NASA-STD-3001 Medical Technical Brief

Urinary Health

OCHMO-MTB-003
Rev A

Executive Summary

Spaceflight is associated with many factors which may promote kidney stone formation, urinary retention, and/or Urinary Tract Infection (UTI). According to the International Space Station (ISS) mission predictions supplied by NASA's Integrated Medical Model, kidney stone is the second most likely reason for emergency medical evacuation from the ISS, with sepsis (urosepsis as primary driver) being the third. Alterations in hydration state (relative dehydration), spaceflight-induced changes in urine biochemistry (urine super-saturation), microgravity-induced alterations in fluid dynamics and position of abdominal structures, and changes in bone metabolism (increased calcium excretion) during exposure to microgravity may all contribute to the increased risk of urinary health issues. This medical technical brief describes the conditions of urinary retention, UTIs, and renal stones, and how they are affected by spaceflight conditions as well as outcomes and countermeasures used to prevent them.

Relevant Technical Requirements

NASA-STD-3001 Volume 1, Rev C

[V1 3001] Selection and Recertification
[V1 3002] Pre-Mission Preventive Health Care
[V1 3003] In-Mission Preventive Health Care
[V1 3004] In-Mission Medical Care
[V1 3007] Medical Evacuation
[V1 3008] In-Mission Evacuation to Definitive Medical Care
[V1 3016] Post-Mission Health Care
[V1 3018] Post-Mission Long-Term Monitoring
[V1 4019] Pre-Mission Nutritional Status
[V1 4020] In-Mission Nutrient Intake
[V1 4022] Post Mission Nutritional Assessment and Treatment
[V1 4027] In-Mission Bone Countermeasures

NASA-STD-3001 Volume 2, Rev E

[V2 6004] Nominal Vehicle/Habitat CO_2 Levels
[V2 6026] Potable Water Quality
[V2 6109] Water Quantity
[V2 7001] Food Quality
[V2 7022] Body Waste Management Privacy
[V2 7023] Body Waste Management Provision
[V2 7024] Body Waste Accommodation
[V2 7035] Urine per Crewmember
[V2 7038] Physiological Countermeasures Capability
[V2 7043] Medical Capability
[V2 7100] Food Nutrient Composition
[V2 7102] Body Waste Quantities
[V2 11013] Suited Body Waste Management
[V2 11014] LEA Suit Urine Collection
[V2 11028] EVA Suit Urine Collection
[V2 11029] LEA Suited Hydration
[V2 11030] EVA Suited Hydration

Physiology

Spaceflight is associated with many factors which may affect crewmember urinary functions/health. Urinary retention, renal stones, and UTIs are all identified as conditions that can be challenged by the spaceflight environment and cause increased risk to crew health and mission outcomes.

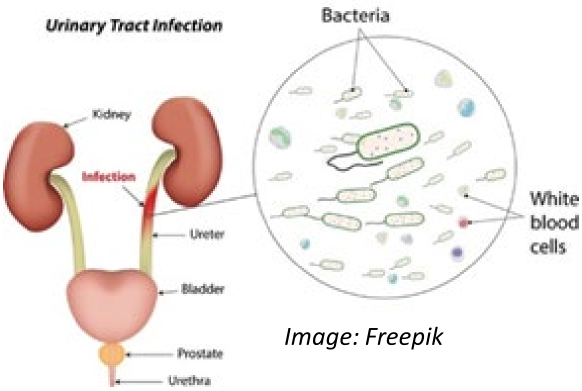


Image: Freepik

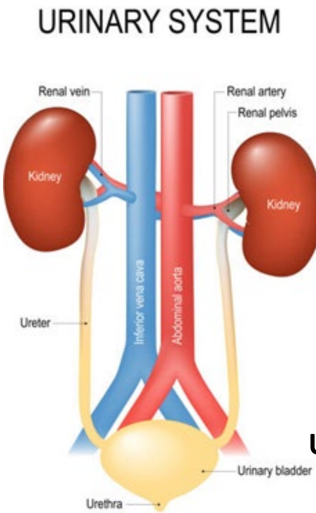


Image: iStock

Renal stones are aggregates of crystals that form in urine supersaturated in minerals, causing hard deposits in the kidneys.

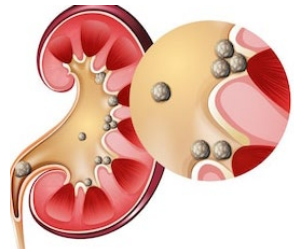


Image: Freepik

UTI is a bacterial infection that occurs when bacteria enters the urinary tract and grows there. The urinary tract includes the kidneys, ureters, bladder, and urethra.

Urinary Retention is the inability, hesitancy, or difficulty in initiating urination.

