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Prehospital Care

An overview of space medicine

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Abstract

Space medicine is fundamental to the human exploration of space. It supports survival, function and performance in this challenging and potentially lethal environment. It is international, intercultural and interdisciplinary, operating at the boundaries of exploration, science, technology and medicine. Space medicine is also the latest UK specialty to be recognized by the Royal College of Physicians in the UK and the General Medical Council. This review introduces the field of space medicine and describes the different types of spaceflight, environmental challenges, associated medical and physiological effects, and operational medical considerations. It will describe the varied roles of the space medicine doctor, including the conduct of surgery and anaesthesia, and concludes with a vision of the future for space medicine in the UK.
Space medicine doctors have a responsibility to space workers and spaceflight participants. These 'flight surgeons' are key in developing mitigation strategies to ensure the safety, health and performance of space travellers in what is an extreme and hazardous environment. This includes all phases from selection, training and spaceflight itself to post-flight rehabilitation and long-term health. The recent recognition of the speciality provides a pathway to train in this fascinating field of medicine and is a key enabler for the UK Government's commercial spaceflight ambition.

Key words: aerospace medicine; space flight; weightlessness

In 2017, the Royal College of Anaesthetists celebrated its 25th anniversary; it was also the 60th anniversary of the Russian launch of Sputnik 1 (first artificial satellite in space), and the 50th anniversary of the launch of Ariel 3, the first UK designed and constructed artificial satellite. It is fitting, therefore, that these anniversaries are marked with this review describing the recently recognised UK specialty of Aviation and Space Medicine.

The establishment of this specialty was achieved through the efforts of individuals from across a broad spectrum of medical disciplines – including several anaesthetists – reflecting its multidisciplinary character. While the discipline features elements drawn from occupational health, primary care, emergency and aviation medicine, a core feature of operational space medicine entails the support and protection of human life and physiology using state of the art life support systems. This, along with the need to consider the challenges of critical care in austere environments, makes this newest of specialties familiar in many ways to those in anaesthetic practice and one to which anaesthetists will be required to make direct contributions in the future.

Space medicine can broadly be defined as: "The practice of all aspects of preventative medicine including screening, health care delivery, and maintaining human performance in the extreme environment of space and preserving the long-term health of space travellers".[1] Here we introduce the core concepts that underpin the theory and practice of space medicine ranging from crew selection and clinical considerations to the interface between life support systems, engineering and human factors (Fig. 1).

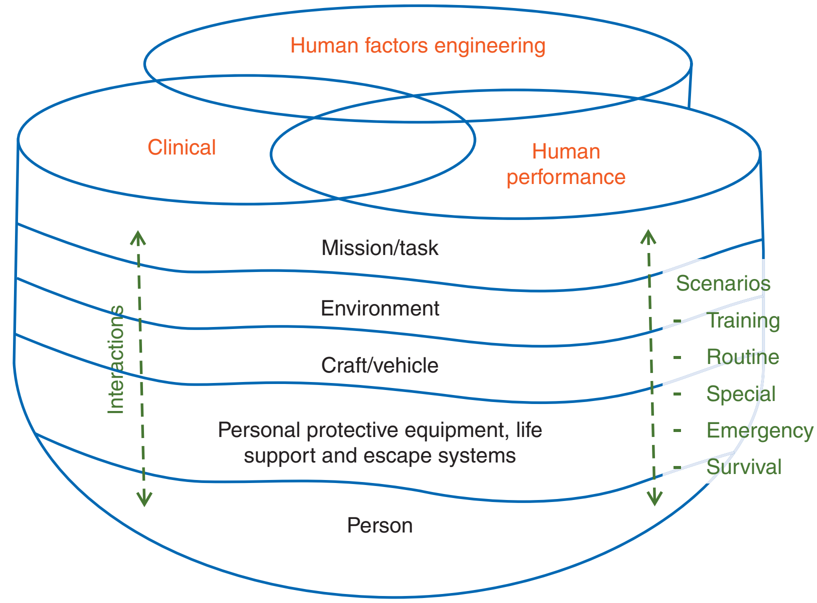

Fig 1 Overview of space medicine. This diagram is inspired by the human factors SHELL model, which was first proposed by Edwards in 1972 and subsequently modified by Hawkins in 1975. The SHELL abbreviation stands for: Software (e.g. standard operating procedures), Hardware (e.g. equipment, systems, vehicles), Environment, Liveware (individual) and Liveware (other people). The SHELL model highlights the importance of interfaces and interactions (along with the inherent variability in each of these) between different components of a manned system.

Types of spaceflight

Spaceflight refers to those journeys that take place more than 100 km above sea level. This internationally recognised altitude boundary is known as the Karman line. In broad terms the Karman line is the altitude above which the atmosphere is insufficiently dense for the aerodynamic control surfaces of conventional aircraft to be effective; beyond that lies space. For the purpose of this article there are three categories of human spaceflight: i) suborbital, ii) low Earth orbit (LEO; e.g. the International Space Station), and iii) exploration class missions (e.g. missions to the Moon and Mars).

Suborbital spaceflights are short, generally lasting no more than a few hrs of which only a few min are spent experiencing the weightlessness of microgravity. The flights involve exposure to increased acceleration in the vertical (Gz) and horizontal (front-to-back; Gx) planes, which can affect the cardiorespiratory systems. The degree of acceleration experienced is typically referenced to the acceleration as a result of gravity near the Earth's surface (g; 9.8 m s^{-2}), for example, +6 Gz is head-to-toe acceleration equal to six times g. Cabin pressures are likely to be equivalent to commercial aircraft cabins (~6–8000 ft pressure altitude).

Low Earth orbit implies vehicles in orbit around Earth at an altitude of 200–400 km. This is where almost all of human space exploration has occurred; from Russia's Vostok 1 through to the US Space Shuttle program and today's International Space Station (ISS).

Exploration class space flight refers to missions beyond low Earth orbit. These encompass expeditions to the Moon, Mars and other celestial objects and locations including Lagrange points and near Earth objects such as asteroids. Lagrange points are locations where gravitational forces between two large bodies (e.g. the Sun and Earth or the Moon and Earth), are balanced such that a smaller body, such as a space station, can effectively be 'parked' in space and is maintained in a stationary position relative to the two larger bodies. The remoteness of these missions from Earth and their comparatively long duration distinguishes them from the vast majority of our experience in human space flight to date.

Medical standards for spaceflight

Human space flight takes place in an austere, remote and physiologically challenging environment with medical provision severely limited by considerations of power, weight and volume and the available skill mix of the crew. Additionally, it represents an environment in which the incapacitation of an individual with a critical role in a mission may threaten the health and safety of the whole crew.

The most successful method of mitigating against the significant physiological risks imposed by spaceflight lies in adequate prevention through screening.[2 3] Therefore medical standards for spaceflight have traditionally played an important role; the aim being to select out any pre-existing medical conditions that might threaten either the safety of the crew or the goals of the mission. Medical standards for spaceflight must be considered in relation to the intended sortie profile and role of the individual within the wider crew.

Professional astronaut medical standards

Standards are stricter for astronauts than for professional aviators. Exclusions are for conditions that; i) may cause acute incapacitation (e.g. coronary artery disease, renal stones, epilepsy), ii) may interact with the space environment or life support systems (e.g. bullous lung disease or asthma; incompatible with