Photo courtesy of NASA.

Surgery for Space Exploration

by S Marlene Grenon, MDCM, MMSc, FRCSC
with sidebars by Jodi B Farmer

If space medicine is a field relatively unexplored, space surgery is even more untouched. Space medicine and surgery are the medical and surgical knowledge and skill set needed to support space exploration. With recent great changes in the United States Space Program, but more importantly with a constant push for space exploration, we will need to be prepared to provide sound medical and surgical care to future space explorers. For that, it is imperative that we understand the critical issues that are a challenge in the space environment, their effects on human physiology, the medical and surgical conditions most likely to be encountered during spaceflight, and the set-up for a possible surgical intervention.

Space medicine is considered a subset of space life sciences, which aim to study the effects of the space environment on living organisms. Aerospace physiology aims to understand the effects of the space environment on the human body, while aerospace or space medicine aims to deal with medical issues arising during spaceflight. As a logical extension, space surgery deals with surgical problems that may arise during space travel.

A discussion of the surgical risks would not be contextual without first discussing the risks of the space environment and their impact on human physiology. Several factors of the space environment affect human physiology. These include the linear acceleration, vibration, acoustic noise, reduced atmospheric pressure (and the risk of decompression sickness), weightless-

LEARNING OBJECTIVES

- Compare and contrast normal gravity and microgravity
- Examine the reasons for space travel and exploration
- Define the challenges facing space surgery
- Identify the hazards of space surgery
- Explore the impact of space travel on the human body

ness (microgravity), exposure to extreme temperatures, circadian dyssynchrony, radiation, the risk of impact with micrometeoroids and debris, lunar and martian dust, as well as the closed and isolated environment that can impact the psychological well-being of the space traveler. Hence, several environmental factors have the potential to impact the body's normal function during spaceflight.

We often describe the impact on the human body as "deconditioning." Spaceflight deconditioning affects all body systems and can be debilitating. The cardiovascular system undergoes fluid redistribution to the upper torso and head, which is perceived as a volume overload and in turn leads to a decrease in plasma volume, or hypovolemia. Consequences include orthostatic dysfunction when astronauts return to earth. Other effects include reduced cardiac volumes and mass, decreased exercise tolerance, and an increased risk for arrhythmias. In addition, bone demineralization occurs as a consequence of decreased osteoblast activity, similar to osteoporosis, leading to decreased bone density and increased risk of fractures. This is accompanied by muscle atrophy secondary to the lack of use of postural muscles. The neurovestibular system is also affected leading the most common medical condition experienced by astronauts: space motion sickness. Furthermore, changes occur in the way the body senses posture, position and coordination. In addition to this, immunosuppression, mostly of the cell-mediated type, and post-spaceflight anemia is also encountered in astronauts. Very interestingly, a few reports have hinted to other cellular changes in microgravity, leading to a decreased wound healing. This could have a tremendous impact on the surgical patient. On another note, the possibility of psychological disturbances warrants attention. Experience has shown that normal individuals placed in stressful environments, especially for extended periods, can easily experience abnormal behavior as well fatigue, asthenia, sleep disturbances, and depression. Although researchers and flight surgeons have worked on identifying and treating the causes of spaceflight deconditioning, several issues remain unknown. Furthermore, other yet unidentified conditions may become the real show-stoppers in space exploration. Overall, we have to remember that some of these factors may affect a surgical patient, such as fluid deletion, anemia, immunosupression, radiation, and decreased wound healing.

Photo courtesy of NASA.

NASA's Spitzer Space Telescope has imaged a coiled galaxy with an eye-like object at its center. The 'eye' at the center of the galaxy is actually a monstrous black hole surrounded by a ring of stars. In this color-coded infrared view from Spitzer, the area around the invisible black hole is blue and the ring of stars, white.

The galaxy, called NGC 1097 and located 50 million light-years away, is spiral-shaped like our Milky Way, with long, spindly arms of stars.

The black hole is huge, about 100 million times the mass of our sun, and is feeding off gas and dust, along with the occasional unlucky star. Our Milky Way's central black hole is tame in comparison, with a mass of a few million suns.

