THERAPEUTIC AND MEDICAL CARE OF SPACECRAFT CREWS

(Providing Medical Care, Equipment, Prophylaxis)

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Introduction

The dispensable lower half of the first lunar landing craft bears an inscribed plaque which will declare for ages to come that in July 1969 A.D. men from the Planet Earth first set foot upon the Moon. The plaque is a testament to man's vision, daring, and determination. Enormous numbers of people in the United States and throughout the world made that historic mission, and those which preceded and followed it, possible. The first lunar landing was the thirty-third in a series of manned space flights that began when cosmonaut Yuri Gagarin first demonstrated that man could survive and function in space. Before any of those who flew were committed to space flight missions, and before future personnel can be comitted to similar missions or to more extensive ones, their physical well-being had to be ensured. Those engaged in the implementation of the science of aerospace medicine bear the responsibility for providing these guarantees.

Aerospace medicine is principally preventive medicine. Its practitioners must anticipate, insofar as is humanly possible, every physiological consequence of exposure to the space flight environment. They must aim to prevent those physiological problems which can be anticipated and to treat any which may arise. This program is broad in scope, involving preflight, inflight, and postflight phases. While it may not always be possible to prevent every illness or injury in space crewmen, any which do occur must, in all honesty, be viewed by practitioners of aerospace medicine as preventive medicine failures. Such failures may then be precluded in future space flight experience by a failure analysis approach, much like that employed by engineers in analyzing the structural or performance failures of spacecraft and spacecraft systems.

This chapter reviews current thinking in both the United States and the Soviet Union regarding therapeutic and prophylactic treatment of space crews. The contribution of the Soviet authors V.G. Terent'yev and T.N. Krupina is gratefully acknowledged as is that of C.A. Jernigan, W.J. Frome and B.C. Wooley. These authors prepared preliminary materials upon which the current chapter was based in part.

Terent'yev and Krupina provide a definition of the aim and purpose of aerospace medical prophylaxis and treatment in the Soviet Union (40). The definition expresses equally well the U.S. concept of the science. Prophylaxis and treatment, they suggest, must involve a system of procedures directed at preserving the health of space crews and maintaining their working ability at a high level. The preventive aspects of such a program must preclude illness, trauma, toxic hazards, and radiation damage, as well as any other functional disturbances which might be produced by space flight factors. The program must provide for timely diagnosis of disorders in space crews and the effective treatment of any crewman requiring such treatment during the period of preparation for flight, during the flight itself, and after return to Earth. The same authors describe the steps in a comprehensive medical prophylactic program for space flight application as follows:

1. Preflight procedures:

-- discovery of latent illnesses and insufficiencies of compensatory mechanisms in the human organism during the process of selection and preparation for flight;

-- preflight sanitation, execution of quarantine or observational and other antiepidemic measures;

-- preventive operational interventions;

-- determination of individual sensitivity to medicinal substances.

2. Inflight procedures:

-- prophylactic, diagnostic and medical procedures aboard the spacecraft during the flight;

-- preparation for and execution of evacuation to Earth;

-- execution of medical procedures intended to increase the resistance of the human organisms to the effects of flight factors during the launching and landing (splashdown).

3. Postflight procedures:

-- medical observation and rendering of medical assistance to the crew members after the flight;

-- organization and execution of quarantine and observational procedures following the flights to other planets;

-- medical observation of the crewman and the development of measures for rapid readaptation of the crewmembers following a flight.

This chapter will treat the problems and procedures relevant to the treatment and prevention of physiological problems of space crews in each of these three phases of a space flight program.

Preflight Procedures

The procedures performed in the preflight period have ensured improved performance of flight tasks and, with rare exceptions, have prevented the outbreak of illness inflight. This outcome has been, in part, the result of medical screening and selection programs designed to provide physically competent crews and to determine their sensitivity to medications. Observation and semi-isolation programs have also helped to detect any latent ailments which might produce frank symptoms inflight and thus limit the possibility of contraction of infection in the preflight period. During this period, also, efforts have lately been made to ensure sufficiently high levels of dietary potassium to preclude the possibility of potassium deficit and its consequences inflight. Finally, a training course is presented to U.S. astronauts to acquaint them with space flight stresses and their effects upon the human organism so that crewmen may recognize any abnormalities in their health status and understand therapeutic measures which may be prescribed inflight.

Medical Screening/Selection

The best medical care is preventive medical care. This is perhaps more true for the care of a select group such as an astronaut population than it is for most other groups. Good preventive care in a population which has been chosen for a particular job begins with the medical selection of that population. Selection standards for astronauts are intended to identify:

1. Individuals who are physically capable of performing astronaut duties, specifically those who possess the necessary physical and psychomotor capabilities and who are not subject to incapacitating disturbances of physiology when exposed to various stresses of space flight.

2. Individuals who are free of underlying physical defects or disease processes which could shorten their useful careers.