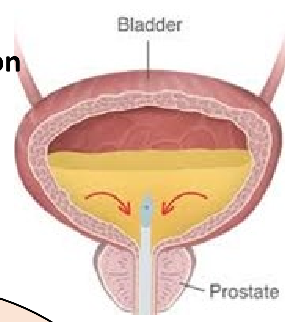


Image: NIDDK 30

<u>Spaceflight Urinary Health Factors</u>

Anatomical/Physiological

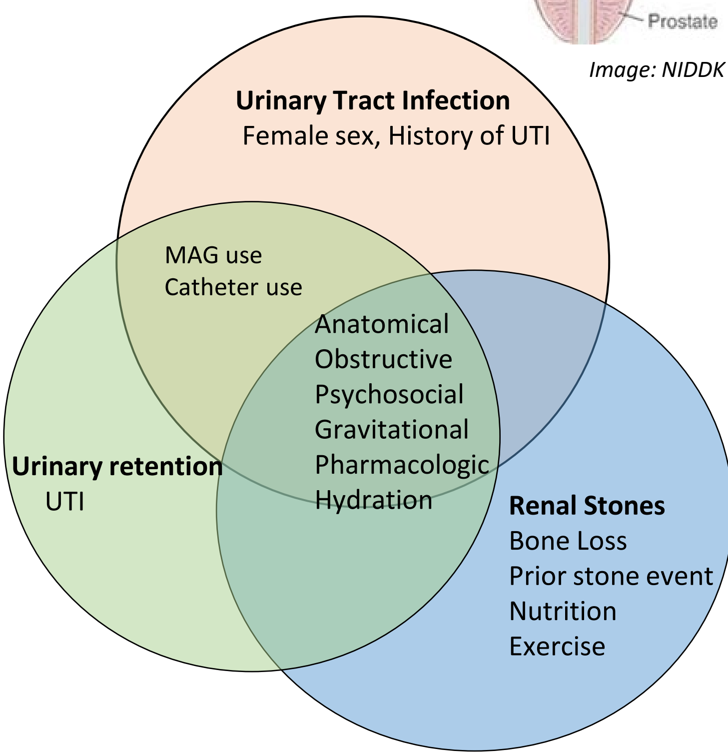
- Male/Female
- Age
- Anatomical obstruction
- History of renal stones
- Psychosocial
- Neurogenic
- Bacterial infection/hygiene

Spaceflight Environment

- Gravitational effects
- Mission duration
- Mission conditions
- Bone loss

In-Mission Activity

- Catheter use
- Nutrition
- Pharmacologic
- Dehydration
- Exercise
- Use of Maximum Absorbency Garment (MAG)



This Medical Technical Brief is derived from NASA-STD-3001 and NASA medical operations and is for reference only. The aim of this Medical Brief is to share clinical knowledge and provide best practices, not to deliver direct medical care recommendations or guidance for individuals.

Physiology

Urinary Health Definitions

Anatomical/obstructive	The structure of female urethras make it easier for bacteria to enter the bladder due to urine splash back, especially when wearing a Maximum Absorbency Garment (MAG). Male obstructive challenges include benign prostatic hyperplasia blocking urine flow and increased urinary retention.
Urine chemistry	Urine chemistry (calcium, potassium, citrate, oxalate and other substances) determines probability that Mineralized Renal Material (MRM) will precipitate from urine and increase stone risk.
Psychosocial effects	Crew may be hesitant to urinate or use MAG, especially at start of flight, leading to urinary retention and associated complications.
Maximum Absorbency Garment (MAG)	Diaper-like device that astronauts wear when they can't take off their spacesuits for extended periods of time. MAGs are worn during liftoff, landing, and spacewalks.
Hydration	Water availability and intake affect risk of renal stones and UTIs.
Spaceflight bone loss	Lack of gravity (skeletal loading) can cause bone and calcium secretion into urine, increasing renal stone risk.
Gravity	Alterations in fluid dynamics and gravitational pull on abdominal organs may increase risk of urinary retention.
Pharmacologic	Anticholinergic medications often used to prevent space adaptation sickness can interfere with normal bladder function causing urinary retention.
Nutrition	Nutrient intake of substances such as oxalate, calcium, magnesium, etc. affect urine chemistry.
Urinary Tract Infection (UTI)	Logistics of MAG use, catheter use, and toileting can increase exposure to bacteria and risk of UTI. Serious or untreated UTI can lead to sepsis.
Nephrolithiasis	Presence of crystalline stones (calculi) within the urinary tract..
Ureterolithiasis	Presence of calculi within the urinary system.
Waste and hygiene compartment	Urine goes into hose, drawn by vacuum into disposal or recycling system. Toilet for solid waste consists of seat and bucket design with vacuum assist; waste is captured in plastic bag and closed after each waste event, can hold approximately 30 deposits.
Catheter	Crew can use catheters to treat urinary retention or other medical needs. Catheter use is associated with increased risk of UTIs.
Bladder obstruction	A physical condition that inhibits urine from flowing from the bladder.
Pyelonephritis/Sepsis	Pyelonephritis: UTI that affects one or both kidneys. Sepsis: life threatening condition when body's immune systems reacts to an infection that has entered the bloodstream, damaging body's tissues and organs.
Post Void Residual (PVR)	Urine left in the bladder after voiding, possibly due to decreased sensation to void due to change in gravity vector.
Urine supersaturation	A condition caused by too much salt and insufficient fluid in the urine.

Reference the following for additional information: OCHMO-TB-031 Exercise, OCHMO-TB-027 Water, OCHMO-TB-013 Food & Nutrition, OCHMO-TB-042 Waste Management, OCHMO-TB-030 Bone Loss

Pathophysiology

"Renal stones are aggregates of crystals formed in urine supersaturated in salt components, causing hard mineral deposits to occur in the kidneys. Renal stones are most often composed of calcium oxalate, uric acid, struvite, and cystine. Nephrolithiasis is the condition marked by development of renal stones."
NASA HRP Evidence Report Risk of Renal Stone Formation

Terrestrial conditions that exacerbate renal stones

- Dietary: high animal protein/purine rich intake
- Dehydration: insufficient water intake
- Bone increases calcium excretion and risk of calcium oxalate stones
- Infections: UTIs change urine pH and increase risk of stones
- Family history
- Previous episodes: 60% will have reoccurrence