The ring around the black hole is bursting with new star formation. An inflow of material toward the central bar of the galaxy is causing the ring to light up with new stars. The galaxy's red spiral arms and the swirling spokes seen between the arms show dust heated by newborn stars. Older populations of stars scattered through the galaxy are blue. The fuzzy blue dot to the left, which appears to fit snugly between the arms, is a companion galaxy. Other dots in the picture are either nearby stars in our galaxy, or distant galaxies.

> The most common medical condition experienced by astronauts is space motion sickness.

The surgical risks of the space environment are related to the "occupational risks" inherent to the space environment as well as the surgical conditions that may occur in individuals on a normal basis. The occupational risks include the risks of blunt and penetrating trauma. This could happen during impact with space debris (which is becoming an increasing problem at the environmental level), during extra-vehicular activity (more commonly called "spacewalks"), during construction and repair of a vehicle or spacecraft, with vehicle docking and refueling, and while servicing payloads. With the advent of the International Space Station and the increasing opportunities for life sciences and other types of research, the risk of chemical contamination and burns is present with electrical equipment repair and chemical or biological research. In the setting of musculoskeletal deconditioning, the risk of orthopedic injuries increases. The risks of minor injuries and dental complaints would be expected, and have, in fact, occurred. Furthermore, the possibility of a "standard" surgical condition, such as appendicitis or cholecystitis, is present. This then leads to the question: should we perform elective appendectomies or cholecystectomies prior to spaceflight? This dilemma remains a subject of debate.

> A voyage to Mars would deteriorate bones to osteoporotic levels if no countermeasures, such as exercise, were used.

COUNTERMEASURES THAT WILL MINIMIZE RISKS BEFORE, DURING AND AFTER SPACEFLIGHT[1]

by Jodi B Farmer

	BEFORE FLIGHT	DURING FLIGHT	AFTER FLIGHT
PHYSIOLOGIC EFFECTS (Shift in body fluids)	None	Exercise, use of negative pressure suits for lower body to help with body fluid distribution, isotonic fluid taken orally, use of pressurized anti-gravity suit to help with fluid distribution on re-entry	Use of midodrine (to counter post-flight orthostatic intolerance) is currently being considered
SPACE MOTION SICKNESS	Neurovestibular conditioning including virtual reality training, and parabolic or aerobatic flights and the use of antinauseant medications	Continued antinauseant medications	Intravenous antinauseant and fluids
MUSCLE ATROPHY	Resistance training, aerobic exercise	Aerobic and strength exercise, possible dietary supplementation and electrical muscle stimulation	Muscle conditioning, exercises, massages, icing and use of nonsteroidal anti-inflammatory agents
BONE DEMINERALIZATION	3 DXA (dual energy x-ray absorptiometry) scans per year	Resistance exercises, dietary supplementation including diary, and vitamins D and K	2 DXA scans within 6 months after space mission, 4 DXA scans over 3 years afterward, temporary restriction of activities such as flying high-performance jets
PSYCHOSOCIAL EFFECTS	Meeting recruitment criteria and specific behavioral competencies, didactic training including teamwork and field-based training	Individualized work schedules, 8 hours of rest daily, short-acting hypnotics to prevent sleep loss and modafanil to enhance performance after periods of reduced sleep	Psychological debriefing sessions
IMMUNE DYSREGULATION	Quarantine program for 1 week before flight	Exposure to artificial gravity and nutrition supplements are currently being considered	Collection of biological samples to measure immune function

WHAT IS MICROGRAVITY?

by Jodi B Farmer

Microgravity is basically just free fall. On Earth, gravity governs us and motions throughout the universe. It holds us to the ground and keeps the moon in orbit around Earth and other plants in orbit around the sun.

Although most people think that there is no gravity in space, the gravitational field is quite strong and this field keeps planets and the moon in orbit. That is how orbiting spacecraft, such as a space shuttle or the space station are kept in orbit around Earth, by gravity.

More than 300 years ago, Sir Isaac Newton first described gravity. He wrote that gravity is the attraction between any two masses, which is most apparent when one mass is very large. An example would be Earth (large) and space shuttle (small). The acceleration of an object toward the ground is called "normal gravity," which is what humans experience on Earth.

In space, objects are actually falling as well. If an astronaut drops something in the space station, it falls although it looks like it is floating. This optical illusion of the item floating is because everything is falling together: the astronaut, the item and the space station. But instead of falling down toward Earth, they're all falling around it at the same rate, which gives off the appearance of floating. This phenomenon is called zero gravity or microgravity.