The original Project Mercury astronauts were a carefully preselected population, chosen from among some 500 military test pilots. Thirty-three of this original group were selected for detailed evaluation after a screening of their career and medical records and after interviews. These 33 candidates were then examined in a seven and a half day protocol at the Lovelace Foundation Clinic at Albuquerque, New Mexico. This very detailed examination included history taking (both aviation and medical), physical examination, laboratory tests, radiographic examination, and physical competence and ventilatory efficiency tests. Following completion of these tests, the candidates went to the U.S. Air Force Research and Development Command's Aerospace Medical Laboratory at Wright-Patterson Air Force Base, where a program of stress testing was performed. Stress tolerances were determined for thermal flux, acceleration forces, low barometric pressure, pressure suit protection, isolation and confinement. Seven astronauts were selected from this group of 33.

Two of these seven men subsequently had signigicant medical problems. Shortly after selection, one was found to have recurrent episodes of atrial fibrillation and was disqualified for space flight. The second man successfully completed the first U.S. manned suborbital ballistic flight, but was later disabled for future participation in space flight for a period of five years by the onset of Menière's disease. His first labyrinthine symptoms occurred three years after the suborbital flight. There is, however, no evidence to indicate that space flight exposure in any way contributed to development of the syndrome. The Menière's symptomatology was relieved by an endolymphatic shunt procedure, and the astronaut later successfully completed a lunar exploration mission. While more extensive cardiac function data might have detected the first problem prior to selection, not enough is understood about the development of Menière's disease to postulate any selection techniques which would have predicted the onset of this problem.

Subsequent groups of U.S. astronauts have been selected by techniques which varied only in minor degree from those applied to the first seven. The standards used closely approximated U.S. Air Force Flying Class I Standards, except in the selection of scientist-astronauts, where it was found necessary to relax the visual standards somewhat in order to qualify a sufficient number of candidates. Examinations have been performed at the U.S. Air Force School of Aerospace Medicine, with findings later evaluated by the NASA Manned Spacecraft Medical Directorate. Between 1959 and 1967, 225 astronaut candidates were examined and 66 selected. Table 1 lists the disqualifying diagnoses. Table 1

Listed below are the components of the examination used in the medical selection of the group of astronauts chosen in 1967:

1. Medical history and review of systems
2. Physical examination
3. Electrocardiographic examinations, including routine electrocardiographic studies at rest, during hyperventilation, carotid massage, and breath holding, a double masters exercise tolerance test, a cold pressor test, and a precordial map
4. Treadmill exercise tolerance test
5. Vectorcardiographic study
6. Phonocardiographic study
7. Tilt table studies
8. Pulmonary function studies
9. Radiographic studies, including cholecystograms, upper GI series, lumbosacral spine, chest, cervical spine and skull films
10. Body composition study, using Tritium dilution
11. Laboratory examinations including complete hematology workup, urinalysis, serologic test, glucose tolerance test, acid alkaline phosphatase, BUN, sodium, potassium, bicarbonate, chloride, calcium, phosphorus, magnesium, uric acid, bilirubin (direct and indirect), thymol turbidity, cephalin flocculation, SGOT, SGPT, total protein with albumin and globulin, separate determinations of Alpha 1 and Aplha 2, Beta and Gamma globulins, protein bound iodine, creatinine, cholesterol, total lipids and phospholipids, hydroxyproline and RBC intracellular sodium and potassium. Stool specimens were examined for occult blood and microscopically for ova and parasites. Aurine culture for bacterial growth was done, and a 24-hour specimen analyzed for 17 ketosteroids and 17 hydroxycorticosteroids.
12. Detailed examination of the sinuses, larynx, eustachian tubes
13. Vestibular studies
14. Diagnostic hearing tests
15. Visual fields and special eye examinations
16. General surgical evaluation
17. Procto-sigmoidoscopy
18. Dental examination
19. Neurological examination
20. Psychologic summary, including Wechsler Adult Intelligence Test, Bender Visual-Motor Gestalt Test, Rorschach Test, Thematic Apperception Test, Draw-A-Person Test, Gordon Personal Profile, Edwards' Personal Preference Schedule, Miller Analogies Test, and Performance Testing (38)
22. Electroencephalographic studies
23. Centrifuge testing

Of the five groups of astronauts selected subsequent to the Mercury Program, only one has been permanently disqualified for astronaut duties because of physical problems. The individual developed aspirin asthma which progressed to moderately severe pulmonary disability. Temporarily disqualifying conditions will be discussed in later sections.

In the Soviet Union, cosmonaut selection takes place in three stages: initial ambulatory selection, stationary examination in specialized medical areas and screening during the first months of professional activity (9). The first stage involves finding those persons who have definite counter-indicators for flight. In the initial examination, the dropout rate is high. The primary reasons for failure are ailments of the otolaryngological organs, as well as internal diseases among which neurocirculatory dystonia and vestibular-vegetative instability predominate.

