BMJ

BMJ 2012;345:e8124 doi: 10.1136/bmj.e8124 (Published 13 December 2012)

FEATURE

CHRISTMAS 2012: TOMORROW'S WORLD

Can I take a space flight? Considerations for doctors

S Marlene Grenon *assistant professor of surgery*[1 2], Joan Saary *assistant professor*[3] *consultant*[4], Gary Gray *senior consultant flight surgeon*[5], James M Vanderploeg *associate professor*[6] *chief medical officer*[7], Millie Hughes-Fulford *professor*[8 9]

[1]Division of Vascular and Endovascular Surgery, University of California, San Francisco, CA 94121, USA; [2]Department of Surgery, San Francisco Veterans Affairs Medical Center, San Francisco, USA; [3]Department of Occupational Medicine, University of Toronto, Toronto, Canada; [4]Canadian Forces Environmental Medicine Establishment, Toronto, Canada; [5]Canadian Space Agency, Montreal, Canada; [6]Aerospace Medicine Program, Department of Preventive Medicine and Community Health, University of Texas Medical Branch, Galveston, USA; [7]Virgin Galactic, New Mexico, USA; [8]Hughes-Fulford Laboratory, Veterans Affairs Medical Center, San Francisco, USA; [9]Department of Medicine, University of California, San Francisco, USA

Abstract

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

Although perhaps unfamiliar with the specific physiological changes associated with commercial air travel, most physicians will have travelled by plane and many will have attended a passenger in need of medical assistance while on a commercial flight. They are, however, unlikely to have experience of space travel.

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. Parabolic flights are already available and allow participants to experience the microgravity environment for short periods (around 20 seconds) during several parabolas. Suborbital flights may eventually become a new way to travel across the globe. Suborbital flight opportunities are currently being planned by companies such as Virgin Galactic, Armadillo Aerospace, and XCOR.

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.

Work related space flights may be for research and development or industrial activity. For example, mining companies may send employees to the Moon or near Earth asteroids to mine planetary resources. Such commercial activities for space workers would add a whole new element to occupational medicine.

Correspondence to: S M Grenon marlene.grenon@ucsfmedctr.org

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⇓).[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]

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 (box 1). 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.

We thank Amy Markowitz (UCSF) for her editorial assistance. This work was supported by start-up funds from the University of California San Francisco and the Northern California Institute for Research and Education. The project described was supported by Award Number KL2RR024130 from the National Center for Research Resources. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Center for Research Resources or the National Institutes of Health.

Contributors: All authors contributed to the conception and design of the manuscript. SMG drafted the manuscript while JS, GG, JMV, and MH-F critically reviewed the content.

Box 1: Pre-existing medical problems in a space tourist

A 57 year old entrepreneur, engineer, and scientist flew to the International Space Station as a private citizen through a self funded trip in 2005. His pre-flight medical clearance was complicated by a history of bullous emphysema, spontaneous pneumothorax with talc pleurodesis, and a lung parenchymal mass.[9] The doctors decided that he should have video assisted thoracoscopic pleurodesis and lung biopsies before flying, and he was able to complete his 10 day mission without medical problems.

Box 2: How space medicine has benefited health

Transfer of technology and innovations from the space sciences have benefited thousands of people. Some commentators estimate that more than 1500 products are spin-offs from space technologies, including several in medicine. These include

NeuroArm—Derived from Canadarm, a remote manipulator system for the space shuttle capable of deploying and retrieving hardware from the shuttle's payload bay. NeuroArm offers improved accuracy and efficiency for high precision neurosurgery[19]

Telemedicine—Development of this global health technology has close ties with the Canadian Space Agency and Canadian expertise in providing healthcare to remote regions

Left ventricular assist device —Designed collaboratively by Michael DeBakey at the Baylor College of Medicine, and David Saucier and other NASA engineers.[20] The device, based on the design of the shuttle's main engine fuel pump, has been used in numerous patients as a bridge to transplantation or to treat heart failure.

In addition to these direct benefits, some authors have charted economic benefits from space activities.[21] Nearly a decade ago, Bezdek and Wendling created economic models related to the influence of space investment on particular regions and states and calculated ratios of indirect to direct benefits in the order of 8:1 or higher. It is therefore interesting that the public generally believes that greater amounts of the budget are spent on space programmes than the actual allocations.[22]

Moreover, even conservative estimates of return on investment and savings of healthcare dollars for common chronic diseases suggest a robust return on a relatively minimal investment. The International Space Station is now an international laboratory, which permits us to study human physiology, medicine, and human molecular biology with new technologies that operate in the absence of Earth's gravity. We are on the cusp of discovery in numerous medical fields. For example, current research includes a search for key regulatory genes in bone homeostasis and new ways of stimulating bone growth in osteoporosis.

Competing interests: All authors have completed the ICMJE unified declaration form at www.icmje.org/coi_disclosure.pdf (available on request from the corresponding author) and declare no support from any organisation for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the past three years; no other relationships or activities that could appear to have influenced the submitted work.