Microgravity can be felt here on Earth. Some amusement park rides are actually called free-fall rides that give off the feeling of microgravity. Most roller coasters create brief periods of weightlessness when they go through the rolling hills of the ride.

NASA also has created two drop towers at its Zero Gravity Research Center in Brook Park, Ohio, that allows objects to free fall from 2 to 5 seconds so researchers can study the effects of weightlessness.

Microgravity's Impact On The Human Body[4,8]

Microgravity is the most profound aspect of the space environment on human physiology. All organ systems are affected when living in a space environment, but there are two major challenges associated with humans who live and work on a space flight: radiation effects and the physiologic consequences of being in a microgravity environment.

Much of the risk of injury or poor wound healing is due to the effects of microgravity. Once in weightlessness, people, objects or structures could cause crushing or lacerating blows because they retain their full mass in microgravity. Since microgravity gives the appearance of lack of weight, humans operating in space can misjudge and misread how much things weigh and end up pushing them to hard throughout the craft or bumping into them. Because of this insensitivity to mass judgments trauma is a major concern during the space flight.

Prolonged exposure to a microgravity environment is also a concern during space missions. It has been shown to decrease bone density, increase head edema (swelling of the brain), reduction in cardiac stroke volume, enlargement of liver and pancreas as well as the reduction in red blood cells. The risk of kidney stones and loss of proteins are also major concerns. Since proteins are essential to maintaining how the body works, and since the body has no space proteins, the loss of them could be debilitating. Proteins help with one's muscle function, cell structure and immune responses. Bed rest studies show a person's protein loss is usually about 15 to 20 percent wherein space protein loss can be a devastating 45 percent decrease.

The risk of radiation to space travelers is great. The occurrence of large solar particle events, also known as SPE, usually is associated with high levels of solar activity. When one is exposed to high doses of solar radiation one may experience acute radiation syndrome. Side effects include nausea, vomiting, hemorrhaging, or even death. Understanding how to prevent radiation sickness will be necessary to help lower radiation risks while in space.

Microgravity also has strong effects on cells and how they grow. Cells use a tension-dependent form of architecture, known as tensegrity. The level of a pre-existing tension is known as pre-stress. Gravity plays a large part in contributing to pre-stress within individual cells. When one enters and lives in a microgravity environment, the cells experience an acute decrease in pre-stress. In a space-like environment, where gravity is non-existent, a cell is less likely to divide and grow, which contributes to slower wound healing and presents more difficulty in treating patients during space flight.

Photo courtesy of NASA.

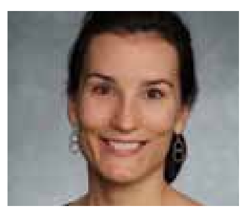
Astronauts Joan E. Higginbotham (foreground), STS-116 mission specialist, and Sunita L. Williams, Expedition 14 flight engineer, refer to a procedures checklist as they work the controls of the Space Station Remote Manipulator System (SSRMS) or Canadarm2 in the Destiny laboratory of the International Space Station.

At the present time, our diagnostic capability is mostly limited to history taking, physical examination and ultrasound. This can be supplemented by telemedicine, although we have to remember that for a flight away from Earth (ie Martian exploration), the time to communicate with mission control may be in the order of 0.5 hours, limiting our ability to have real-time feed-back, which may be critical. The capability to provide basic life support that includes obtaining an airway and ventilation, as well as the performance of cardio-pulmonary resuscitation, has been established in analog environments of weightlessness. Astronauts have, in fact, had the opportunity to practice these skills on the International Space Station, although they have not been applied in a real emergency.

For anesthesia, local and intravenous anesthetic agents appear to be the preferred methods for major operations during spaceflight because of potential risks associated with inhalational anesthetics and spinal anesthetics. With the proper equipment (sterile drapes, sutures, instruments, operating table) and restraining system (for patient, surgeon and equipment), surgical techniques can be performed in microgravity. Some critical aspects however have remained poorly investigated and may represent challenges for successful surgical care. These include aspects related to pharmacodynamics, pharmacokinetics and bioavailability (particularly in the setting of fluid shifts known to occur in microgravity), wound healing, and the effects of immune-suppression and radiation on post-operative infection. Finally, the most appropriate training and skill-set maintenance for the future space surgeon is also unclear.