A stationary examination provides for a very careful, complex examination of the organism in order to reveal latent pathology. In this stage, the principal causes for failure are ailments of the internal organs (about half of the unsuccessful candidates), vestibular-vegetative instability, ailments of the otolaryngological organs, anomalies of development and degenerative changes in the spine.

In the ambulatory examination, the dropout rate due to vestibular disturbances decreases considerably. To study the barofunction * of the ear, Soviet investigators have widely used "a descent from high altitude" in a pressure chamber.

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* The capacity to equilibrate the pressure on both sides of the tympanic membrane: a test for the permeability of the Eustachian tubes.

Professional cosmonaut activity is reported to cause functional changes in some individuals. Approximately ten percent have been pronounced unsuitable at this stage of the selection process(9).

Health Stabilization

The problem of communicable disease exposure prior to flight with subsequent development of symptoms inflight was recognized as a potential hazard from the beginning of the U.S. space program. Total isolation of flight crews for a period fo time prior to launch offers indisputable advantages but has been rejected because of the operational difficulties involved since flight crews are required to be in contact with large numbers of people and to move from place to place during the last few weeks of their training in preparation for a space flight. However, when physiological problems of operational significance were noted during the preflight period for Apollo missions 9 and 13, it became apparent that some preflight health stabilization program was imperative.

The purpose of the Flight Crew Health Stabilization Program finally conceived and implemented is to minimize or eliminate the possibility of adverse alterations in the health of flight crews during the immediate preflight, flight, and postflight periods. The elements of the program are indicated in Figure 1. Each of these program elements warrants discussion in terms of the direction taken for implementation in Apollo Programs and subsequent missions. Fig. 1

Clinical Medicine.

Because it is critical that all astronauts be maintained in good health, the Government provides a clinical medicine program for crewmembers and members of their families. This health program is a continual one. It is initiated immediately upon selection of flight crewmembers and continues as long as astronuats are on flight status. The program provides both routine and emergency physical examinations. Rapid diagnosis and prompt effective treatment of any disease event in crewmembers and their families are insured by complete virological, bacteriological, immunological, serological, and biochemical studies at the National Aeronautics and Space Administration's Manned Spacecraft Center.

Immunology.

Ideally one would desire to immunize crewmembers and their families against all disease agents to preclude the expression of disease symptoms. However, the number of diseases for which there are satisfactory immunizations is extremely limited. Indeed, immunizations are not available for the illnesses most likely to occur — viral and bacterial infections of the upper respiratory and gastrointestinal tracts. The immunizations listed in Table 2 are those currently administered. These were selected after careful review of all known immunizations by NASA medical personnel and a microbiology advisory committee of the National Academy of Sciences. Table 2

Other immunizations were excluded on the following bases: (1) questionable effectiveness; (2) traumatic side reactions; and (3) low probability of disease agent exposure. Serological tests are conducted to determine immunity levels prior to immunizations. Tuberculin skin tests are given and serological tests are performed for tetanus, syphilis, typhoid, mumps, polio, rubella, rubeola and yellow fever.

Exposure Prevention.

Disease exposure prevention is the most important aspect of a successful preventive medicine program. If exposure to infectious diseases is not minimized or eliminated the program will be unsuccessful, regardless of the effectiveness of all other aspects combined. Diseases can be transmitted by fomites (contaminated inanimate objects), contaminated consumables (air, food, water, etc.), and personal contacts. Fomites probably represent the least important source of infectious diseases. Nevertheless, the precaution of using separate headsets, microphones, and so forth, for crewmembers is observed. Contaminated consumables pose a greater danger. To prevent transmission of an infectious disease through the air, a closely controlled living environment is provided during the prelaunch period.

All areas in which crewmembers reside or work are equipped with ultra-high efficiency bacterial filters in all air supply ducts. This precludes exposure to microbial agents from adjacent, non-medically controlled areas and individuals. Air conditioning systems are also balanced to provide positive air pressure in those areas inhabited by crewmembers, as compared with areas outside. Air leakage around windows, doors, floors, walls, and ceilings is directed outward rather than inward toward crewmembers.

The food supply which eventually will be consumed by flight crewmembers is a source of potentially infectious microorganisms. As a precautionary measure, no set or publicized pattern of food procurement has been established. Crew quarters food procurement is supervised by members of the medical team. Portions of each lot of food procured are subjected to microbiological evaluations and all food preparation areas are inspected daily for cleanliness and maintenance of satisfactory sanitary conditions. Drinking water sources are limited to drinking fountains provided in the quarters and working areas. Water samples are taken daily from all areas visited by the crewmembers and subjected to microbiological evaluations.

By far the most important means of preventing crew exposure to infectious diseases is to minimize exposure to personal contacts during the critical preflight period. The areas which may be visited by crewmembers are strictly limited and the number of individuals who may have contact with the crewmembers is reduced to slightly over one hundred people with mission-related responsibilities. A medical surveillance program of primary contacts is conducted to insure that those people who do have contact with the flight crewmembers represent a low probability of disease transmission.