1 Federal Aviation Administration. Forecasts: suborbital reusable vehicles: a 10-year forecast of market demand. www.faa.gov/about/office_org/headquarters_offices/ast/media/Suborbital_Reusable_Vehicles_Report_Full.pdf.
2 Bogomolov VV, Castrucci F, Comtois J-M, Damann V, Davis J, Duncan JM, et al. International space station medical standards and certification for space flight participants. *Aviat Space Environ Med* 2007;78:1162-9.
3 Hughes-Fulford M. To infinity . . . and beyond! Human spaceflight and life science. *FASEB J* 2011;25:2858-64.
4 Williams D, Thirsk R, Kuipers A, Mukai C. Limited onboard amenities. *CMAJ* 2009;180:1292-3.
5 Thirsk R, Kuipers A, Mukai C, Williams D. Spinoffs from space. *CMAJ* 2009;180:1324-5.
6 Williams D, Kuipers A, Mukai C, Thirsk R. Acclimation during space flight: effects on human physiology. *CMAJ* 2009;180:1317-23.
7 Thirsk R, Kuipers A, Mukai C, Williams D. The space-flight environment: the International Space Station and beyond. *CMAJ* 2009;180:1216-20.
8 Mader TH, Gibson CR, Pass AF, Kramer LA, Lee AG, Fogarty J, et al. Optic disc edema, global flattening, choroidal folds and hyperopic shifts observed in astronauts after long duration spaceflight. *Ophthalmology* 2001;118:2058-69.
9 Jennings RT, Murphy DM, Ware DL, Aunon SM, Moon RE, Bogomolov VV, et al. Medical qualification of a commercial spaceflight participant: not your average astronaut. *Aviat Space Environ Med* 2006;77:475-84.
10 Blue S, Riccitello J, Tizard J, Hamilton R, Vanderploeg J. Commercial spaceflight participant g-force tolerance during centrifuge-simulated suborbital flight. *Aviat Space Environ Med* 2012;83:929-34.
11 Aerospace Medical Association Commercial Spaceflight Working Group. Suborbital commercial spaceflight crewmember medical issues. *Aviat Space Environ Med* 2011;82:475-84.
12 Aerospace Medical Association Task Force On Space Travel. Medical guidelines for space passengers. *Aviat Space Environ Med* 2001;72:948-50.
13 Aerospace Medical Association Space Passenger Task Force. Medical guidelines for space passengers—II. *Aviat Space Environ Med* 2002;73:1132-4.
14 International Academy of Astronautics. Medical safety and liability issues for short-duration commercial orbital space flights. 2009. www.spacemedicineassociates.com/userfiles/file/sg26finalreport.pdf.
15 Federal Aviation Administration. Guidance for medical screening of commercial aerospace passengers. Final report. 2006. www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA460819.
16 Center of Excellence for Commercial Space Transportation. Flight crew medical standards and spaceflight participant medical acceptance guidelines for commercial space flight. www.coe-cst.org/core/scripts/wysiwyg/kcfinder/upload/files/2012.08.06%20Task%20183-UTMB%20Final%20Report.pdf.
17 Gray G, Johnston S. Medical evaluations and standards. In: Barratt MR, Pool SL, ed. Principles of clinical medicine for spaceflight. New York, 2008:59-68.
18 FAA Office of Commercial Space Transportation. Regulations. www.faa.gov/about/office_org/headquarters_offices/ast/regulations/.
19 Pandya S, Motkoski JW, Serrano-Almeida C, Greer AD, Latour I, Sutherland GR. Advancing neurosurgery with image-guided robotics. *J Neurosurg* 2009;111:1141-9.
20 Wilhelm MJ, Hammel D, Schmid C, Stypmann J, Asfour B, Kemper D, et al. Clinical experience with nine patients supported by the continuous flow Debakey VAD. *J Heart Lung Transplant* 2001;20:201.
21 Bezdek RH, Wendling RM. Sharing out NASA's spoils. *Nature* 1992;355:105-6.
22 Launius RD. Public opinion polls and perceptions of US human spaceflight. *Space Policy* 2003;19:163-175.

Accepted: 6 November 2012

Cite this as: *BMJ* 2012;345:e8124

Tables

Table 1| Medical conditions associated with spaceflight and potential countermeasures

Physiological system	Condition	Countermeasure/treatment
Neurovestibular	Motion sickness	Anti-nauseant
	Headache	Analgesic
	Conjunctival irritation (foreign body in the eye)	Removal of foreign body
Cardiovascular	Fluid redistribution	Exercise
	Decrease in exercise capacity	Exercise
	Orthostatic intolerance (on landing)	Exercise, midodrine, fluid loading
	Cardiac dysrhythmias	Drug treatment
Respiratory	Upper respiratory tract infections	Drug treatment if required
	Pneumonitis-like syndrome (from lunar dust)	Conservative management
Gastrointestinal	Loss of appetite	Conservative management
	Constipation	Drug treatment
	Diarrhoea	Drug treatment
Genitourinary	Urinary tract infections	Drug treatment
	Nephrolithiasis	? Evacuation
Musculoskeletal	Bone loss	Exercise, diet supplemented by calcium and vitamins D and K
	Muscle atrophy	Exercise
	Back pain	Drug treatment
Immune and haematological	Increased risk of infections	
	Anaemia	Conservative management
Psychological	Fatigue	Individualised work schedules
	Insomnia	Short acting hypnotics
Others	Radiation exposure	Keep as low as reasonably achievable
	Dermatitis	As needed (eg, topical treatment)
	Bends (decompression sickness)	Spacesuit, prevention protocol (100% oxygen)
	Intracranial hypertension	Acetazolamide

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