Konstantin Tsiolkovsky, who is considered the father of Cosmonautics once said: "Earth is the cradle of mankind, but one cannot stay in the cradle forever." In the coming centuries, we are likely to face some major uncertainties such as the availability of food to supply world's burgeoning population, the reserves of energy sources for our expanding economies, and the effects of pollution on our environment. Although space exploration may seem like an extravagance now, it may become the key to assuring our survival as a species. Space medicine and surgery becomes an important facet to this endeavor. Several important milestones have been reached with regards to surgical care in space but certain areas still remain to be developed. It will be critical to address these issues in the coming years and decades, particularly in order to keep humankind's leap out of its cradle as a safe journey.

ABOUT THE AUTHOR



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Although space exploration may seem like an extravagance now, it may become the key to assuring the survival as a species. Space medicine and surgery becomes an important facet to this endeavor.

THE EFFECTS OF SPACE TRAVEL ON THE HUMAN BODY

by Jodi B Farmer

Before one can understand the effects of space travel on the human body, one must understand how the term acclimation is used. Acclimation is defined as acute changes in normal physiology in response to abnormal environments. Two lengths of time are typically measured: short-term exposure (hours to days), and long-term exposure (days to months). A space traveler's ability to adapt to acclimation plays a large part in their wellbeing while in space. Microgravity has the largest effect on human physiology and all organs are affected to some degree.

Cardiovascular, neurovestibular, musculoskeletal, immune deficiencies and psychosocial differences are the most common changes one goes though while participating in space travel. The effects of microgravity also play a part in changing cells and their structure, which also leads to adaptations in surgical procedures. Radiation exposure also plays a part in how a space traveler will feel during the space mission. The most critical conditions, however, may be unidentified conditions, as medical experts would have to quickly and effectively treat these symptoms without much knowledge of why they are being caused. With some areas of weightlessness not yet thoroughly understood, unidentified conditions may pose the highest risk of space flight.

CARDIOVASCULAR CHANGES

Hypovolemia occurs when fluids are redistributed to the upper torso and head, causing a decrease in plasma volume. This is due to the supine prelaunch position that sets the lower limbs above the torso and head. This position during launch, which continues into orbit, initiates a fluid shift where the body's fluids move toward the head. In space, where the pull of gravity is missing, the head-to-toe gradient of blood pressure vanishes. This effect results in facial fullness and a puffy appearance of the head. The changes of cardiovascular systems in microgravity suggest a more complex process of acclimation. When the body's fluid shifts upward toward the head, the baroreceptors of the central vasculature triggers suppression of the renin-angiotension-aldosterone system, releases atrial natriuretic peptide and reduces the plasma volume. The release of atrial natriuretic peptide leads to an increased renal excretion of salt and water. The decrease of the plasma volume appears to also decrease the erythropoietin secretion, which leads to a reduction in red blood cells. The effect of the reduction is about 10 percent less in a space traveler's total blood volume.

These changes also contribute to landing-day orthostatic stress. When the travelers reenter the Earth's orbit, their body fluids pool back into the vasculature of the lower body and create great stress on the body. It has been shown that typically one in four astronauts is unable to stand for 10 minutes within hours of landing because they exhibit body redistribution systems including light-headedness, heart palpitations and syncope, also known as fainting. To decrease the risk of landing-day orthostatic stress, it is advised that space travelers continue to participate in aerobic capacity and use techniques and devices that help redistribute body fluids before landing.

NEUROVESTIBULAR CHANGES

Neurovestibular acclimation occurs in most astronauts and usually affects them during the first couple days after arriving in space. Predominant symptoms may include facial pallor, cold sweating, nausea and vomiting. The same symptoms can also occur during the reacclimation period when astronauts return to Earth. The most common motion sickness usually occurs when astronauts first begin to work in the weightlessness environment of space. The redistribution of body fluids that occurs on entry into microgravity may account for some early symptoms of space motion sickness. Because the autonomic nervous system, gastrointestinal system, neurovestibular system and cardiovascular system are all affected, a range of symptoms are usually reported. These symptoms are usually short-lived, with most space travelers showing improvement within two to three days. These neurovestibular conditions also usually occur for one to two days after returning to Earth and, in some cases, have required intravenous drug and fluid treatment upon arrival after landing. Other changes within the neurovestibular systems include the way the body senses posture, position and coordination.