NASA STS-107 Space Research

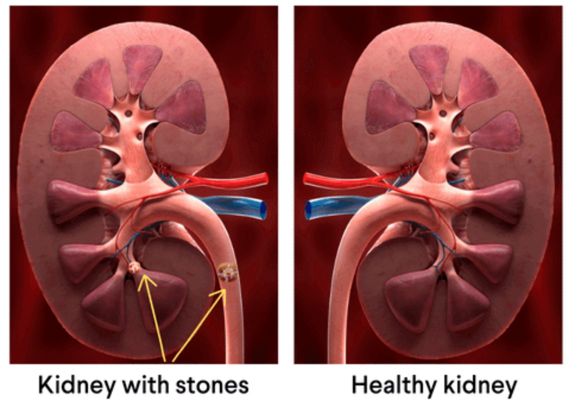


Image: Florida Urology Center

Calcium Oxalate Stones
Image: NASA

Renal stones are often small and go unnoticed, however stones become problematic when they increase in size causing pain, blocking the drainage of the kidney and causing urinary obstruction, affecting kidney function and increasing risk of UTIs. Potential complications include:

- Renal colic (pain)
- Hematuria (blood in urine)
- Infection/sepsis
- Hydronephrosis due to excess backed up urine

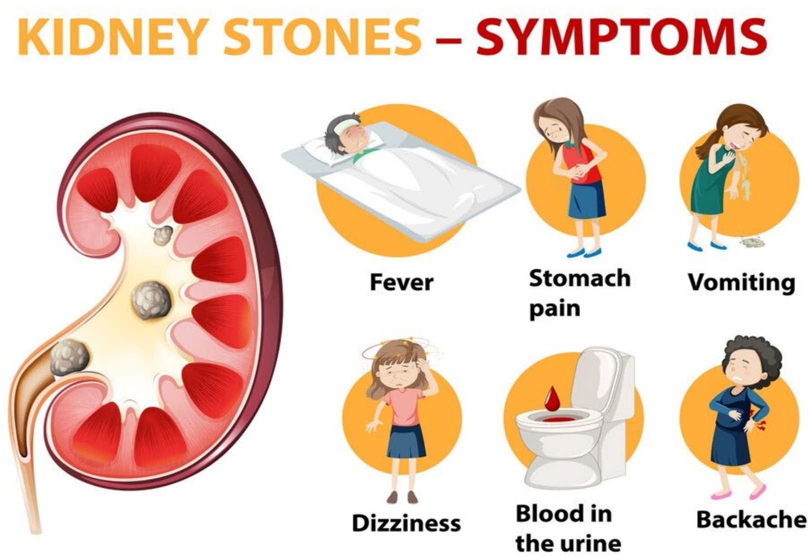


Image: Free Vector

Renal stone screening: History of renal stones were once a disqualifying condition for potential astronauts. Currently, astronauts are individually evaluated and assessed with ultrasound and MRI prior to flight. If evaluation determines an acceptable renal stone risk profile, they may be cleared to fly. The protocol will be evaluated for longer duration Moon/Mars missions.

Pathophysiology

Risk of Renal Stone Formation – "Given changes in urinary biochemistry during spaceflight, there is a possibility that symptomatic renal stones will occur, which could cause renal colic (pain), nausea, vomiting, hematuria, infection, and/or hydronephrosis." *NASA HSRB Renal Stone Risk (2022)*

Spaceflight conditions that increase Renal Stone risk:

- Altered gravity/weightlessness increases bone resorption/loss and increases urinary calcium.
- Fluid changes including cephalad fluid shift.
- Decreased water intake
- Altered bladder habits; i.e., self-imposed dehydration to avoid time-consuming toileting
- Changes in nutrient intake including high sodium and high animal protein.
- Changes in urinary pH and solute concentrations can affect urine chemistry.

Human Adaptation to Spaceflight: The Role of Food and Nutrition Scott et al.

Renal Stone Screening Profile: A renal stone risk profile is generated preflight based on urine volume and chemistry. These data are used to determine the risk of supersaturation, which could lead to one or more of several types of kidney stones.

Pre-flight Assessment: calcium oxalate, brushite, sodium urate, struvite, uric acid supersaturation

Pre/Post-flight Measurement: calcium oxalate, uric acid, citrate, pH, total volume, sodium, sulfate, phosphorus, magnesium, potassium, creatinine

Monitoring/Management of Renal Stones – Terrestrially, renal stones are detected using renal ultrasound, CT imaging, and lab work including white blood count (indicates infection) and kidney function (creatinine, blood urea nitrogen, and blood chemistries). Pre-flight and post-flight renal ultrasound are standard. If renal stones are suspected in-flight, ultrasound and limited lab work can detect and help enable stone risk management. Promising technology (e.g., propulsive ultrasound, burst wave lithotripsy) is being studied for the possibility of manipulation of stones, moving or breaking them up to assist with in-flight stone elimination or symptom reduction. NASA has tested (picture below) guided ultrasound testing software (*AMOS*) to better enable non-physician astronauts to scan and monitor for kidney stones.

Image (left): NASA astronauts using AMOS (Autonomous Medical Officer Support) kidney stone ultrasound software.

