Gynecological and Reproductive Issues for Women in Space: A Review

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Abstract

Women have been an integral part of United States space crews since the initial flight of Dr. Sally Ride in 1983, and a total of 40 women have been selected as U.S. astronauts. This article examines the reproductive and gynecological aspects of selecting, training, medically certifying, and flying women in space. Gynecological data from the astronaut selection cycles in 1991 to 1997 are reviewed. In addition, the reproductive implications of delaying childbearing for a career as an astronaut and the impact of new technology such as assisted reproductive techniques are examined. The reproductive outcomes of U.S. female astronauts after spaceflight are also presented.

Because women have gained considerable operational experience on the Shuttle and Mir, the unique operational considerations for preflight certification, menstruation control and hygiene, contraception, and urination are discussed. Medical and surgical implications for women on long-duration missions to remote locations are still evolving, and enabling technologies for health care delivery are being developed. There has been considerable progress in the development of zero-gravity surgical techniques, including laparoscopy, thoracoscopy, and laparotomy. The concepts of prevention of illness, conversion of surgical conditions to medically treatable conditions, and surgical intervention for long-duration spaceflights are explored in detail. There currently are no operational gynecological or reproductive constraints for women that would preclude their successful participation in the exploration of our nearby solar system.

Target Audience: Obstetricians & Gynecologists, Family Physicians

Learning Objectives: After completion of this article, the reader will be able to describe the various gynecological and reproductive issues for women involved in space travel and to explain how these issues can be managed, and also to be able to describe the appropriate evaluation for a woman entering the astronaut training program.

Humans have flown in space for 38 years, and women have participated since Valentina Tereshkova’s Vostok 6 flight in 1963. Svetlana Savitskaya followed with a Soyuz flight in 1982. In the United States, the early astronaut selection classes were limited to military jet test pilots. Inasmuch as there were no female military test pilots, this policy delayed spaceflights by women for two decades (1). The initial U.S. astronaut class that included women was the class selected in 1977 and included 6 women in a class of 35. To date, there have been 40 career female astronauts selected for the U.S. space program. Dr. Sally Ride was the first female U.S. mission specialist to fly in space in 1983, and a total of 28 female mission specialists or pilots have orbited in the U.S. space program. The first woman to fly as a Shuttle pilot or Shuttle Commander was Eileen Collins. Three female payload specialists and one female cosmonaut have also flown on the Shuttle. Payload specialists are selected for participation in a single flight, based on their scientific expertise. Dr. Shannon Lucid currently holds the record for the longest spaceflight by an American (and a woman) at 188 days. Dr. Lucid traveled 75 million miles during her Mir flight that stretched from March 22, 1996 to September 26, 1996. She and Dr. Bonnie Dunbar share the record for the most spaceflights by women with five. One female astronaut, Judy Resnick, and 1 female spaceflight participant, Christa McAuliffe, have died as a direct result of spaceflight.

Although it is no longer necessary to prove that women belong in space, it is clear that women offer many advantages for spaceflight. These usually include reduced height, mass, consumable demand, and waste production compared with men. To a large degree, spaceflight and weightlessness negate the size and strength advantage of men, whereas the closed environmental systems, limited consumables of oxygen, water, and food, and necessity to process solid, liquid, and exhaled waste products favor smaller individuals. The overall implications of women in the high-performance environment and space have been adequately reviewed by several authors and will not be examined in this article (2-5). Although there are differences in the ability to withstand extremes such as hypoxia, decompression, heat, cold, acceleration, isolation, and impact, these differences are generally minor, often depend on acclimatization and individual variation, and favor women as often as men.
Regardless of their relative assets and liabilities, both women and men will form future space crews, and it is prudent to examine the unique aspects of astronaut selection plus the medical, surgical, gynecological, and reproductive care requirements that female crewmembers present on remote long-duration space flights. This article examines the obstetrical and gynecological considerations presented during selection, training, and spaceflight activities for female crewmembers. It also discusses the growing database of reassuring gynecological information obtained from Shuttle flights and looks forward at the implications of long-duration missions to the International Space Station (ISS), Mars, or a lunar base. In addition, the required enabling medical technology for prevention, diagnosis, and treatment of disease in women on remote, long-duration flights are examined.

