REVIEW

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The Place of Urology in Aerospace Medicine; A New Horizon

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Abstract

In space, the special conditions of microgravity and exposure to cosmic radiation make substantial alterations compared to terrestrial circumstances to the human body and organ functions. This review will try summarizing the recent development in the urological aspect of the microgravitational environment and aerospace medicine despite the limited data as the topic. Aerospace has effects on kidney physiology, body fluid, urination, and fertility. The overall renal response to microgravity can be summarized as is the retention of sodium, edema, decreased blood volume, and an increase in the sympathetic tonus. Also, microgravitational environments facilitate urinary tract infections. Changes in urine volume, urinary pH, and urinary citrate, calcium, and oxalate levels during a flight may predispose to urolithiasis. The urological conditions necessitate special expertise in the field of space medicine. New technologies are also needed to develop providing better service in the field of urological space medicine.

Keywords: Urology, microgravity, space

INTRODUCTION

It has been almost half a century since Neil Armstrong, the NASA astronaut, walked on the moon's surface and spoke the phenomenal words "That's one small step for a man. One giant leap for human beings" (1). Nowadays, the steps of human beings are approaching Mars. Because of this effort, our species will eventually be an interplanetary species. This great success brings many different problems that need to be solved. There are two major parts of an aerospace mission. One is the vehicle and engineering problems, and the other is the crew and the physiological problems.

Homo sapiens evolved under gravitational forces. The physiology of the body faces the gravitational force in every aspect of life. The bones, blood pressure, muscle strength, the vertical position of the body, lungs, almost up to cell diffusion pressures, the gravitational forces must be in the equation.

As healthcare professionals, we must think, read, research and at least develop some hypotheses about the upcoming health issues in aerospace. This effort has started by Dr. Abraham T.K. Cockett et al. (2) who firstly published the urologic implications in zero gravity. This review will try summarizing the recent development in the urological aspect of the microgravitational environment and aerospace medicine despite the limited data as the topic.

Kidney Physiology, Body Fluid, and Microgravity

Renal adaptation in space has been studied during various space missions since the early 70s. Different hypotheses are suggested explaining water and electrolyte homeostasis. Alternative simulation models have also been suggested such as head-out water immersion, head-down bed rest, supine lying, and parabolic flights for human and tail-suspended rats for animals. However, the physiology of humans showed differently in the earth, in the lab, and in space (3,4).

The recent hypothesis about the adaptation of the human body to the non-gravity environment splits the process into acute and chronic phases. In the acute phase, the body fluids move up to the cephalad locations of the body in the early period of the flight (5).

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The overall result of the redistribution of the fluids to the head, neck, and thorax area is the dilatation of the small veins and astronauts have puffy faces. This alteration causes such symptoms as nasal congestion, headache, the elevation of intraocular pressure, and photophobia (6). Despite these alterations, because of the disappearance of the gravitational forces, central venous pressure is decreased and the left atrium capacity and central blood volume are increased (5).

During the chronic phase of the adaptation, the body weight remains the same while the effective blood volume decreases markedly and the activity of the renin-angiotensin-aldosterone system also increases. The overall renal response in the chronic phase to microgravity can be summarized as is the retention of sodium, edema, decreased blood volume, and an increase in the sympathetic tonus (7).

Voiding in Space

On a normal day on earth regular person void 6-8 times per day. However, voiding in space is fundamentally different from the earth in terms of physiology, collecting, recycling, or eliminating urine. It is an obligation to produce reliable solutions for urination, which is a physiological requirement repeated 6 to 8 times a day, suitable for extraterrestrial conditions.

In space, the lack of gravity influence the urine in the bladder. Normally on earth, urine collects at the bladder neck, while in space it adheres to the bladder wall. The surface tension is the major force for the urine. Thus, the sensation for urination triggers only when the bladder is completely full. In the continuation, negative pressure helps capillary action for the urine transport from the bladder to the outward (8,9).

The difference in the environment may cause urinary retention occasionally. There was a considerable number of acute urinary retention (AUR) events reported during space flights. The importance of AUR in space is an emergency that should be intervened immediately and may also cause a mission cancelation. The pathophysiology of the AUR was attributed to different mechanisms. The altered sensation of the urination, anticholinergic effects of the antiemetic drugs such as scopolamine and promethazine taken for space motion sickness, and possible unidentified voiding dysfunction were the major reported causes of AUR There was one prolonged AUR (more than 24 h) reported in astronauts who visited the orbit and required catheterization (10,11).

Despite there being no mission cancelation reported due to AUR, percutaneous bladder catheterization had been tested in microgravity. Jones et al. (12) had conducted the study and tested the feasibility of suprapubic catheterization on the anesthetized porcine model, in a scenario of a urethral catheterization is impossible. They also had used ultrasonography to facilitate the puncture. According to their reported result, suprapubic bladder drainage is a safe and effective method in microgravity in case of an emergency (12).