Additionally, crewmembers are isolated from potentially infected carriers, such as transient populations (launch-site visitors), high incidence groups (children), and uncontrolled contacts (maintenance and other personnel about whom no medical information is known). Launch site visitors come from all over the United States and from many foreign nations and bring with them a flora that differs significantly from that normally experienced by the astronauts. Children are the most common carriers and transmitters of upper respiratory and gastrointestinal infections. Astronauts are therefore isolated even from their own children. The need for this measure was borne out by epidemiological data obtained during initial implementation of the health stabilization program in support of the Apollo 14 mission.

To implement an exposure prevention program several options are available. Building facilities to house crews and primary contacts for the prelaunch period or modifying existing ones to this end are effective approaches, but they are economically prohibitive. The solution finally arrived at provides for strict isolation of flight crewmembers, both prime and back-up, in crew quarters and limiting their contacts to medically approved individuals only. These latter individuals are permitted to maintain their residence at home. However, their health status is constantly monitored to minimize the possibility of their exposing flight crewmembers to any infectious disease agent. This monitoring of primary contacts resulted in the epidemiological surveillance program.

Epidemiological Surveillance.

The medical surveillance program, initiated three months prior to launch, begins with the taking of medical histories and other critical information from each primary contact. Each is then subjected to an extensive physical examination at approximately 60 days prior to launch and microbiological samples are obtained to identify carriers. Based on this information, certain individuals are medically approved for access to flight crewmembers during the 21-day prelaunch period.

Each primary contact and all his family members are subjected to medical surveillance during the F-21 period. Primary contacts are instructed to report to the medical examination facility whenever they or any of their family become ill or have been exposed to any infectious diseases. Reports of illness events are also obtained from all schools attended by primary contacts' or astronauts' children. Daily reports are solicited from each school of interest concerning the total number of absences, including absences of the children of any crewmember or primary contact. (Approximately 30 percent of the illnesses in primary contacts has occurred previously in one or more of their family members.) Additional daily reports are obtained from public health authorities in the launch site area to determine trends and incidence of specific disease events within the population where primary contacts may have exposure. A computerized data processing system has been developed to maintain complete and up to date records on all crewmembers, primary contacts, and their families. The system links the medical analyses laboratories at the NASA Manned Spacecraft Center in Houston, Texas, with the Medical Surveillance Office at the launch site at Cape Kennedy, Florida. Medical information on any individual can be immediately made available by this system. This program was implemented for the first time in support of the Apollo 14 mission and has operated successfully since that time. As mission durations become longer and infectious disease poses a greater threat to mission success, a more strict isolation program may be needed.

To prevent respiratory and adenoviral diseases, the Soviets have found it sufficient to limit the contact of service personnel with cosmonauts for one week prior to flight, to perform daily examinations, to relieve those who become ill or appear to be becoming ill of their responsibilities, to use protective measures, and to perform constant disinfection of the area.(40)

Preflight Medical Examinations

The physical examinations of flight crewmembers conducted in the final month prior to launch are intended to detect any medical problems during the preflight period which might require remedial or preventive intervention and to provide a baseline for postflight comparison. The physical examination profile employed for the Apollo 14 crew is representative of the preflight physical examination format used in the U.S. space program. The profile was as follows:

1. Preliminary examination - F-27 days. Interval history, vital signs, and general physical examination.

2. Interim examination - F-15 days. General physical examination, vital signs, and dental examination.

3. Comprehensive examination - F-5 days. Interval history. Detailed physical examination to include height and weight, audiometry, near and distant visual acuity, near point accommodation, visual fields, standard 12 lead EKG, chest X-ray, rectal examination, detailed neurological examination, and photographs of skin areas of significant interest.

4. Cursory examination - F-4 to F-0 days. Brief physical examination and history, daily vital signs (weight on F-0).

The preliminary physical examination, conducted 27 days prior to flight for the Apollo 14 crew, must be performed not before 30 days and not after 21 days prior to lift-off in order to permit time for evaluation and for preventive or remedial measures to be taken for any health problems of recent onset which may be found. A comprehensive examination is performed within five days of launch in order to accurately document the physical status of each crewmember at the onset of the mission. The final examination prior to flight involves recording weights and vital signs under standardized conditions to provide a reliable basis for postflight comparisons.

Dietary Potassium Control

An additional preflight measure was adopted after the observation of cardiac arrhythmias in the Apollo 15 crew. It involves the strict control of preflight diet with the objective of insuring that potassium intake is sufficiently high. A diet high in potassium is provided so that no crewmember begins his mission with a potassium deficit. This precautionary measure was taken for the first time during the Apollo 16 mission when such diets were provided for 72 hours prior to launch. Potassium supplements are also taken inflight (105 milliequivalents versus a normal of 70 in the command module diet, and 135 milliequivalents in the lunar module diet). These procedures, coupled with improved work/rest schedules, seemed to prevent a recurrence in the Apollo 16 crew of the cardiac arrhythmias experienced in the Apollo 15 crew. Similar measures used for Apollo 17 crewmen were not equally successful in preventing potassium deficits but the physiological problems that had been believed to be a consequence of these deficits did not recur.

