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Can I take a space flight? Considerations for doctors

Commercial investment is bringing space tourism closer to reality. **Marlene Grenon and colleagues** outline what doctors will need to know

The right stuff (early 21st century)

DUNCAN SMITH

Numerous commercial enterprises exist that will eventually provide competitively priced access to spaceflight experiences for paying customers. With spaceports construction under way, bookings are already taking place. Physicians can in future expect patients to ask questions and request clearance processes (such as fitness to fly certificates) for space travel as they do for commercial airplane flights today. Here, we provide some background to the field of space medicine for non-experts and point to resources for clinicians when a patient presents with requests related to space travel.

Current landscape of space travel

Despite the ending of space shuttle flights in July 2011, the US continues to invest billions of dollars in space travel, including extending the International Space Station and developing new space craft with companies such as Boeing, Space X, and Sierra Nevada. The aim is to make spaceflight available for both the federal government and commercial customers. Furthermore, the Federal Aviation Administration (FAA) has recently granted funds for infrastructure on three commercial spaceports. The European Space Agency takes a stand of "cautious interest and informed support" for space tourism, and Virgin Galactic is now accepting reservations for suborbital flights onboard SpaceShipTwo for $200 000 (£125 000; €155 000). A recent report by the FAA forecasts that the demand for seats on suborbital reusable vehicles (for tourism, research, education, point to point transportation, etc) will be 4518 seats at baseline, growing to 13 134 seats over 10 years once the vehicles become operational.[1]

These developments suggest we can expect flight opportunities to become increasingly available to the general public either for individual travel (referred to as space tourism) or for work, as companies exploit the commercial opportunities of space flight. The types of flight activities that are related to space tourism comprise parabolic flights, suborbital flights, and orbital flights, such as visits to the International Space Station or other orbiting destinations.

Although more expensive, flights to the International Space Station are already available through the Russian Space Agency in a Soyuz capsule. These usually last one to two weeks but require extensive medical screening[2] and training beforehand. It may also become possible to fly to an orbiting Bigelow Aerospace hotel or laboratory in the future.

As access to space travel for personal or employment reasons increases, clinicians may be faced with new medical challenges and questions in their daily practice. For example: How long after a hip replacement can my patient safely embark on a ballistic two hour flight to Australia? Can my patient with stable angina and a pacemaker for complete heart block participate in a suborbital Virgin Galactic flight? What is the maximum allowable time that my patient with osteoporosis can spend on a planned vacation at a space hotel? Of course, all physicians will not be expected to be experts in space medicine, just as they are currently not experts in the physiology of airplane flight, but they will have to understand how it affects their patients.

Physiological and clinical implications of increased space travel

Research in space sciences and space medicine has allowed us to discover, understand, and militate against important changes in human physiology that take place outside Earth's gravity and protective atmosphere—for example, volume shifts leading to cardiovascular deconditioning, bone and muscle atrophy, and immunosuppression. Space medicine experts are also investigating and designing preventive and post-flight treatments for observed clinical consequences of space travel, including space motion sickness, orthostatic intolerance, and neurovestibular dysfunction on return to Earth, increased risk of cardiac dysrhythmias, osteoporosis, muscle atrophy, increased risk of kidney stones and infections, and a possible increased risk of cancer with exposure to radiation and immunosuppression (table 1, bmj.com).[3-7] Space intracranial hypertension with ocular complications, including papilloedema and permanent changes in visual acuity, is a newly recognised complication of extended exposure to microgravity.[8]