Ultrasound image of kidney stone
Source: SpringerLink

Pathophysiology

To date there has been one reported episode of nephrolithiasis during spaceflight; a cosmonaut experienced severe lower abdominal pain that spontaneously resolved. No USOS crewmembers have reported kidney stones while in flight. A total of 43 stone events in 29 crewmembers have been recorded by NASA since 2016. *NASA Evidence Report Risk of Renal Stone Formation HRP ExMC 2017, NASA HSRB Renal stone Risk package LSAH Surveillance Data 2022*

Urinary Tract Stone Events in the Astronaut Corps

Time	Total # of Events
Early NASA Career	4
In-flight	0
Post-flight	8
Between-flight	6
R>360 days after spaceflight	2
Post Flight Career	23
Total	43

NASA HRP 2024 Renal Stone Evidence Report

Terrestrially, the annual prevalence of renal stones is approximately 9% in the United States. The terrestrial rate is higher in men (10.6%) than women (7.1%). *Prevalence of Kidney Stones in the Unites States Scales (2013)*

NASA's Chris Cassidy explains some of the challenges of toilet design in space:
How to use the Bathroom in Space
From: NASA Johnson (YouTube)
https://youtu.be/3VoeRAR0YgE

Microbial Tracking-2 by the toilet in the node 3 module, that monitors microbes present to assess the ISS and understand the effects of the spaceflight environment on viral and microbial pathogen dynamics. *Image: NASA*

Toilet design and toileting challenges (shown above) can contribute to urinary retention and urinary tract infection risk during spaceflight.

Pathophysiology

Countermeasures/Treatment for Renal Stones:
- Pre-flight screening and selection measures detect problems prior to flight.
- Hydration - ensure crew has ample supply of water and is encouraged to drink an adequate amount.
- Exercise can preserve bone mineral density, decreasing the amount of stone forming calcium in urine.
- Manage the amount of stone forming substances including oxalate, calcium, magnesium, and salt contained in food.
- Pharmaceuticals - potassium citrate (Kcit) (Whitson et al., 2009) and thiazide (Reilly et al., 2010) directly affect urine chemistry and can prevent stone formation; bisphosphonates can affect bone remodeling and decrease calcium released into blood (Leblanc et al., 2013).
- Tamsulosin can relax ureter smooth muscle and allow stones to pass faster (Cui et al., 2019), NSAIDS and opioids can assist with stone pain, ondansetron can assist with nausea associated with stone pain.
- Catheter/nephrostomy tube can be used in cases of urinary retention to help drain fluid that is blocked.

Potassium Citrate (KCit) – provides an alkali influence, increasing urinary pH, decreasing urinary calcium excretion and calcium oxalate supersaturation, ultimately decreasing risk of renal stones. KCit and potassium magnesium citrate supplements have successfully reduced the number of incidents of renal stones during bed rest studies, and KCit is now available on ISS for use at the flight surgeon's discretion if clinically indicated. The size and potential volume of KCit tablets for an astronaut crew is a challenge to spaceflight programs. *Whitson 2009.*

Bisphosphonates – inhibit osteoclastic bone resorption and increase osteoclast apoptosis which decreases bone breakdown, decreasing calcium in urine and ultimately renal stones. Bisphosphonates have been studied in long-duration astronauts and the data collected from these studies suggest that this class of drug reduces the loss of trabecular bone mineral density and helps preserve total bone mass in space as well as prevent hypercalciuria (and renal stone formation). Bisphosphonates are associated with significant side effects including osteonecrosis of the jaw (ONJ), atypical femur fractures, esophageal complications, and kidney changes. *(Rosenthal 2024)*

Water Quantities and Temperatures

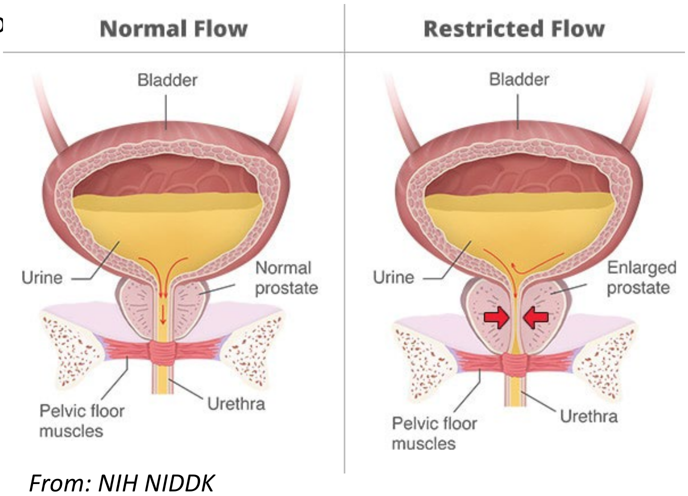
Requirement	Quantity	Hot Temperature	Nominal Temperature	Cold Temperature
Potable Water for Hydration	Minimum 2.5 L per crewmember	Between 68 °C – 79°C	Between 18 °C – 27 °C	Maximum temp of 16 °C
Potable Water for EVA Operations	Minimum 240 ml per crewmember /EVA hour	Between 68 °C – 79°C	Between 18°C --27 °C	Maximum temp of 16 °C

From: NASA-STD-3001 Volume 2

Hydration is a countermeasure to Renal Stones supported by:
Water Quantity [V2 6109]
The system **shall** provide a minimum water quantity as specified in the Table (modified left), for expected needs of each mission, considered mutually independent.