Table 3 lists preflight medical problems noted in conjunction with the Apollo missions including etiology, where identifiable, and the number of occurrences of each symptom or finding. Table 3

Medication Sensitivity Testing

Medicinal sensitivity testing is conducted to determine the response of flight crewmembers to each item in the medical kit so that allergic reactions and other undesirable side effects are precluded. Each U.S. crewmember is tested under controlled conditions to determine his response to medical kit items carried onboard the spacecraft. (The medical kit is described in the section of this chapter concerning inflight items and procedures.) After a medical history is obtained by a physician regarding the experience of each crewmember with each medication under test and it has been determined that (1) no adverse reaction has been experienced and

(2) there is no evidence of impaired health at the time of testing, the medication is administered to the astronaut-subject. The crew-member is observed by the physician for an appropriate period of time following administration of the medication and is queried concerning subjective responses. If positive subjective findings are reported, the test is either repeated with a double-blind placebo method, or an appropriate drug is substituted for which no undesirable side effects have been reported. Individuals are additionally tested for any allergic reaction to the electrode paste.

Soviet cosmonauts are similarly tested for medicinal sensitivity. Parin et al. (31) have recommended that the sensitivity of the individual to medication be determined both during rest and with flight factor simulation in order to study the effects of medications during changes in reactivity of the organism. These authors further suggest that when it is necessary to take some medicine during the flight, it is most advantageous for the cosmonaut to conduct a biological test of his ability to withstand the preparation, by taking the preparation not in its full dose, but only one-fifth or one-fourth of it. If no exaggerated or paradoxial reaction is observed after 30 to 45 minutes, the cosmonaut can consider it safe to take the full dose of the preparation. If the cosmonaut experiences an allergic reaction from taking the preparation, appropriate medicine must be provided in the kit to enable him to overcome these complications; the cosmonaut must know which medicines these are and how to use them correctly. Finally, the authors note, it should be taken into account when assembling medicine chests that there will be changes in the reactivity of the organism to medicines as a result of certain flight factors acting on the organism.

Table 4 shows drug administration and observation constraints Table4 applied in the U.S. space program. All medications used are treated in a similar fashion.

Table 4

Medical Training

To be properly equipped for his job, a space crewman must understand the interaction of space flight stresses and their effects on the human organism, including the manner in which the body adapts to space flight effects. Further, the crewman should be able to recognize any abnormalities in his health status and understand the therapeutic measures which may be prescribed for inflight problems.

Yaroshenko and Terent'yev wrote in 1970 (46) that medical preparation of cosmonauts must involve sufficient training to permit the performance of the necessary amount of medical self-help. This training must include the necessary minimum of anatomical and physiological knowledge, information about difficulties and ailments that may crop up on long space flights as well as their differential diagnosis, and, as noted previously, effects of medications included in the supplies available to cosmonauts.

Medical training for U.S. Gemini and Apollo crews began shortly after the selection of the space crews, with a series of classes concerned with space flight physiology and therapeutics. The following curriculum, studied by the group of astronauts selected in 1967, illustrates the scope of this training program. The curriculum encompassed 16 hours of didactic instruction provided by experts in each topic area.

Cardiovascular System: Brief outline of anatomy and physiology, methods of observing and monitoring cardiac activity, system response to acceleration, weightlessness, work and other stresses, functional testing, such as tilt table, lower body negative pressure, bicycle and treadmill systems.

Pulmonary System: Brief outline of anatomy and physiology, pulmonary function, gas exchange, problems related to hypo- and hyperbaric environments, physiologic limits of spacecraft atmospheres, contemplated atmospheres for future vehicles, respiratory response to acceleration, weightlessness and work, physical conditioning and testing, respiratory capacity.

Hematology and Laboratory Medicine: Review of Mercury and Gemini findings involving blood elements and chemistries, review of present programs scheduled for Apollo and Skylab Programs, illustration of the need to establish good baseline data, controls and possible expansion of the present program.

Human Engineering and Human Factors as Applied to Apollo Programs

The Role of Psychiatry in Crew Selection: Crew and dependents support, personal considerations of long term confinement, group dynamics, and responses to various stresses encountered in flight and on the ground.

Description of Vestibular Apparatus: Its function and equilibrium and testing thereof, response of the vestibular system to acceleration, weightlessness, flight experiments in Gemini, and planning for Apollo and Skylab Programs.

Visual Apparatus: Brief description of anatomy and physiology, relationships to other sensor organs, effects of acceleration and weightlessness on eye and visual system, problems in space, such as light, ultraviolet trauma, high closing speeds, and depth perception without reference points.

Refresher courses are required of each astronaut every third year in the technical and practical aspects of altitude physiology and the medical aspects of survival. Before each mission, a detailed medical briefing is provided. This reviews the medical experiments and procedures to be performed before, during, and after a given mission; the medical kit items and their use; and reporting and consulting procedures for the inflight period.