FEMALE ASTRONAUT SELECTION

The prevention of gynecological or other medical conditions in space begins with the selection process and continues with preventive medicine programs during an astronaut’s Earth-based career. The medical selection criteria for female Shuttle astronauts are generally identical to that for males with the exception of the reproductive system and radiation exposure limits. Radiation exposure limits are based on guidance issued in 1989 from the National Council on Radiation Protection and Measurements (NCRP) and are set to allow a maximum lifetime increase in cancer risk of 3 percent (6). The career exposure limits for women at all ages are lower than that for men due mainly to the breast and thyroid cancer risk and range from 2 to 4 sieverts (Sv). The National Aeronautics and Space Administrations (NASA) Astronaut Medical Standards for Selection and Annual Medical Certification are reviewed for minor changes every 2 years and undergo major revisions in approximately 5-year cycles. The gynecological standards have evolved as spaceflight experience progressed and generally have been relaxed over time. For example, the standards from the initial Shuttle selection class that included women in 1977, disqualified anyone with a history of endometriosis. This was due to concern that zero gravity would make retrograde menstruation more likely, and that radiation would also increase the risk of endometriosis formation (7-9). The current standards permit a history of endometriosis, but disqualify for endometriosis that results in serious dysmenorrhea, endometriomas, or pelvic adhesive disease. Premenstrual syndrome must interfere with the performance of duties to be disqualified. Any gynecological malignancy is disqualifying for space flight except successfully treated in situ disease of the cervix. It is likely that the standards for a Mars or lunar mission will be more stringent in some areas than the current Shuttle or ISS standards. The standards for the ISS and future Mars missions will be developed by all the international partners and may occasionally include compromises at variance with current U.S. medical philosophy.

Astronauts-in-training who develop a disqualifying defect are often granted a waiver if the medical threat is eliminated or mitigated. For instance, someone with a prior history of corpus hemorrhagicum requiring operative intervention might be placed on oral contraceptives and allowed to participate on a long-duration mission. Leiomyomata uteri that are symptomatic or cause menorrhagia may be treated successfully by surgery. Decisions regarding waivers are usually made on a case-by-case basis after thorough review of the condition, input from outside specialty consultants, and successful intervention. Waivers usually are not issued during astronaut candidate selection; however, some candidates are deemed disqualified, but with conditions that are surgically correctable. Pending successful treatment, some candidates may become eligible for selection in that same cycle.

As part of an extensive week-long astronaut-selection physical examination and interview process, each female astronaut-candidate finalist receives a pelvic/abdominal ultrasound, proctosigmoidoscopy, gynecological examination, and Pap smear. Women who have reached the age of 35 are given mammography. The mean age for women who are astronaut-candidate finalists is 32. The gynecologic conditions found during the selection examinations are probably not different than that found in equally educated individuals of the same age in other professions. A review of gynecologic findings during the selection examinations in 1994, 1996, and 1997 showed that 16 of 69 had a history of current or treated dysplasia. The 88 women-finalist candidates examined in 1991, 1994, 1995, and 1996 had a total of five ovarian masses that required additional evaluation, and 9 had leiomyomata uteri. No female finalist has been disqualified because of a gynecological condition found at the time of the selection examination. However, several applicants have been disqualified during the selection prescreening process. Several astronaut-candidate finalists have been required to undergo surgical procedures to rule out disqualifying pathology, particularly neoplasia in ovarian cysts, breast masses, and breast microcalcifications. No active astronaut has ever been permanently grounded because of a gynecologic condition that developed after selection.

One problem that does seem to recur each selection cycle is a current pregnancy in an astronaut-candidate finalist. Pregnancy in itself is not a disqualifying condition for selection, but the selection examination cannot be completed during the pregnancy. This has caused a few candidates to delay their examination or have their selection examination postponed until the subsequent astronaut selection cycle.

PREGNANCY AFTER SPACEFLIGHT

The vast majority of women finalists for astronaut candidate selection have not had children. During the five selection cycles between 1989 and 1997, a total of 99 female finalist candidates were examined. Only 18 of the 99 were parous, and the total number of living children born to this group was 24. The delay in childbearing is often due to educational and career objectives that involve decisions about both marriage and children. Because of the training constraints that pregnancies cause, most of these individuals prefer to delay their first pregnancy until after completing one or two spaceflights. This has lead to deliveries at more advanced maternal age. The average maternal age at the time of delivery for the 7 children born to 6 U.S. women after spaceflight is 40. The mean age of the 6 that have spontaneously aborted after spaceflight is 41. At this time there are three on-going pregnancies in astronauts who have flown in space and the mean maternal age is 42 years. There has been considerable need for infertility services and assisted reproductive technology (ART) in older astronauts due primarily to gamete age. The success rates for ART in astronauts have been low, but comparable with other older ART patients. It is likely that the poor per-cycle fecundability relates to age alone and not spaceflight, but no study has been accomplished to assure that fact.