Pathophysiology

Urinary Retention is the impaired ability to urinate due to mechanical or functional obstruction of urinary tract, including hesitancy or difficulty to initiate urinatio



From: NIH NIDDK

Urinary Retention Predisposing Factors

9 cases of urinary retention have been documented during spaceflight-the potential causes include:

- Obstructive (anatomical) i.e., enlarged prostate
- Psychosocial – retention due to schedule and toilet access *i.e.*, not wanting to use MAG
- Infection (UTI)
- Altered Gravity Vector – Post Void Residual (PVR) is urine left in the bladder after voiding. PVR may be due to decreased sensation to void due to change in gravity vector. PVR is not considered urinary retention but can lead to UTI and retention
- Pharmacologic – anticholinergic use
- Radiation, hostile closed environment, and isolation and confinement can increase inflammation which can increase risk
- Urinary muscle changes that occur in altered gravity environments
- Age, sex, and genetic predisposition
- Retention risk increased on post-flight day 1; this could impact planetary missions upon landing on celestial bodies

P<0.01	Retention Rate	95% Confidence Limits	
Female	**0.0510**	0.0217	0.1151
Male	**0.0111**	0.0053	0.0230

NASA HSRB Risk of Urinary Retention Rev A.3

- The odds of developing urinary retention in-flight are 4.5x higher among female astronauts, which is very different from terrestrial data and may be attributed to the altered gravity vector, limited bathroom facilities, MAG use, and psychosocial factors
- Terrestrially, urinary retention ratio is 10 Male to 1 Female. Urinary retention in men becomes more common with age, often related to prostate gland issues
- Other causes (independent of gender) include neoplasms, trauma, acute inflammation, damage to nerves that supply the bladder, and spinal cord trauma (neurogenic retention)

Management of lower urinary retention in a limited resource setting. Ugare et al.

The higher prevalence of spaceflight urinary retention in females is even more concerning given that there have been many more males in space than females.

	Shuttle	ISS	Catheter Required	EVA Related	SMS Med Usage
Urinary Retention	8	1	4	1	7
Bladder fullness/pressure	2	0	0	0	1
Difficulty initiating/hesitancy	5	0	0	1	4
Total	15	1	4	2	12

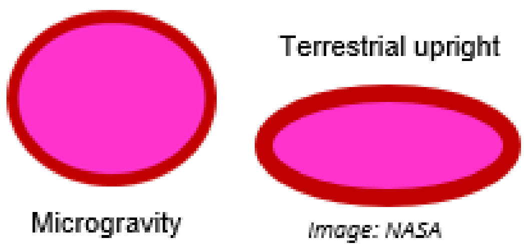
9 cases of urinary retention have been documented in-flight, 16 total if symptoms suggestive of urinary retention are included.

NASA HSRB Risk of Urinary Retention Rev A.3

Pathophysiology

NASA Risk of Urinary Retention
Given that the spaceflight environment alters the gravity vector involved in terrestrial urination and causes physiological changes that may require use of medications, and that mission operational schedules may limit access to voiding, there is a possibility of performance impact during spaceflight due to significant discomfort from urinary retention and associated UTI. Symptomatic urinary retention happens in flight and on landing day.

Bladder shape changes in microgravity



Bladder physiology in space: The impact of bladder physiology is uncertain. One theory is lack of gravity influences urine in the bladder. Terrestrially, 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. *The Place of Urology in Aerospace Medicine Mar 2022*

Consequences of urinary retention: UTIs, pyelonephritis (kidney infection), and potentially sepsis if untreated. Renal colic, retention pain, and hydronephrosis can result from urinary retention or urine flow disruption. All of these if untreated can potentially lead to acute renal failure with implications for evacuation, loss of crew life, and long-term health issues including permanent bladder dysfunction and long-term renal failure.

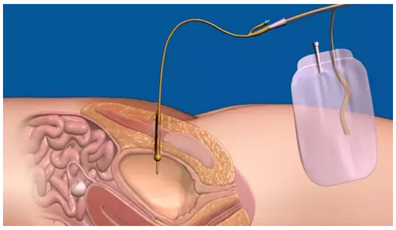
Countermeasures and Treatment:
- Catheter use
- Pharmacologic – tamsulosin increases urine flow
- Percutaneous bladder catheterization – has been studied but to date has not been used

Normal Catheter
Image: *Shutterstock*

Catheter use can increase risk of UTI. Once an indwelling catheter is placed, the daily incidence of bacteriuria is 3-10% http://emedicine.medscape.com/article/

Catheter use challenges "To perform the procedure requires training and maintenance of proficiency, adequate supplies including disinfection swabs, lubricant, catheters, and collection devices. A private environment, patient ability to lie flat can be complicated by microgravity or aircraft ferrying a post-flight crewmember. The procedure can be time-consuming negatively impacting tight operational schedules." *Law & Cardy (2023) Pharmacological relief of acute urinary retention in a remote environment.*

Percutaneous bladder catheterization and drainage can be successfully performed in weightless conditions under ultrasound guidance. Ultrasound provides a low-power, portable means to safely guide minimally invasive procedures in pertinent organs and tissues.



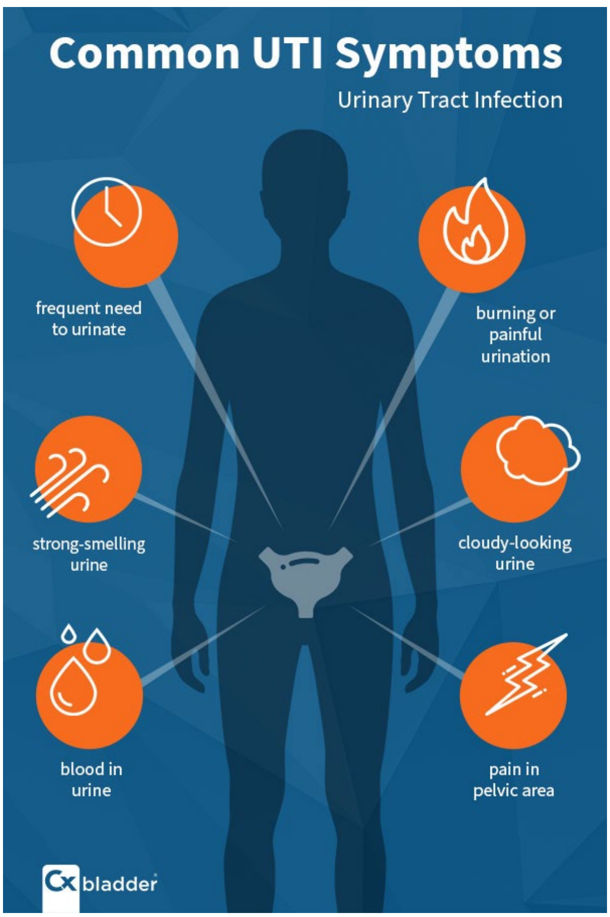
Suprapubic bladder catheterization
Image: Simtutor.com

