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Editorial

The Final Frontier

Dr John Purvis

When I was young, I very much enjoyed reading and watching science fiction – every week, it seemed quite straightforward to dial in warp factor 9 and reach another star in a matter of minutes. The technology varied from programme to programme – jumpgates, stardrives and of course, in the UK, Doctor Who could travel through both space and time, perhaps a little unreliably but always with great charm. Maybe when I grew up, I might also travel to the stars.

The Apollo programme certainly gave some encouragement as grainy images were beamed from the surface of the Moon. Many were optimistic. After all, wasn't it just 66 years from the flight of the *Kitty Hawk* to the landing of the lunar module *Eagle* in 1969? Where would we be after 100 years or 150 years?

There were some problems however, lunar dust is jagged and sharp to a level not seen on Earth where wind and wave smooth away the edges. Static electricity also causes the dust to adhere to everything and it wasn't long before the lunar astronauts reported respiratory issues and the joints in their spacesuits began to seize as the dust seeped in.

On the way to the Moon, the astronauts also reported occasional bright flashes of light even when their eyes were shut. We now know this was due to cosmic rays – high energy ionized atomic nuclei flung off at near light speed by neutron stars, galactic cores and supernovae explosions as well as our Sun- most of these are hydrogen nuclei – protons - but some are much heavier atoms and have considerable potential for cellular damage as they power through our insubstantial bodies on their cosmic journey. We often think of space radiation exposure in terms of medical X-rays but its more like standing inside the particle accelerator at CERN.

Its now 2020 and NASA has discounted a 3-year journey to Mars in favour of developing a programme for sustainable missions to the Moon. I think this is a wise choice – we really know very little about how the human body can survive out there.

A Mars mission would entail potentially lethal exposure to solar particle and radiation storms – the Apollo crews were fortunate that their missions took place during a quiet phase of the Sun's 11-year activity cycle – the odds for a long Mars return trip are not so good. The spaceship's ability to recycle water and oxygen, scrub CO2 and deal with human waste would need to be superb – not many spare parts out there! Humans also expire significant quantities of ammonia and methane which can become toxic in an enclosed environment over time unless chemically scrubbed.

We don't have the capacity to build centripetal sections or a gym into any potential Mars vessel which means that the astronauts would have to physically adapt from years of zero-G to a full Martian 1/3 G on landing – they might have to spend days in their craft acclimatising before they could walk on the Martian surface.

The plan for the Moon is to build a smaller version of the International Space Station (ISS) called the Gateway in an orbit that covers the entire surface of the Moon. From the Gateway, reusable landers can be dropped down anywhere on the lunar surface. Its hoped that robotic missions could land some habitation and infrastructure modules to gradually build up a Moonbase in the same way that the ISS was assembled. If things go wrong or there is a medical emergency, evacuation from the Moon should be possible in 2 or 3 days whereas once set in orbit, a Mars mission would be committed to the entire flight – no coming back for a kidney stone.

An opportunity arose in 2015 for NASA to investigate some of the medical aspects of a long-term mission when 50-year old veteran astronaut, Scott Kelly undertook a year-long stay (340 days) on the ISS. His identical twin brother, Mark who had a similar career stayed on Earth and served as the control.[1]

It was fully appreciated that this is a study with 1 subject in each arm but of the 533 people who have flown in space – few have had available identical twins!

It should be stressed that the ISS orbits within the Earth's magnetic field which is an effective shield against radiation and high energy particles. Nevertheless, Scott accumulated an effective dose of 146.34 mSv equivalent to 54 years of background exposure in the UK or 22 CT scans of the chest.[2]

The twins submitted themselves to extensive blood, saliva, excretory, opthalmological and cognitive tests. NASA divided the results by potential risks to the astronauts.

LOW RISK

Immune function as measured T-cell response by a flu vaccination was well preserved during spaceflight. Chromosome telomeres lengthened in flight which is suggestive of decreased risk of aging, chronic disease and cancer but the authors speculated this might reflect the intense exercise regimen and healthy diet provided on station – Scott's brother on Earth didn't follow the same regimen. Changes in gut microbiota were relatively minor.

MEDIUM RISK

There was increased urinary excretion of collagen components in flight suggesting loss of connective and support tissue in microgravity.

Microgravity is associated with hypernatraemia, risk of dehydration and kidney stone formation – Aquaporin 2 (AQP2) is a protein that regulates water reabsorption in the kidneys –urinary levels were elevated in flight and may prove a useful marker in the future for identification of astronauts at risk.

Although chromosome telomeres lengthened in flight, they tended to *persistently shorten* on return to Earth suggesting increased risk of aging, chronic disease and cancer.

HIGH RISK

About 40% of astronauts have reported problems with their vision during or after flight – this is of significant concern to NASA. Intravascular fluid shifts cranially in microgravity leading to optic disc oedema, globe flattening, choroidal folding and retinal cotton wool spots. NASA calls this Spaceflight Associated Neuro-ocular syndrome (SANS). It is thought to get worse with repeated exposure – Scott showed additional changes during this mission. In some astronauts, the changes are irreversible.

Lack of gravity induces a shift of body fluid towards the head, this is associated with a reduced blood pressure but increase in cardiac output. Vascular stiffness and carotid intima/media thickness increased associated with vascular disease – long term consequences are uncertain.

Finally, Scott exhibited some impairment of judgement in tests performed post-flight. These recovered, but NASA has concerns that a crew landing on Mars after a long journey may be both physically weakened and cognitively impaired at first.

CONCLUSIONS

Overall, it looks as though long duration human spaceflight may be more hazardous than we initially thought. My boyhood dreams have faded, perhaps I should learn to love the Earth a bit more instead.

FINAL THANKS

As this is my last Editorial, I wish to thank my Editorial Assistants, Marie and Kathy, my sub-editor, Mary Crickard and my contacts at Dorman and Sons, Peter and Mike. Thank you to my predecessors, Professors Barry Kelly and Patrick Morrison for their valuable insights and finally thank you to the UMJ Editorial Board and UMS Council for giving me the wonderful opportunity of editing UMJ for the last 5 years.

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REFERENCES

1. Garrett-Bakelman FE, Darshi M, Green SJ et al. The NASA Twins Study: a multidimensional analysis of a year-long human spaceflight. *Science* 2019;**364**: (6436)

2. UK Government. Guidance: Ionising radiation: dose comparisons. https://www.gov.uk/government/publications/ionising-radiation-dose-comparisons/ionising-radiation-dose-comparisons. Last accessed 12th January 2020.

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