Table 2 | Hypothetical spaceflight considerations for common medical entities

Medical condition	Influence of spaceflight	Preflight intervention
Coronary artery disease	May increase the risk for cardiac dysrhythmias or myocardial ischaemia	If patient decides to fly, ensure that blood pressure and cardiac rhythm are properly controlled
Cerebrovascular disease	Possible altered flow patterns in a carotid lesion	Optimise medical treatment and consider repair as per current guidelines
Peripheral arterial disease	Volume shifts may exacerbate symptoms	Optimise medical management; consider treatment of critical limb ischaemia and claudication
Abdominal/thoracic aortic aneurysm	Impact of linear acceleration during launch could increase the risk of rupture	Consider treating (endovascular or open)
Aortic dissection (type B)	Impact of linear acceleration during launch could worsen the extent of the dissection	Consider treating (endovascular or open)
Chronic obstructive pulmonary disease/asthma	Symptoms may increase with the stress of flight	Optimise medical management
Osteoporosis	Increase in bone loss during spaceflight	Consider bisphosphonate treatments for longer duration flights (probably no effect for suborbital flights)
Cancer	Possibility that immune suppression (and exposure to radiation) may exacerbate condition	Consider postponing flight
History of deep venous thrombosis	Theoretical increased risk of thrombosis with stasis and decreased use of lower extremities	Prophylactic low molecular weight heparin injections during flight
Gastrointestinal reflux	May exacerbate with the lack of gravity	Ensure that patients, symptoms are well controlled with appropriate medical therapy
Transient infections (urinary tract infection, pneumonia, ears, skin infection)	Could exacerbate with effects on the immune system, increased growth of bacteria in space, unknown efficacy of common antibiotics with changes in pharmacokinetics and pharmacodynamics	Consider postponing flight until the acute process is resolved
Psychiatric problems	May exacerbate (or possibly improve) state	Ensure that the patient is not a threat to himself/herself or others
Pregnancy	Unknown data on effects	Consider postponing the flight until after pregnancy

Some conditions are common during spaceflight, including loss of appetite, motion sickness, fatigue, insomnia, dehydration, dermatitis, and back pain. These are usually dealt with conservatively or with drug treatment. Medical evacuation from orbital stations has occurred only three times in the history of human spaceflight—for intractable headaches (Salyut 5, 1976), prostatitis induced sepsis (Salyut 7, 1985), and cardiac dysrhythmia (Mir, 1987). An evacuation was also planned but cancelled for an astronaut with kidney stones (Salyut 7, 1982). However, astronauts are generally fit and undergo extensive medical tests before flight. With more opportunities for space tourism, an increasing number of less healthy individuals can be expected to fly. This could have important implications for the risk of in-flight medical events. Table 2 lists some of the potential problems, but myriad medical conditions are likely to challenge clinicians, and the whole medical encyclopaedia may need to be redefined for the conditions of space travel.

Regulating bodies and responsibility of healthcare practitioners

How should general physicians deal with patients with health problems who are thinking of taking a commercial spaceflight? Important considerations include the recognition that there are risks associated with spaceflight, that spaceflight causes changes in normal physiology, and that spaceflight is likely to affect abnormal physiology and disease conditions, although the exact nature of these effects is yet to be determined. Blue and colleagues tested future spaceflight participants for *g* force tolerance and concluded that most people with well controlled medical conditions are capable of withstanding the acceleration forces involved in the launch and landing of commercial spaceflight vehicles.[10] Last year, the Aerospace Medical Association Commercial Spaceflight Working Group published a document describing the medical effects of suborbital flights among crew members and proposing recommendations for participation for operationally critical crew members.[11]

Resources and standards documents are being developed for space travellers who have not been through the extensive selection process that is the current norm for professional astronauts.[12-16] In 2007, a special report was published on the certification requirements for those wishing to fly to the International Space Station.[2] This document describes the medical evaluation procedures and causes for rejection. There are no published data on medical disqualification of potential space tourists or spaceflight participants. However, for professional astronauts, common reasons for disqualification include vision or ophthalmological conditions, cardiovascular conditions, chronic sinusitis, migraine, kidney stones, and asthma.[17]

The FAA has taken the lead in drafting legislation regulating commercial human spaceflight through its Office of Commercial Space Transportation. It makes no specific statements about the medical requirements for passengers,[18] perhaps because experience in aviation medicine has shown that over-regulation could inhibit development of the sector. The crew of commercial space vehicles are required to have an FAA second class airman medical certificate and demonstrate the ability to withstand the stresses of spaceflight, but it is presently the responsibility of commercial space vehicle operators to ensure that there are appropriate medical screening programmes for passengers. The FAA does not propose to regulate medical aspects of space passengers beyond requiring informed consent.