Percutaneous bladder catheterization is a standard procedure when luminal bladder catheterization is not possible; this technique can be successfully modified for use in space medicine applications. *Percutaneous bladder catheterization in microgravity Jeffrey A. Jones et al.*

Pathophysiology

A urinary tract infection (UTI) is a bacterial infection that occurs in the urinary tract, including kidneys, ureters, bladder or urethra. Among all medical conditions, infections pose one of the biggest threats to astronaut health and mission success. UTIs are caused from bacteria, often from the large intestine traveling from the anus or other exposure to genital area skin, then into the urethra, bladder, and potentially kidneys if not treated early enough. Females are more susceptible to UTIs due to their shorter urethra.

The toileting conditions of spaceflight cause increased exposure to bacteria from wearing a MAG, PVR, and limited space in the toilet area making usual cleaning more difficult. In addition, urinary retention is treated with catheterization which increases risk of UTIs.



UTI Countermeasures and Treatment

- Antibiotics are the treatment of choice for UTI.
- Prophylactic antibiotic use can be considered, especially in susceptible patients or patients with catheter use.
- Hydration– staying hydrated can help prevent conditions that favor UTI development.
- Analgesics can help with pain/discomfort associated with UTI.

Possible challenges to antibiotics in space:

- Medication supplies can become depleted, shelf live issues and potentially decreased antibiotic effectiveness
- Potential for bacterial resistance
- Theoretical increased pathogen virulence
- Altered immune function
- Inadequately treated UTI may lead to pyelonephritis and sepsis evacuation or mission impact

Maximum Absorbency Garment (MAG). Diaper-like device that astronauts wear when they can't take off their spacesuits for extended periods of time. MAGs are worn during liftoff, landing, and spacewalks. *Image: NASA*

Using the MAG, especially for long duration exposure can cause irritation to the skin and increase urinary tract infection risk. The Orion contingency plan in the event of a depressed cabin is to spend a maximum of 144 hours in the suit, although a purpose-built waste contingency system is used instead of MAGs.

Treatment Guidance for NASA Astronauts

The guidelines discussed are made based on accepted standards of care, with deviations to account for the unique mission needs of NASA astronauts. The risks of the spaceflight environment require more frequent monitoring and aggressive treatment, particularly in astronauts that are assigned to an upcoming mission, than would otherwise be found with the usual practice of medicine.

1. All active astronauts will receive a yearly screening ultrasound specific for renal mineralized renal material (MRM).
2. All mission-assigned astronauts will get a screening ultrasound 6 months before launch.
3. All astronauts will get a screening ultrasound at one month after return.
4. All astronauts with any prior history of MRM will get yearly urine studies.
5. All CT scans should be done using radiation dosing as low as reasonably achievable (ALARA).
6. History of recurrent stones, multiple stones, metabolic abnormality, or anatomic abnormality will require evaluation by urology, and may be cause for restriction of flight duties.

Renal Stone Management Matrix

Annual Ultrasound *MRM found?*	Mission-Assigned Astronaut?*	
	No	**Yes**
No	No action	No action
Equivocal (size <3 mm)	24-hour Urine**	24-hour Urine**
Yes (size 3 to 6 mm)	24-hour Urine -AND- Urology Consult (Do not CT)	CT -THEN- Flexible Ureteroscopy
Yes (size > 6 mm)	CT -THEN- Urology Consult	CT -THEN- Flexible Ureteroscopy

*For astronauts assigned to a mission, ultrasound will also be conducted at L-6 months and R + 1 month. Due to the elevated risk of health complications due to renal stones during a spaceflight mission and difficulty or lack of ability for an emergency evacuation, astronauts who are assigned to a mission and are found to have a stone are treated more aggressively than nominal terrestrial guidelines.

**History of prior MRM/stone also requires an annual 24-hour urine study, regardless of MRM status.

Treatment Guidance for NASA Astronauts

Progression of small, asymptomatic stones:

1. There is a near linear relationship between stone size and rate of spontaneous passage, with the rate of passage decreasing as stone size increases.
2. Renal stones are often oblong in shape. The shorter dimension determines chance of spontaneous passage, while the longer dimension determines time to passage.
3. A 3 mm stone may take an average of 7 days to pass, with a range of 0 to 40 days.
4. Stones around 3 mm pass spontaneously on their own >90% of the time.
5. 3 mm provides a conservative cut-off point for treat / no-treat decisions.

Summary of treatment guidelines:

1. Flexible ureteroscopy (FURS) is the treatment method of choice, having direct visualization of the renal collecting system and a high stone-free treatment rate.
2. After treatment, an astronaut will have restricted flight duty for:
   a) 2 weeks following spontaneous passage
   b) 4 weeks after Extracorporeal Shock Wave Lithotripsy (ESWL) or FURS
   c) 12 weeks following invasive procedure, such as percutaneous nephrolithotomy (surgical removal of kidney stones)
3. Following invasive procedure, the managing urology consultant must clear the astronaut for return to duty.
4. All persons with history of stone must follow the guidance for prevention of stones, including an annual 24-hour urine study.