MUSCULOSKELETAL CHANGES

One of the most common changes in the human body during space flight is the change in muscle mass. During flight, muscles lose mass and strength with the postural muscles being the most affected. The postural muscles allow our bodies to maintain an upright position in a gravitational environment. Studies show that after two weeks in space, muscle mass is diminished by as much as 20 percent. Muscle atrophy, defined as decrease in muscle size and wasting away of a body part or tissue, happens because of the absence of gravitational loading during space flight. Muscle unloading results in biochemical and structural changes and affects the posture and position of astronauts. It also can greatly affect coordination of space travelers, which could have a huge impact on medical experts when traveling in space. Muscles may also be affected by suboptimal nutrition as well as stress while aboard the space craft during flight.

After returning to Earth, astronauts' deconditioned muscles are again affected by gravitational forces and most travelers report muscle soreness, tight muscles and stiff joints. Preflight exercise and exercise during space flight proves helpful to space travelers, although it does not fully prevent muscle loss. Through muscle conditioning and rehabilitation programs after returning to Earth, tests show that most space travelers will recover their strength and regain their full muscle mass within in one to two months.

Another condition affecting the human body during space flight is the microgravity pull on bones and the loss of bone density. Bone demineralization occurs as a consequence of decreased osteoblast activity, similar to osteoporosis, leading to decreased bone density and increased risk of fractures. This is accompanied by muscle atrophy secondary to the lack of use of postural muscles. Bone demineralization begins the first day in space and prompts the concern for increased fractures during and after space flight as well as a complete loss of bone density. According to NASA, a voyage to Mars would deteriorate bones to osteoporotic levels if no countermeasures, such as exercise, were used. Some of the bone loss would be so great that osteoblasts (a cell that makes bone) would be unable to rebuild the bone upon returning to Earth. Although severe, NASA found that most astronauts fully recover their bone density within three years although some never regain the bone density they lost in space.

IMMUNE DYSREGULATION

A few reports have hinted to other cellular changes in microgravity, leading to a decreased wound healing. This could have a tremendous impact on the surgical patient. Space travelers' immune systems are affected by the pressure of space, and astronauts have reported bacterial or viral infections that occurred during flight or after returning to Earth. Researchers think that astronauts' immune impairment before and after space flight is the result of high levels of physical and psychological stress endured during the flight. Some of the effects for impairment during space travel may include physiologic stress, isolation, confinement, and disrupted circadian rhythms. The impairment of cell-mediated immunity could lead to a change in a space traveler's immune system. Also, astronauts' immune systems after landing have shown many changes, including redistribution of circulating leukocytes, decreased activity of natural killer cells, decreased activation of T cells, varying levels of immunoglobulins, as well as other virus-causing changes. All of these changes could lead to autoimmunity, allergies, infectious and even malignant diseases.

PSYCHOLOGICAL DISTURBANCES

Because the space-flight environment is unique with temperature extremes, circadian dyssynchrony, isolated and confined living quarters and abnormal acoustic noise, space travelers face unique obstacles to maintaining any kind of normal routine, especially a normal sleep schedule, which may greatly affect one's mental and physical performance in space. Throughout space flights, NASA has noticed that astronaut's emotional states remain mostly positive with the exception of some discord with interrupted sleep patterns. Fatigue increases the chances that one in space flight could make an error and decreases the capacity of space travelers to deal with adversity, frustration and interpersonal changes. Since the risk of surgery is already at a heightened state, sleep deprivation would definitely impact surgeries being performed in space. Due to the tight and isolated living arrangement on such space flights, travelers would also need to be checked for claustrophobic tendencies as well as being constantly screened for depression.

CHALLENGES FACING SPACE SURGERY

Technological limitations affecting the physical space aboard the craft would strictly limit how much equipment would be allowed. Equipment and tools would need to be restrained and there would also need to be restraints for the patients, surgeons and operative staff.

Other obstacles for performing surgery in a microgravity environment would include a limited amount of water and other supplies, disinfection of equipment, adjusting to new aseptic techniques, safe removal of hazardous material, and the stability and mobility of the persons performing the procedure. The risk of contamination is high and new procedures would have to be followed to make sure the patient and others on the craft would be free of contaminants following the procedure. After surgery, risk of infection would be higher than it is on Earth. Since microgravity greatly slows down wound healing, surgical patients would have to be constantly watched to make sure they remain stable.