OPERATIONAL CONSIDERATIONS

Astronaut Training

Astronauts currently spend the majority of their time in generic training and performing work in support of the space program. Mission-specific training begins 1 to 2 years before an assigned mission. Crewmembers are required to fly regularly in T-38 aircraft, maintain self-contained underwater breathing apparatus (SCUBA) qualification, undergo physiologic training in an altitude chamber, and practice extravehicular activity (EVA) in the Sonny Carter Neutral Buoyancy Laboratory (NBL). Crewmembers assigned to EVA are given additional experience in their extravehicular mobility units (EMUs) in a vacuum chamber. Suit pressure is maintained with 100 percent oxygen at 4.3 psi. Because the T-38 aircraft is equipped with an ejection seat, female crewmembers are not allowed to fly after the first trimester of pregnancy. The cabin altitude in the pressurized T-38 may reach 18,000 feet, but all crewmembers breathe supplemental oxygen. Accidental decompression must be considered, because at-altitude accidental decompression occurs occasionally, and because NASA operations are common up to 43,000 feet altitude. NASA has not had anyone suffer from altitude decompression sickness with T-38 operations, but has had episodes with vacuum chamber runs. Special precautions are taken to avoid decompressive illness if underwater EVA or SCUBA training had occurred before the flight.
Women who are known to be pregnant are not allowed to dive in the NBL. The rationale for this preclusion involves the prolonged length of each dive during EVA training (up to 8 hours), the pool depth of 40 feet, and the limited information available about prolonged diving in pregnancy. In addition, oxygen-enriched air (nitrox) is used in the NBL, and there are essentially no data regarding nitrox diving and pregnancy.

Physiologic training involves altitude chamber ascents to 35,000 feet cabin altitude and several minutes of hypoxia exposure at 25,000 feet. Pregnant astronauts are prohibited from participation. Although there are data that women are at greater risk for decompressive illness when the exposure to altitude occurs during and immediately after menstruation, the menstrual cycle is not currently considered for timing this training (10). Additionally, EVA crewmembers are given hypercarbia experience using a rebreathing system with brief exposures of up to 7 to 8 percent carbon dioxide. Pregnant astronauts are precluded from this activity as well. Water survival courses, Shuttle emergency egress and escape slide training, vacuum chamber exposure, and periodic parachute training are not permitted during pregnancies. One NASA aircraft operations pilot successfully performed repetitive zero-gravity flights in the KC-135E aircraft until 36 weeks of gestational age, but pregnant astronauts are not usually permitted to train in the KC-135E because of the trauma potential while flying unrestrained in the larger cargo area. The fetal effects of repetitive zero-gravity flights with 40 to 60 parabolas and 2 g pullouts per flight are not known, but the NASA pilot delivered an infant without abnormalities. In summary, the multiple constraints to training for women astronauts who are pregnant often result in planned delay of pregnancies until after the first or second spaceflight.