Waiver guidelines:

1. History of multiple stones, recurrent stones within one year, or metabolic or anatomic abnormalities are cause for restriction of flight duties
2. Anatomic abnormalities with a favorable urologic evaluation can be waived
3. Metabolic abnormalities normalized by preventive measures for at least 1 year and with a favorable urologic evaluation may be waived

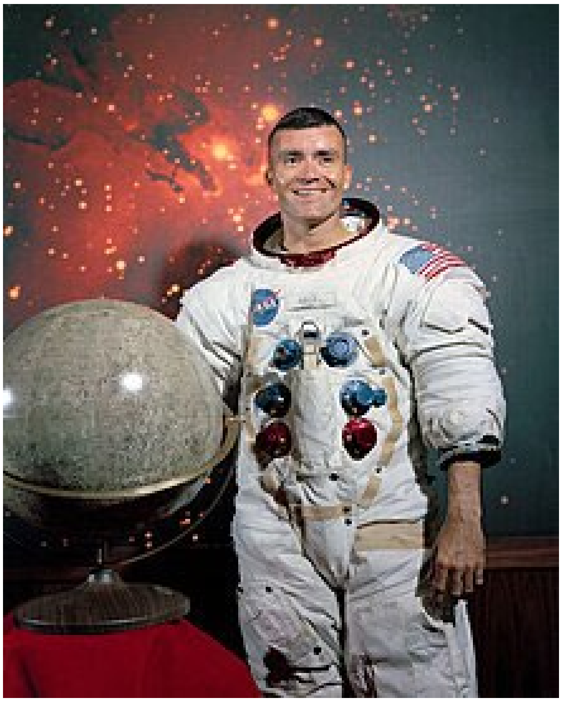
Due to the close medical scrutiny of NASA astronauts, the majority of MRM found have been small and asymptomatic. These incidental, asymptomatic MRM can be found within the renal parenchyma or collecting system, and if within the parenchyma, are likely to be non-mobile. Asymptomatic MRM found within the collecting system may fit the classic definition of a renal stone and are at risk to become symptomatic in the future.

- Renal stones occur in the astronaut population on par with the incidence in commercial aviation pilots, and at about half the rate of the general population
- Many astronauts had abnormal urine studies prior to diagnosis of renal stones
- Treatment and preventive measures have varied widely over time
- Monitoring parameters for stones have varied widely

Application

Apollo 13 Fred Haise

Fred Haise developed a serious UTI during Apollo 13. Haise became increasingly unwell during the last 4 days of the mission and was feverish during the final day. It is speculated that he developed a UTI, possibly from catheter use and the bacteria, *Pseudomonas aeruginosa*, spread to his kidneys, causing intense pain and threatening to infect other parts of his body.



Pseudomonas is an opportunistic pathogen that has difficulty infecting healthy people. However, astronaut bodies are under a lot of stress. For example, microgravity changes the way fluids distribute in the body and affects immune function. Additionally, on Apollo 13, Haise was faced with significant additional mental and physical stresses. Crammed into the Lunar Module after the Command Module lost power, he endured freezing temperatures and was dehydrated from water rationing, all while facing the very real possibility of not making it home.

"Numerous factors could have increased Haise's susceptibility to infection, including potential changes in the behavior of the pathogen itself and how it interacted with Haise's own suite of microorganisms—his microbiome. A growing body of evidence suggests that some microbes behave differently in space than on Earth, and space travel alters the microbiome of astronauts in ways not yet completely understood. Although Haise survived and had no lasting effects, a longer flight may have had grim consequences."
Microbial Hitchhiker's Guide to the Galaxy: Researchers race to understand effects of deep space on microbiome

NASA is researching the impact of space flight on pathogens to better understand their impact to crew, helping to prepare us for longer spaceflight, including multi year missions to Mars, which will pose new and unknown challenges to crew health.

Haise was treated with an antibiotic and made a complete recovery after landing. It is suspected that the infection could have become debilitating if the mission had lasted much longer.
Source: *Apollo Journal*

Back-Up

Major Changes Between Revisions

Original → Rev A

- Added information on *AMOS* (Autonomous Medical Officer Support) kidney stone ultrasound software (Page 5).
- Added information on guidance for treatment of NASA astronauts based on accepted standards of care, with deviations to account for the unique mission needs of astronauts.

View the current versions of NASA-STD-3001 Volume 1 & Volume 2 on the OCHMO Standards website

Referenced Technical Requirements

NASA-STD-3001 Volume 1 Revision C

[V1 3001] Selection and Recertification Crewmembers shall be medically and psychologically selected and annually recertified following the guidance in OCHMO-STD-100.1A, NASA Astronaut Medical Standards Selection and Annual Recertification.

[V1 3002] Pre-Mission Preventive Health Care Pre-mission preventive strategies shall be used to reduce in-mission and long-term health medical risks, including, but not limited to: (see NASA-STD-3001 Volume 1 Rev C for full technical requirement).

[V1 3003] In-Mission Preventive Health Care All programs shall provide training, in-mission capabilities, and resources to monitor physiological and psychosocial well-being and enable delivery of in-mission preventive health care, based on epidemiological evidence-based probabilistic risk assessment (PRA), individual crewmember needs, clinical practice guidelines, flight surgeon expertise, historical review, mission parameters, and vehicle derived limitations. These analyses consider the needs and limitations of each specific vehicle and design reference mission (DRM) with particular attention to parameters such as mission duration, expected return time to Earth, mission route and destination, expected radiation profile, concept of operations, and more. In-mission preventive care includes, but is not limited to: (see NASA-STD-3001 Volume 1 Rev C for full technical requirement).

