions, due to the dose-response relationship observed. This is especially relevant as if a kidney cancer developed and it impaired renal function, this would be mission critical.

Identified markers, RPS15A and phospho-SPAK, may provide the first actionable tools for developing a kidney-specific molecular surveillance strategy, and may hold translational relevance for public cancer screening programs.

Limitations

Our radiation exposures were limited to Low Earth Orbit; more data from deep-space analogues is required to assess true Mars-mission risk.

Also, the small sample sizes (n=4) resulted in underpowered comparisons across all groups.

Acknowledgements

I would like to thank my supervisor, Keith Siew for his invaluable support and guidance throughout this project.

References:

Durante, M. and Cucinotta, F.A. (2008), "Heavy ion carcinogenesis and human space exploration", Nature Reviews Cancer, Vol. 8 No. 6, pp. 465–472, doi: 10.1038/nrc2391.
Siew, K., Nestler, K.A., Nelson, C., D'Ambrosio, V., Zhong, C., Li, Z., Grillo, A., et al. (2024), "Cosmic kidney disease: an integrated pan-omic, physiological and morphological study into spaceflight-induced renal dysfunction", Nature Communications, Nature Research, Vol. 15 No. 1, doi: 10.1038/s41467-024-49212-1.
Turker, M.S., Grygoryev, D., Lasarev, M., Ohlrich, A., Rwatambuga, F.A., Johnson, S., Dan, C., et al. (2017), "Simulated space radiation-induced mutants in the mouse kidney display widespread genomic change", PLoS ONE, Public Library of Science, Vol. 12 No. 7, doi: 10.1371/journal.pone.0180412.
National Aeronautics and Space Administration. (n.d.). Risk of Radiation Carcinogenesis. Human Health and Performance. Retrieved October 12, 2025, from https://www.nasa.gov/directorates/esdmd/hhp/risk-of-radiation-carcinogenesis/
European Space Agency. (2019, May 31). The radiation showstopper for Mars exploration. https://www.esa.int/Science_Exploration/Human_and_Robotic_Exploration/The_radiation_showstopper_for_Mars_exploration