With this in mind, if a potential space traveller asks his or her physician for a medical letter of clearance for space travel, the physician will share responsibility for determination of suitability with the commercial space operator. As such, clinicians should consider developing a resource file for future reference. An example of a resource file may contain findings from the history and physical examination and, possibly, a discussion of the risks of the medical condition for case scenarios where the pathology would be exacerbated by spaceflight. A delicate balance will need to be established to make this sector viable; the flight of the passenger and other passengers should be kept safe, but too stringent criteria may decrease the market.

Expectations of increased access to space will lead to challenges for medical experts and non-experts alike. Despite the fact that space shuttles are now consigned to history, we should not relegate to a museum shelf an important international dialogue on space travel as it pertains to all of us and to the health of our patients.

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Case report of ET

Gregory Scott and **Edward Presswood** present the intriguing case of ET and provide advice for those who have a medical close encounter with an extraterrestrial

In his 1982 film, *E.T.–The Extra-Terrestrial*, Steven Spielberg documented the short period when an alien named ET was stranded in a suburban region of North America.[1] The film portrays the special relationship between ET and an alienated young schoolboy, Elliott. Previous work has looked at the cinematic importance of the film, but there has hitherto been no serious medical account of ET, despite the depiction of various pathophysiological states and detailed footage of ET's medical care.

Based on an analysis of available footage, and disregarding the film's emotional distractions,[2] we report the medical case of ET. We describe his anatomy and pathophysiology, examine his medical care, and shed light on his glowing digits and luminous heart.

MARK THOMAS

Given that ET's species evolved on a remote planet, the similarities are a striking example of convergent evolution (yet) his premorbid status suggests inadequate physical screening for interplanetary space exploration

Case presentation

ET is an alien botanist and explorer who became unwell after being abandoned during an expedition to a forest in North America. Nothing is known of ET's medical history, but his selection for interplanetary exploration suggests he was previously fit and well.

ET is a bilaterian tetrapod, sharing many of the physical characteristics of primates. Given that ET's species evolved on a remote planet, the similarities are a striking example of convergent evolution.[3] ET's age is unclear. He is presumed to be male, although his external genitalia have never been observed. He weighs 35 lb (15.75 kg) and is about 4ft 6 in (1.35 m) tall, a measurement that varies because of his extensible cervical spine. Despite having the mass of a 4 year old boy,[4] ET has a body habitus associated with increased cardiovascular risk.[5]

ET's upper limbs are similar to the vertebrate pentadactyl limb, although he has only three fingers and an opposable thumb. The first finger of his right hand is grossly elongated at the terminal phalanx, with a drumstick appearance consistent with stage four clubbing. This finger has a remarkable ability to fluoresce with a red candescence. This may be a form of bioluminescence similar to that seen in *Lampyris noctiluca*, the common glow-worm. The same phenomenon is seen in his thorax and is associated with translucency of the chest wall. These periods of illumination serendipitously reveal aspects of ET's cardiac anatomy, the appearances of which are consistent with dextrocardia, with a single ventricle and juxtaposition of the right atrial appendage.[6 7] This unusual configuration, although rather beautiful, may well signify a cardiovascular system ill equipped to compensate for haemodynamic stress.

ET's lower limbs are very short, with the appearance of lymphoedema. He has a Trendelenberg gait and severely limited walking speed. ET's impaired mobility may explain why he did not originally make it back to his spacecraft. He may have pre-existing joint pathology, comparable to Perthe's disease in childhood. This possibility, combined with other concerns about ET's premorbid status (box 1, see bmj.com), suggests he may have undergone inadequate physical screening for interplanetary space exploration.