[V1 3004] In-Mission Medical Care All programs shall provide training, in-mission medical capabilities, and resources to diagnose and treat potential medical conditions based on epidemiological evidence-based PRA, individual crewmember needs, clinical practice guidelines, flight surgeon expertise, historical review, mission parameters, and vehicle-derived limitations. These analyses consider the needs and limitations of each specific vehicle and design reference mission (DRM) with particular attention to parameters such as mission duration, expected return time to Earth, mission route and destination, expected radiation profile, concept of operations, and more. In-mission capabilities (including hardware and software), resources (including consumables), and training to enable in-mission medical care, and behavioral care, are to include, but are not limited to: (see NASA-STD-3001 Volume 1 Rev C for full technical requirement).

[V1 3007] Medical Evacuation Medical evacuation to a location with a higher level of medical care shall be available for illness/injuries occurring during a spaceflight mission, which are beyond the medical capabilities available at the crew's location.

[V1 3008] In-Mission Evacuation to Definitive Medical Care Plans and vehicle(s) shall be available to transport severely ill or injured crewmember(s) to appropriate Medical Care Facilities, including Definitive Medical Care Facilities (DMCF) in the event of a contingency scenario.

[V1 3016] Post-Mission Health Care Post-mission health care shall be provided to minimize occurrence of deconditioning-related illness or injury, including but not limited to: (see NASA-STD-3001 Volume 1 Rev C for full technical requirement).

[V1 3018] Post-Mission Long-Term Monitoring Crewmembers returning from spaceflight shall be monitored longitudinally for health, behavioral health, and well-being parameters in a standardized manner.

[V1 4019] Pre-Mission Nutritional Status Pre-mission nutritional status shall be assessed, and any deficiencies mitigated prior to launch.

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[V1 4020] In-Mission Nutrient Intake Programs shall provide each crewmember with 100% of their calculated nutrient and energy requirements, based on an individual's age, sex, body mass (kg), height (m), and an appropriate activity factor.

[V1 4022] Post Mission Nutritional Assessment and Treatment Post-mission nutritional assessment and treatment shall be aimed at returning to pre-mission baseline

[V1 4027] In-Mission Bone Countermeasures Countermeasures shall maintain bone mineral density of the hip and spine at or above 95% of pre-mission values and at or above 90% for the femoral neck.

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[V2 6004] Nominal Vehicle/Habitat Carbon Dioxide Levels The system shall limit the average one-hour CO2 partial pressure (ppCO2) in the habitable volume to no more than 3mmHg.

[V2 6026] Potable Water Quality At the point of crew consumption or contact, the system shall provide aesthetically acceptable potable water that is chemically and microbiologically safe for human use, including drinking, food rehydration, personal hygiene, and medical needs.

[V2 6109] Water Quantity The system shall provide a minimum water quantity as specified in Table 6.3-1—Water Quantities and Temperatures, for the expected needs of each mission, which should be considered mutually independent.

[V2 7001] Food Quality The food system shall maintain food safety and nutrition during all phases of the mission

[V2 7022] Body Waste Management Privacy The system shall provide privacy during use of the body waste management system.

[V2 7023] Body Waste Management Provision Body waste management supplies shall be provided for each crewmember and be located within reach of crewmembers using the body waste management system.

[V2 7024] Body Waste Accommodation The body waste management system shall allow a crewmember to urinate and defecate simultaneously without completely removing lower clothing.

[V2 7035] Urine per Crewmember The human body waste management system shall be capable of collecting and containing urine for either processing or disposal of an average total urine output volume of Vu = 3 + 2.5t liters per crewmember, where t is the mission length in days.

[V2 7038] Physiological Countermeasures Capability The system shall provide countermeasures to meet crew bone, muscle, sensorimotor, thermoregulation, and aerobic/cardiovascular requirements defined in NASA-STD-3001, Volume 1.

[V2 7043] Medical Capability A medical system shall be provided to the crew to meet the medical requirements of NASA-STD-3001, Volume 1.

[V2 7100] Food Nutrient Composition The system shall provide a food system with a diet including the nutrient composition that is indicated in the Dietary Reference Intake (DRI) values as recommended by the National Institutes of Health, with the exception of those adjusted for spaceflight as noted in Table 7.1-2—Nutrient Guidelines for Spaceflight.

Referenced Technical Requirements

View the current versions of NASA-STD-3001 Volume 1 & Volume 2 on the [OCHMO Standards website]

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[V2 7102] Body Waste Quantities The human body waste management system shall be capable of collecting and containing the various human body waste as specified in Table 7.3-1—Body Waste Quantities, for the expected needs of each mission and task.

[V2 11013] Suited Body Waste Management Suits shall provide for management of urine, feces, menses, and vomitus of suited crewmembers.

[V2 11014] LEA Suit Urine Collection LEA suits shall be capable of collecting a total urine volume of Vu = 0.5 + 2t/24 L throughout suited operations, where t is suited duration in hours.

[V2 11028] EVA Suit Urine Collection EVA suits shall be capable of collecting a total urine volume of Vu = 0.5 +2.24t/24 L, where t is suited duration in hours.

[V2 11029] LEA Suited Hydration The system shall provide a means for on-demand crewmember hydration while suited, including a minimum quantity of potable water of 2 L (67.6 fl oz) per 24 hours for the LEA suit.

[V2 11030] EVA Suited Hydration The system shall provide a means for on-demand crewmember hydration while suited, including a minimum quantity of potable water of 240 mL (8.1 fl oz) per hour for EVA suited operations.

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