U.S. Skylab crews will be the best medically trained of any U.S. space crews. The astronauts are given intensive medical training at Sheppard Air Force Base, Texas, which is designed to prepare them to observe symptoms, take histories, and treat, in consultation with ground-based physicians, medical problems. This training is, in a sense, an abbreviated version of that given medical students. Instruction in diseases of the skin, eye, head, and cardiovascular, pulmonary, abdominal, and musculoskeletal systems is provided by physicians specializing in each given area. By using checklists, astronauts will be able to treat physical problems as simple as athlete's foot or as complex as tracheotomy. The latter procedure has, however, been simplified by inclusion in the medical supplies of an instrument that makes an incision and inserts a tracheotomy button in one step. Special instruction is also provided in the use of dental equipment and oral surgery. Crews are also trained to perform such procedures as catheterization of the urinary bladder, naso-gastric intubation, splinting, and bandaging.

The more complicated procedures, for example catheterization, are to be accomplished under the direction of ground-based physicians. Simpler procedures will be conducted by astronauts on their own initiative without help from the ground. The training schedule is an intensive one, with all aspects covered in a three-day program.

Ongoing Medical Care

Once selected, retention of space crewmen on flying status assumes great importance for a number of reasons, not the least important of which is the large amount of money invested in training such individuals. Consequently, comprehensive health care is presently provided all U.S. astronauts and their families through a preventive, diagnostic, and therapeutic program managed by the NASA Manned Spacecraft Center, Flight Medicine Branch, with aid from many civilian and military consultants. Care of the family by the same physicians rendering care to the astronauts provides an understanding of the total milieu in which the astronaut lives and functions.

Astronauts are encouraged to report any and all illnesses and injuries for evaluation and treatment. Once yearly, during the month of their birth, a thorough physical examination is performed, whether or not an astronaut remains on active duty status. Astronauts represent a unique population. They have been exposed to some environmental factors never before experienced by man and to others to which men have been exposed but not in the same combination or sequence. As such, they represent the opportunity for a longitudinal study which must not be bypassed. The components of the annual examination are:

1. History, including

    a. Review of medical record

    b. Interval history (questionnaire completed by the patient and reviewed with him by the examining physician).

    c. Updating of the case index, family history, and immunity index.

2. Physical examination by a physician. This includes tonometry performed annually and sigmoidoscopy performed biannually between the ages of 35 to 40, and annually thereafter.

3. Optometric examination

4. Audiometry

5. Chest and abdomen radiographic examination

6. Laboratory examinations, including

    a. Urinalysis

    b. Hematology

    c. Biochemistry

    d. Immunology

7. Cardiovascular examination, including standard 12-lead electrocardiogram, Masters Two-Step, and Orthostatic Tolerance Test.

8. Cardiopulmonary evaluation, including pulmonary function test.

9. Dental examination and prophylaxis

10. Tuberculin skin testing

11. Physician critique, findings and recommendations for treatment or preventive measures.

These periodic medical examinations are of value in the following ways:

  a. Early detection of disease processes in order that timely corrective action may be taken.

  b. Longitudinal evaluation of the space flight program effects upon man, and evaluation of the preventive medicine program now in use.

Listed in Tables 5 through 11 are significant problems detected upon annual physical examination and those problems brought to the attention of the Flight Surgeon in the periods between such examinations. Tables 5-11

Because dental disease is fundamentally microbiological in origin, a part of the dental care program is directed toward studies of the response of oral tissues of both humans and primates to simulated spacecraft environments. Attention is also directed to the influence of the oral microbial population on general health, either directly or via cross-contamination and to the effect of fluorides (currently used to afford resistance to dental caries) on bone metabolism and disease. It should be noted that persons are barred from entry into the U.S. astronaut corps who have severe periodontal diseases or use prostheses which if lost or broken would not permit clear enunciation or adequate mastication.

Prediction of Medical Problems

An essential part of a comprehensive program of medical care for space crews involves the ability to predict reliably the types of medical and psychological problems which might be experienced in flight and the severity of reactions to be expected. Efforts have been made to clarify these issues from the inception of the space program in both the United States and the Soviet Union. Predictive data have been derived from many sources: the general population; small, isolated groups in the Arctic, Antarctic, and aboard submarines; subjects under simulated space flight conditions on Earth; and individuals engaged in actual space flight. Although certain factors of the space flight environment, for example acceleration, radiation, and weightlessness, are difficult if not impossible to simulate on Earth, certain other factors of that environment can be realistically paralleled. These include prolonged neuropsychiatric stress, deterioration of hygienic conditions, relative hypokinesia, relative isolation, and relative sensory deprivation. Under combinations of these conditions, subjects in Earth-based tests have exhibited numerous changes which have proved to be similar in kind if not in degree to those noted in space crews engaged in the relatively brief space missions accomplished so far. The principal changes which have been noted involve the neuromuscular system (6, 24), the cardiovascular system (5,9,10,34) and alterations in human microflora (5,17,26,33). The neuropsychic disturbances and reactions seen in individuals in a state of hypokinesia for long periods of time /tests as long as 100 days have been conducted in the Soviet Union (2,16,25, (41)/ have no parallel so far in space flight but may be of importance for long-term missions.