ET's linguistic faculties are impressive. While at first making only primitive vocalisations, within days he showed a grasp of spoken English. His grammatical understanding was initially flawed ("ET home phone"), but he quickly learnt the subject-verb-object structure ("ET phone home"), a feat that takes human children years to acquire. Incidentally, this syntax is something that Master Yoda refused to adopt,[8] despite his advanced age ("When 900 years old you reach, look as good you will not").[9]

ET's newfound and haphazard Western diet may have led to profound malnutrition, contributing to his deterioration. His carefree attitude to nutrition may also explain his centripetal adiposity. Interestingly, ET rapidly developed features of alcohol intoxication (disorientation, disinhibition, and ataxia) after consuming one can of American beer. Such a dramatic reaction suggests that ET has a deficiency of the enzyme acetaldehyde dehydrogenase. This could result from a lack of exposure to ethanol during his evolutionary past, as is seen in some humans of East Asian ancestry.[10]

ET's illness and treatment

ET became unwell in the days after arriving on Earth. He was found stranded in a stream after a failed attempt to phone home via a makeshift telecommunication device. He came to medical attention after he was returned to Elliott's home and parental assistance was sought. ET was found lying on the bathroom floor; he was very unwell, pale, tachypnoeic, and delirious.

ET was moved to a temporary medical facility. He became critically ill, shocked, and hypoxic. Various investigations and treatment measures were undertaken (box 2, see bmj.com). Despite aggressive management, ET had a ventricular fibrillation cardiac arrest. Chest compressions were started at a rate of 60/min. Bag mask ventilation was applied. A direct current shock was delivered. Intravenous lidocaine and noradrenaline (epinephrine) were administered. There was no return of circulation, however, and the resuscitation attempt was abandoned.

The management of the arrest was in keeping with the standards of the time, but the immediate outcome might have been better if modern resuscitation guidelines had been followed.[11,12] The differences would include faster chest compressions (100-120/min) and greater emphasis on minimising delay to defibrillation. Lidocaine is no longer first line treatment, and it may have been ineffective in the presence of hypomagnesaemia.[11] A systematic approach to the reversible causes

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The perils of junk food?

of the arrest (using the mnemonic "4H's and 4T's") might have improved the outcome. His hypovolaemia, hypoxia, and hypothermia were treated, but surprisingly he was not given magnesium to correct the hypomagnesaemia. Tension pneumothorax or tamponade was not suspected. Toxins are a possibility given ET's new diet and his recent trips to a forest. A coronary thrombosis is also possible given ET's cardiovascular risk profile. It is disappointing that the diagnosis of a massive pulmonary embolism was overlooked, given his recent long haul flight.

Recovery

After his death, ET's body lay in a freezer compartment. Elliott was allowed to say farewell. Remarkably, ET came back to life and repeatedly chanted "ET phone home." This verbal perseveration suggests frontal lobe damage resulting from a hypoxic brain injury that was not ameliorated by the cooling process. Nevertheless, ET made an exceptional functional recovery, balancing in the basket of Elliott's bicycle and performing feats of telekinesis en route to the site of his eventual departure.

Conclusions

We are able to draw some conclusions about the care of extraterrestrials. The following points should be borne in mind in any close encounter:

- Earth's environment and our diet are unlikely to be optimal for sustaining extraterrestrial life. Even simple medical interventions, such as oxygen and fluid resuscitation, require careful consideration.
- A collateral history is paramount in extraterrestrial cases. That said, an accurate medical history is a challenge to obtain from the records even for earthly life forms registered with a general practitioner. Obtaining a collateral history for an extraterrestrial, especially on a Friday afternoon, will probably be almost as challenging.
- Any extraterrestrial who has succeeded in travelling to Earth is likely to be intellectually superior to most humans, even neurologists. This will provide a contrast for Earth based doctors, who are used to feeling superior to their patients. Usefully, involving the extraterrestrial patient in medical decision making represents not only exemplary ethical treatment, but will probably result in a more favourable outcome.
- If you are involved in the treatment of an extraterrestrial, do ensure that this experience is fully reflected in your revalidation portfolio.

We realise that most doctors will not need specialist skills in extraterrestrial medicine: in his or her career, the average GP will see no cases of ET illness. Nevertheless, we suggest that specialists be trained in this branch of medicine, because such alien encounters are likely to be more common with the explosion in space travel.

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