Another option would be to have a robot on board to help with any operations. Robotic assistants already assist surgeons on Earth with a number of minimally invasive surgical procedures. Advanced versions of the robotic surgical assistants could help surgeons carry out procedures in space. The steady grip of a robotic arm increases the safety of endoscopic procedures and would limit the risk of contamination following a surgery in space.

Overall, many factors may affect a surgical patient, such as fluid deletion, anemia, immunosupression, radiation, and decreased wound healing. Studies of operative procedures have shown increases in force and volume of venous bleeding in microgravity when compared to normal gravitational environments. Patients would also have to be watched when returning to a gravitational environment to lower the risk of future complications.

For now, it seems minor surgeries have a greater chance at succeeding while being performed in a space setting. For complex surgeries such as an appendectomy researchers are in debate about whether to perform these elective surgeries before one travels to space to reduce the risk of performing such surgeries in a space environment. Providing basic life support remains the most important issue of caring for space travelers. Continued extensive training will be necessary to learn the best and most effective ways to perform surgical procedures in space. Researchers still need to do more work to see how cells react in microgravity to gain a better understanding of more complex processes such as wound healing and bone and muscle physiology. If future space travelers can train within simulated microgravity environments, more medical experts will have a greater understanding of a wider set of medical questions and what needs to be done to decrease one's surgical risk during space travel.

ADVANCES IN MEDICAL TECHNOLOGY THAT HAVE RESULTED FROM SPACE EXPLORATION by Jodi B Farmer

Photo courtesy of NASA.

At about 100 meters from the cargo bay of the space shuttle Challenger, Bruce McCandless II was further out than anyone had ever been before. Guided by a Manned Maneuvering Unit (MMU), astronaut McCandless, pictured above, was floating free in space. McCandless and fellow NASA astronaut Robert Stewart were the first to experience such an "untethered space walk" during Space Shuttle mission 41-B in 1984. The MMU works by shooting jets of nitrogen and has since been used to help deploy and retrieve satellites. With a mass over 140 kilograms, a MMU is heavy on Earth, but, like everything, is weightless when drifting in orbit. The MMU was replaced with the SAFER backpack propulsion unit.

Space exploration is not just for exploring space and finding possible future habitats. It also has produced many benefits that assist in the quality of life on Earth. Many of the technological applications needed for space flight have helped improved humans' lives as well. One example includes the Hubble Space Telescope. The Charge Coupled Device (CCD) chips for digital image breast biopsies is one spinoff created from the telescope. The LORAD Stereo Guide Breast Biopsy system uses CCDs as part of a digital camera system. The device can view breast tissue more clearly and efficiently that any other existing technologies and are so advanced that they can detect the smallest differences between malignant or benign tumors without a biopsy. Since more than 500,000 women every year need breast biopsies, this technology has not only allowed for a less invasive and traumatic procedure, but has created economic benefits as well by reducing the cost and time of the procedure.

Other space technology spinoffs also have improved the lives of mankind. Laser angioplasty offers fewer complications and a more precise nonsurgical cleaning of clogged arteries than a balloon angioplasty. The ultrasound skin damage assessment uses NASA technology to survey damage depth of burn patients. Using NASA's technology, the programmable pacemaker allows the implant and physician's computer console to communicate through wireless telemetry signals; and a cool suit circulates coolant through tubes to lower a patient's body temperature. This technology made from space suits helps improve the conditions of multiple sclerosis, cerebral palsy, and spina bifida.

Through NASA teleoperator and robotic technology, a voice-controlled wheelchair and manipulator responds to 35 one-word commands that helps patients perform daily tasks, such as turning on appliances and opening doors. Other space technology advances include the human tissue stimulator, which helps a patient control chronic pain and involuntary motions through electrical stimulation; ocular screening, which helps detect vision problems in young children; the medical gas analyzer that monitors operating rooms for the amount of anesthetic gasses and measurements of oxygen, carbon dioxide, and nitrogen during surgery; as well as portable X-ray devices, invisible braces, MRI equipment, bone analyzers, and cataract surgery tools.