Soviet investigators have developed mathematical predictions of inflight illness based on the types of data described above and report that these predictors have been essentially verified during long-term experiments, and, to some extent, by short-term space flights (40). Similar predictive analyses regarding the likelihood of dental problems performed by U.S. scientists indicate that dental problems serious enough to compromise a crewman's efficiency can be expected to occur once each 9000 man days. Minor problems which would produce minimal inconvenience to the afflicted crewman can be anticipated once each 1500 man days.

Both U.S. and Soviet scientists are in agreement that data for prediction must be considered preliminary and must be subjected to further refinement. A problem which compounds the difficulty of predicting space flight illness is the possibility that interaction of space flight stresses may produce disorders previously unknown. Moreover, unknown space-related factors may further complicate this problem. Because of these difficulties, efforts are ongoing to quantify the risks of illness involved in space flight and to define the need for and development of the indicated inflight treatment capability.

Inflight Procedures

The inflight phase of prophylaxis and therapeutics has involved long distance diagnoses, made possible by biotelemetry, and onboard treatment with the appropriate medical kit items. This treatment has been carried out by space crews themselves under the direction of ground-based physicians. The single exception to this approach has been one Soviet flight which included a doctor-cosmonaut. The forthcoming U.S. Skylab Program will also include at least one physician-astronaut.

Monitoring

When the U.S. space program began, the notion of obtaining continuous physiological data by instrumenting the human operator was a new one. No sufficiently reliable off-the-shelf items were available. Since that time, sophisticated and highly reliable biotelemetry devices have been developed both in the United States and the Soviet Union. Table 12 lists the principal devices used to provide comprehensive monitoring of biomedical status. Electrocardiographic equipment, for example, permitted real-time monitoring of the cardiac arrhythmias noted in an Apollo 15 crew-member. Small segments of these recordings are illustrated in Figure 2. In this case, fortunately, no pharmacological intervention was required. Should it be needed, however, it is available in the form of lidocaine and atropine injectors as well as procainamide capsules to be administered as prescribed by the ground-based physician in charge.

Table 12

Fig.2

Inflight Medications

The earliest data on the use of medications in the weightless state were obtained during flights aboard aircraft flying Keplarian trajectories (48). During these tests it was established that the intake of oral medications was not impeded if medicines were given in tablet form, in special tubes packed in foil, etc. Glass ampules cannot be used for ordinary injections; medicines in solution must be contained in cartridge-type syringes or injectors (47). Droplets, suppositories, solutions, tinctures, decoctions, and powders, according to Saksonov et al. (36), must not be included in the medical kit. The same authors suggest that the most convenient and suitable forms for medications to take for space travel are dragee, pills, capsules, tablets, and hypodermic syringes.

Planning the volume of medical equipment stowed onboard must, of course, be based on data concerning the types of disorders which may be experienced and on the possibility of medical manipulation (examination, establishment of diagnosis, and medical procedures) in the weightless state aboard a spacecraft (36).

The initial philosophy regarding the use of medications in space flight was that these would be provided for use in medical emergencies only. Additional experience and the confidence gained thereby have permitted some relaxation of this philosophy so that certain medicines are now routinely prescribed whenever a need for them is indicated. For example, sleep medications are prescribed for both U.S. and Soviet space crews when inadequate rest is obtainable and sound sleep is especially important.

Medical Kits in the U.S. Space Program. Medical kits carried aboard United States spacecraft have varied in composition relative to duration of the mission and previous experience. In the first four Mercury missions, the drugs carried were an anodyne, an anti-motion sickness drug (both of these in automatic injectors which made possible self-administration through the pressure suit), a stimulant, and a vasoconstrictor for treatment of shock. In later missions only the anti-motion sickness drug and the anodyne (Demerol) were stowed. For the last Mercury flight, tablets of dextro-amphetamine sulfate, an anti-motion sickness drug, and an antihistamine tablet, were placed both in the suit pocket and the survival kit. The only medication used was dextro-amphetamine sulfate, with one tablet taken upon instructions from the medical monitor at about 33 hours into the 34½ hour flight, prior to initiation of the retrofire sequence, to relieve the astronauts' fatigue.

The zero-g environment and the requirement to wear gloves called for the development of special measures for packaging tablets. The pill case developed consisted of an aluminum container lined with velcro and having a velcro top flap which could be lifted easily from either end with a gloved hand. The tablets were broken and placed in capsules which were then sewn with a single thread to the velcro flap. As the flap was lifted back, the individual capsule could be easily bitten off and ingested (4).