GYNECOLOGICAL CONSIDERATIONS ON SHUTTLE FLIGHTS

Female crewmembers require a few unique operational considerations for current Shuttle and Mir flights. Pregnancy is disqualifying for space flight for reasons that have been well documented elsewhere (11, 12). Each female crewmember is checked for pregnancy during preflight medical examinations at launch minus 10 and 2 days. Any pregnant crewmember would be checked from the flight, although this has never occurred. Although astronauts have used essentially every form of contraception, the prohibition of pregnancy for flight has lead to increased preflight use of contraceptive methods that have a small failure rate. Crewmembers are encouraged to continue their current contraceptive method during training and in-flight, and most contraceptive methods including IUDs, levonorgestrel implants, and oral contraceptives have been continued during Shuttle missions. For medical reasons, depot medroxyprogesterone acetate with estrogen/progesterone addback has also been used in-flight. Oral contraceptives offer the opportunity to reduce the volume of menstrual efflux and to move menstruation earlier or later in the cycle to acceleration training. There are considerable initial concerns about menstruation in space, yet this has not been a problem. Consultants met with NASA medical operations at Houston in 1982 to discuss menstruation in microgravity before the first U.S. spaceflights with women crewmembers. This group recommended that female crewmembers consider depot medroxyprogesterone acetate, oral contraceptives, or danazol for menstruation management during spaceflight. Oral contraceptives with 30 to 35 µg of ethinyl estradiol were deemed most practical. Debrief data from the Shuttle program have confirmed that menstrual efflux and the hygiene measures required are similar to that experienced on Earth. There have been no abdominal symptoms, shoulder pain, or reduced menstrual flow that would suggest increased retrograde menstruation. Female astronauts on the Shuttle have access to multiple sanitary products for menstruation. These include pads, minipads, and tampons in plain and deodorant versions. For EVA and launch/landing, the crewmembers of both sexes have available a maximum absorbency garment (MAGs) that can retain up to 2000 ml of urine, blood, or feces. The MAGs are made by replacing the absorbent material in an adult diaper with the super absorbent material used in urine-containment devices.

A unique area of difference for women in space involves urination. Each crewmember has his/her own urine cup for integration to the Shuttle waste collection system. Due to anatomical differences, the female cups are shaped differently than the male cups. However, several women have reported difficulty drying after urination. This may be because of urine entering the vaginal orifice by surface tension or urine remaining in the distal urethra. Regardless of the cause, the small amount of leaking that occurs after urination is a minor annoyance that a few women have noted.

CONSIDERATIONS ON LONG-DURATION FLIGHTS

Prevention

Long-duration flights to the moon or Mars present special problems because a ready return to Earth is not possible. The total duration of a Mars mission will be about 1 year, depending on the trajectory, surface interval, and the vehicle selected. In addition to the time required away from Earth, the gravity during transit and on the surface will vary. Transit will most likely be at zero-g, whereas exposure on the lunar surface and Mars will be at one-sixth and one-third gravity, respectively (13). The radiation exposure rate will be higher during transit because the surface of Mars offers some radiation protection from galactic cosmic radiation and solar particle events because of its radiation blocking mass and carbon dioxide atmosphere.

From a gynecological perspective, several concepts will be important for women. These include prevention of illness, conversion of surgical conditions to medically treatable conditions, and provision of surgical capability. It will be imperative to prevent pregnancies. The difficulty with pregnancy has been well documented, but for all practical purposes, the radiation dosage expected for a Mars mission will exceed 0.5 Sv (50 roentgen-equivalent-man [rem]) per year and makes pregnancies ill advised at this stage of the space program (11-17). The NCRP recommends that the total radiation dose received by a pregnant woman not exceed 0.5 rem. Exposures over 10 rem may be associated with microcephaly and mental retardation. In addition, with normal and contingency operations, the risk of toxic chemical exposure, reduced atmospheric pressure, altered breathing gas concentrations, and possible zero-gravity effect on early embryogenesis preclude planned pregnancies. At some time in the future, if adequate radiation shielding is established on the lunar or Martian surface for both the pregnancy and later child development, it may be possible to consider space-based human pregnancies.

The preventive program for long-duration flight begins with care on Earth. Each astronaut is examined annually with emphasis placed on preventive care. The examinations include a physical examination, extensive blood analysis and periodic exercise tolerance tests, proctosigmoidoscopy, mammography, and bone density analysis. Considerable attention is given to Health Risk Appraisal, counseling, and early medical intervention, if needed.

Many Earth-based prevention concepts are appropriate for gynecologic care for women in space. Just as on Earth, the noncontraceptive benefits of oral contraceptives make sense for spaceflight. These benefits include reduced menses and menses-related hygiene requirements, dysmenorrhea, and total menstrual flow. The reduced menstrual efflux may help minimize the loss of red blood cell mass that is associated with spaceflight in both men and women. Women on oral contraceptives are less likely to form ovarian cysts that could undergo torsion and are also less likely to experience other potential surgical conditions such as corpus
hemorrhagic. It is not known what will happen to the natural menstrual cycle in zero-gravity, inasmuch as all U.S. spaceflights except those of Phase 1 (Shuttle/Mir Space Station Program) have been 18 days or less. There is some concern that the exercise necessary to prevent muscle atrophy, cardiovascular deconditioning, and osteoporosis in-flight, when combined with stress and zero-gravity, might have a deleterious effect on menstrual function. However, if problems are encountered with menstrual cycling, oral contraceptives provide an effective way to manage dysfunctional bleeding and reduce the chance of endometrial hyperplasia or menorrhagia.