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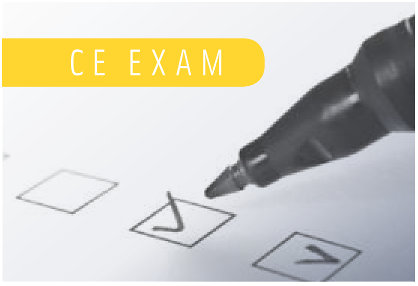

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Surgery for Space Exploration

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1. ___ is the study of the effects of space on the human body.
- **a.** Space medicine
- **b.** Aerospace physiology
- **c.** Spaceflight deconditioning
- **d.** Long-term exposure

2. ___ are among the most common changes the body experiences during space flight.
- **a.** Neurovestibular deficiencies
- **b.** Musculoskeletal deficiencies
- **c.** Immune deficiencies
- **d.** All of the above

3. Hypervolemia causes all but ___.
- **a.** Decrease in plasma volume
- **b.** Increase in red blood cells
- **c.** Reduced cardiac volumes
- **d.** Increased risk for arrhythmias.

4. Light-headedness and fainting are associated with landing day due to ___.
- **a.** Orthostatic stress
- **b.** Immune deficiencies
- **c.** Spaceflight deconditioning
- **d.** Body fluid redistribution

5. The most common medical condition experienced by astronauts is ___.
- **a.** Spaceflight deconditioning
- **b.** Facial pallor
- **c.** Space motion sickness
- **d.** None of the above

6. Spending two weeks in space can diminish a person's muscle mass by ___.
- **a.** 5% **c.** 15%
- **b.** 10% **d.** 20%

7. Muscle loss can be mitigated with ___.
- **a.** Preflight exercise
- **b.** Exercise during flight
- **c.** Nutritional supplementation
- **d.** All of the above

8. Blunt and penetrating trauma requiring surgery is unlikely to occur during ___.
- **a.** Launch procedures
- **b.** Space walks
- **c.** Vehicle docking
- **d.** Servicing payloads

9. The physical risk of ___ injuries is increased in space.
- **a.** Dental **c.** Orthopedic
- **b.** Psychological **d.** Minor

10. Obstacles for performing space surgery include limited ___.
1. Water
2. Physical space on board
3. Disinfectants
4. Oxygen
- **a.** 2 and 3 only
- **b.** 1 and 2 only
- **c.** 1,2 and 3 only
- **d.** All of the above

11. ___ is a preferred anesthetic for use in space.
1. Local **3. Spinal**
2. Inhalational **4. Intravenous**
- **a.** 1 and 4 only
- **b.** 1 and 2 only
- **c.** 2 and 3 only
- **d.** 1, 3 and 4 only

12. Challenges facing space surgery patients include ___.
- **a.** Decreased wound healing
- **b.** Radiation
- **c.** Anemia
- **d.** All of the above

13. Konstantin Tsiolkovsky is considered the ___.
- **a.** Father of space surgery
- **b.** Father of Cosmonautics
- **c.** First space surgery patient
- **d.** First astronaut

14. There is no gravity in space.
- **a.** True
- **b.** False

15. The mass of objects affected by microgravity ___.
- **a.** Increases
- **b.** Decreases
- **c.** Remains the same
- **d.** Fluctuates

16. Protein loss in space can be ___ that of people on bed rest on Earth.
- **a.** Three times
- **b.** Equivalent to
- **c.** Less than
- **d.** None of the above

17. Acute radiation syndrome is not caused by ___.
- **a.** Large solar particle events
- **b.** High levels of solar activity
- **c.** Exposure to high doses of solar radiation
- **d.** High risk of hemorrhaging or death

18. When something "floats" in space, it is due to ___.
- **a.** Microgravity
- **b.** Optical Illusion
- **c.** Zero gravity
- **d.** All of the above

19. Resistance exercise and vitamins D and K are recommended during flight to combat ___.
- **a.** Muscle atrophy
- **b.** Bone demineralization
- **c.** Immune dysregulation
- **d.** All of the above

20. NASA technology has been used on Earth to ___.
- **a.** Clean arteries nonsurgically
- **b.** Manipulate voice-controlled wheel-chairs
- **c.** Create portable X-ray devices
- **d.** All of the above

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Mark one box next to each number.
Only one correct or best answer can be selected for each question.