Another problem with the voiding in space is collecting the urine. In the first American space flight on the 5th of May, 1961, there was no urine collection system in the pressurized space suit. The mission duration was planned for only 15 min. However, unplanned delays caused the astronaut Alan Shepard to had to wait for 4 h on the launch pad and his body, naturally, continued to function. As a result, the land crew told the astronaut to do it in the space suit without any idea about the consequences of the electronics of the suit (13).

In early versions of space suits, there was no urine collecting system. Consequently, developers have planned to use urethral catheters for continuous drainage of the urine. However, this solution was harmful to astronauts due to being uncomfortable, non-hygienic, and could result in infection. Different urine collecting devices were developed in the logic of a condom shape cap, a connector, and a collecting bag. However, all designs were incapable of collecting the urine properly in the absence of gravity. Leakage, the flow of urine in one way in a pressurized suit, positioning the collecting bag, and cleaning the system were the major tackles. Recently, female astronauts were added to the crew and the developed systems were not suitable for female anatomy (8,13). Despite some efforts to develop a female version of a urine collecting device, it was not used widespread (14).

In the research to develop a gender-neutral urine collection method, the point is to use maximum absorbency garments with additional moisture wicking capability which is also called “space diapers”. These garments look like bike shorts and collect up to 2 liters of liquid and, worn by both male and female astronauts during launch, reentry, spacewalks, and emergencies (8).

Urinary Tract Infections

One of the important points in a long-term space flight is to maintain the health of the astronauts. It has been shown that space flights cause a state of immunosuppression (15). Also, virulence and antibiotic resistance of microorganisms is increased in a microgravitational environment (16-18). These factors facilitate a urinary tract infection during a space mission. Consequently, there were different types of genitourinary infections reported during space flights such as pyelonephritis or prostatitis. However, none of them caused early termination of the mission and were treated successfully with antibiotics (9). The resources of a space shuttle are limited to diagnosing a urinary tract infection whereas the international space station has resources that allow through biochemical analysis of the blood or urine. Also, basic ultrasound can be performed with the guidance of ground control to diagnose a complicated factor such as urinary tract calculi. Different antibiotic options including broad-spectrum intravenous antibiotics exist in the international space station (19,20).

Urolithiasis in Space

Urolithiasis is an important medical condition that should be considered not only to impact the astronaut's health but also to affect the continuation of the mission. Various studies and reports showed that total urine volume, urinary pH, and urinary citrate decreased and urinary calcium and oxalate increased during a space flight (21). These alterations could depend on the limited intake of water, lack of fruit, and fresh vegetables (as a source of citrate), decreased vitamin D levels (decreased ultraviolet light exposure), limited mobilization (bone demineralization) (22,23).

Most of the space flight crew members developed stone after the mission. There were 12 NASA astronauts and 1 Russian cosmonaut who developed renal stone (21). None of the renal stone events have caused the cancelation of the mission. However, efforts remained to prevent the development of urolithiasis in astronauts during space missions. Whitson et al. (24) showed the efficacy of potassium citrate intake to prevent the development of renal stone in astronauts in their double-blind, placebo-controlled study. Besides the preventive efforts, a compact system to diagnose, burst, and reposition the stone has been developing (25). The goal is to redefine the kidney stone from an uncontrolled factor to a controlled component of space flight.

Fertility in Space

The magnetosphere layer of our planet protects all creatures living on earth from the radioactive effect of highly ionized heavy particles coming from space. However, during a space flight, radiation exposure is increased which has potential consequences such as nuclear damage (26). It has been shown that 150 mSv and 650 mSv radiation in men and women, respectively, to the gonadal tissues are sufficient to cause temporary infertility (27). Experiments on animals showed that short-term space flight does not influence the cytoskeletal of sperm-specific proteins while there are changes at the gene expression level (28). However, a different experimental animal study in mice claimed that long-term space flight causes degenerative changes in the seminiferous tubules and the reduction of the number of epididymal sperms (26).

These data suggest that the reliable solution for reproduction in space is to protect both male and female gametes from exposure to space radiation. Another experimental study demonstrated that the freeze-dried spermatozoa which are protected from space radiation in a special vehicle could be used to generate offspring (29). The future of human beings in space seems to be related to the improvements in assisted reproductive technologies.

CONCLUSION

Human beings are closer than ever to becoming an interplanetary species. Advances in space travel are pushing the boundaries of medicine in this regard. The urological conditions necessitate special expertise in the field of space medicine. New technologies are also needed to develop providing better service in the field of urological space medicine. This field, which is still in its infancy, can become popular in close future.

Ethics

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Authorship Contributions

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