Bone loss associated with spaceflight is a major concern. Data from the Skylab program and Shuttle/Mir program have shown that bone density is lost at about 1 percent per month, even with existing countermeasures. It is hoped that oral contraceptives for younger astronauts and hormone replacement therapy for postmenopausal astronauts will be effective in mitigating some of this loss. Bedrest studies are currently underway at the Johnson Space Center to evaluate the biphosphate alendronate for the same purpose. Although osteoporosis is more common in women of certain ages on Earth, there are no spaceflight data yet to suggest that women of astronaut age are at more risk for zero-gravity loss than men.

For women who have completed their family, real consideration can now be given to providing endometrial ablation before prolonged spaceflight. This technology is evolving, and there are multiple methods of safely ablating the endometrium such as Thermachoice uterine balloon therapy systems (Gynecare, div. of Ethicon, Somerville, NJ) that do not require great technical skill. Endometrial resection, rollerball electrocoagulation, and laser ablation of the endometrium are also currently available. Endometrial ablation provides several advantages when compared with hysterectomy, including reduced chance for postoperative adhesions and possible subsequent bowel obstruction. On the other hand, elective laparoscopic appendectomies may be indicated before prolonged lunar or Mars missions.

The delay in childbearing and radiation exposure required for a flight to Mars poses a dilemma for certain astronauts who desire children. Spaceflight results in exposure to galactic cosmic radiation, solar particle radiation, trapped radiation, and secondary radiation produced when high-energy particles are stopped by shielding material. Radiation exposure in space includes a combination of protons (charged hydrogen nuclei), alpha particles (charged helium nuclei), neutrons, high linear energy transfer (LET) particles, gamma rays, and x-rays that have not been modeled in humans on Earth. Although the risk of gamete genetic damage for women is probably not overwhelming, it is less likely than for men. Considerable questions remain about the long-term reproductive impact for individuals of both sexes. Women who desire pregnancies after a prolonged trip to the moon or Mars no doubt will be offered the opportunity to freeze embryos during the preflight collection, pregnancy outcome should be enhanced by cryopreservation of embryos in women who elect to delay pregnancy while their fertility potential is rapidly declining. Hopefully, cryopreservation of ova also will advance to the point that women are not in a stable relationship can preserve their gametes for future fertilization and transfer postflight. Of course, many female crewmembers will either have completed their family or not have any future pregnancy desires.

Avoiding Surgery

Another area of importance for exploration-class missions is the conversion of surgical conditions into medically treatable conditions, or at least mitigating these surgical conditions for delayed treatment on return to Earth. An excellent example of this process is the successful treatment of early ectopic pregnancies with methotrexate. Previously, ectopic pregnancy was considered a surgical emergency, but with earlier diagnosis and medical therapy with methotrexate, many now are managed medically as outpatients. Other therapies are now available such as GnRH agonists with estrogen/progestosterone add-back for leiomyomata uteri, endometriosis, adenomyosis, or dysfunctional bleeding. In gynecologic practice, GnRH agonists have been helpful short term in reducing menorrhagia, reducing uterine size, converting abdominal surgical cases into vaginal procedures, or allowing patients to increase their hematocrit before surgery. For certain cases of menorrhagia resistant to hormonal management, the placement of a Foley catheter with a 30-ml balloon in the endometrial cavity could avoid a dilatation and curettage. In space, these and other options will be available to successfully treat individuals and delay definitive surgical procedures until back on Earth. Development of alternative treatment methods for managing gynecological problems should continue. It is hoped that additional innovative treatment modalities that incorporate planned on-board medical equipment and supplies can be developed.

Surgery in Microgravity

Despite preventive measures and reducing the need for surgery, occasionally it will be necessary to provide surgical intervention. Projections from other analog environments with equally fit individuals isolated for 2 to 3 years suggest that surgery will not be required frequently in a crew of approximately six healthy young astronauts. Trauma potential is a real consideration for spaceflight, and minimally invasive surgery such as laparoscopy can be an important adjunct to abdominal ultrasound and laboratory analysis for managing severe blunt trauma in space (18). It is expected that ultrasound and digital x-ray will be the principal modes of diagnostic imaging on a Mars mission or lunar base, and it will be imperative to understand the effect that zero-gravity has on normal and pathological studies.

The development of zero-gravity surgery is well established, and multiple procedures have been accomplished while at zero-gravity or reduced gravity obtained by flying Keplerian parabolas in a KC-135E aircraft. To date, laparoscopy, laparotomy, thoracoscopy, advanced cardiac life support (ACLS), advanced trauma life support (ATLS), and telemedicine procedures have been accomplished in animal models during the repetitive 20- to 25-second microgravity parabolas provided by the NASA Reduced Gravity Program (19-26). Additional experience has been obtained recently on the Shuttle, including the first surgery on-orbit with animals surviving postoperatively.

Using the KC-135E, the development of surgical techniques for zero-gravity has progressed through a series of logical steps. These have included studying restraint systems, sterile technique, fluid and blood control, and performing laparotomy, laparoscopy, and thoracoscopy in animal models. There has been no surgery on humans in microgravity. During the development period, surgical isolation systems, surgical overhead canopies (SOC), restraint systems for patients and surgeons, and techniques for scrubbing, gowning, gloving, and patient draping were tested. Results of these studies have been reassuring. Capillary and venous bleeding can be controlled by local measures, whereas arterial bleeding may be associated with projectile dispersion of blood droplets. The SOC has been helpful with arterial bleeding, but direct pressure with an absorbent sponge can change a projectile arterial bleeder into a dome of blood. Most bleeding areas form domes or coat body surfaces due to surface tension, and blood or fluid is not usually released into the cabin atmosphere. It is necessary to remove the domes to allow appropriate operative exposure. Traditional suction devices have not been that successful and occasionally disperse blood droplets resulting in fragmentation and potential atmospheric contamination. Loose-weave sponges for blotting have worked better than tight-weave sponges. It has proven helpful to apply sponges gently to avoid fracturing or propelling the droplets.

Laparotomy has been accomplished on rabbits without difficulty. There was no problem returning abdominal contents to the abdomen; however, care was required for entering the peritoneal cavity because the intestines do not fall away from the incision when the tented peritoneum is entered sharply. Laparoscopy has
been performed repeatedly on porcine models with favorable results when compared with the same procedure at 1 g. However, in these studies a pneumoperitoneum was established at 1 g. It is possible that the initial pneumoperitoneum may be difficult to establish in zero-gravity, and that an open technique of laparoscopy may be required. Proprietary surgical balloon devices for creating operative abdominal space were used during the KC-135E series and were successful, but the initial success with traditional laparoscopy made the balloon devices less desirable. At any rate, it seems laparoscopy for treatment of surgical intra-abdominal conditions and gynecological problems in women offers many advantages including reduced anesthesia requirements, containment of blood, debris, and fluids plus minimally invasive surgical techniques. Laparoscopy also minimizes the size of the exposed incision. Incisional length and duration of exposure may be important factors during zero-gravity when airborne particulate size and number are increased dramatically over that encountered at 1 g. Video downlink available with laparoscopy also provides the advantage of either real-time or tape-delayed second opinions from Earth-based consultants. Eventually, laparoscopy in low-Earth orbit on the ISS or on a lunar base may be possible using surgical telerobotics. However, the time delay of up to 22 minutes for transmission to Mars will present a problem for real-time consultation.

Although considerable work remains to develop this enabling technology for human space flight, the early animal data suggest that laparoscopy will be a very practical and effective way to approach surgical gynecological and other abdominal pathology. Additionally, the continued development of smaller equipment with improved multifunctional capabilities and the potential for Earth-based experts directing less well-trained providers in space makes laparoscopy an ideal option for surgical care of gynecological problems in space.

CONCLUSION

Human space flight is approaching its 40th anniversary, yet we are clearly entering a challenging and exciting new phase of exploration. Women have been involved integrally as crew members for many years and have performed well, as expected. The medical data regarding women in space have been very reassuring, and no medical or gynecological problems have developed that cannot be addressed with current or planned intervention capabilities. Remote medical care capability will be required during the zero-gravity in-flight period and during deployment on the Martian or lunar surface. Furthermore, development and refinement of microgravity physiological countermeasures and enabling medical and surgical technologies should continue. Mission success will depend on assurance that crew members that develop medical, surgical, or gynecological conditions can be successfully treated. With appropriate attention to planning, it is not likely that medical problems for women will impede the exploration of the planets and moons nearby in our galaxy.

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