A number of investigators predicted that for missions appreciably longer than the Mercury flights, man would require drugs to help him cope with the space flight environment. Sedation prior to launch and stimulation prior to reentry had been mentioned. In the absence of truly definitive information to the contrary, a drug kit containing these and other items was made available for inflight prescription for the Project Gemini missions. As previously noted, crews were pretested for each drug. Aspirin and APC's (a combination of aspirin, phenacetin, and caffeine) were used in flight for occasional mild headache, and for relief of muscular discomfort prior to sleep. Dextro-amphetamine sulfate was used on several occasions by fatigued Gemini crewmen prior to reentry. A decongestant relieved nasal congestion and reduced the need for frequent clearing of the ears prior to reentry. An anti-motion sickness medication was taken in one instance prior to reentry to minimize the problem of motion sickness in the capsule after splashdown in a heavy sea. An inhibitor of gastro-intestinal propulsion was prescribed on occasion for limiting in-flight defecation. No difficulty was experienced in the use of any of these medications. Gemini medical kit items are listed in Table 13. Table 13

The Apollo medical kit contained a greater variety of drugs than did the Gemini kit. Certain drugs were replaced by more effective ones and others were added as needed. The addition of sleeping medication has already been noted. After cardiac arrhythmias were experienced by two Apollo 15 crewmen, anti-arrhythmic drugs were included in the medical kit (lidocaine and procainamide). These medications and other additions and deletions to the Apollo medical kit are indicated in Table 14, along with Skylab, etc. Table 14

<u>Medical Kits Used in Soviet Space Program</u>. Special medicine chests have also been installed aboard Soviet spacecraft. These chests have contained radioprotective substances, stimulants for the central nervous system, analgesics and other preparations. All of the flights that have been made thus far have taken place under favorable radiation conditions, so that there were no direct medical indications for use of radioprotective drugs (36). Table 15 lists the medications contained in the Soyuz II/Salyut medical kit, along with indications for usage. Saksonov et al (35) note that while there has been as yet "essentially no direct medical indication that medicines should be used inflight, on longer missions the need for medication will surely develop." Table 15

A medicine chest for use on space flights lasting longer than two weeks must include medicine, bandages, several instruments and medical tools required for sampling urine and gases provided for skin care, and so on. The medicines should include, in addition to the chemical radioprotective substances already mentioned, materials for treating radiation burns, cardiovascular and gastrointestinal problems, antimicrobials and antiviral substances (antibiotics, sulfamide preparations, etc.), analgesics, soporifics, sedatives, tranquilizers, antiallergic preparations, preparations for stimulating and activating the nervous system, substances for combatting hemorrhage and shock, means of treating motion sickness, materials for treating fatigue and preventing nausea, preparations for preventing coughing, protecting the skin, vitamins, methods of preventing muscle asthenia, supplies for rendering assistance in case of problems affecting the eyes, teeth, and antiseptics (40).

Kotsyurba suggests medical preparations be sterilized prior to the flight, using radioactive radiation (18). Semeykina (37) recommends testing medicine storage techniques. Such tests would provide data concerning destruction of tablets, particularly under the influence of vibration and overloads.

A brief survey of studies on problems of space pharmacology and pharmacy shows that work on solving the problems facing space medicine is still far from complete and many more pertinent studies are needed (40).

Selection of Medications. In selecting medicines, one must bear in mind that the medical kit should include preparations that can be used for a variety of purposes and these must be the most effective ones. Preparations that reduce the resistance of the individual to flight factors must be excluded. Most tranquilizers, for instance, produce a less-than-normal individual with unpredictable mental attitudes. They may alter judgment and change orientation to reality. Some of these drugs also reduce tolerance to several types of stresses, including altitude and acceleration (4). Another medication that had received consideration, 9-alpha-fluorohydrocortisone, is very effective in maintaining fluid balance (39). It has, however, the undesirable effect of accelerating potassium loss. It is obviously desirable to find and include in medical kits pharmacological preparations that reduce the sensitivity of the organism to unfavorable space flight factors, but which in no way compromise other areas of physiological, psychological, or psychomotor performance.

A number of studies have shown that certain pharmacological preparations have unfavorable effects on the ability of the organism to withstand space flight factors. After taking cystamine, an increase in sensitivity to rolling movement and high temperature has been observed (28); cystamine aminoethylisothiuronium and serotonin may depress the resistance of the organism to radial acceleration. Injections of cystamine were found to reduce the resistance of mice to physical stress (20).

The negative effect on the vestibular apparatus of streptomycin has been noticed (29). This same antibiotic also increases hemorrhagic phenomena and leukopenia in acute radiation disease (32). Saksonov et al (36) suggest that aspirin, pyramidone, and salicylate not be used in space flight because they sensitize the organism to ionizing radiation.

Certain preparations have been found to have a distorted effect under special conditions. For example, following irradiation of animals, corazole has produced a toxic effect instead of a stimulating one (15), and a distorted effect of the action of pituitrin has also been noted in prolonged hypokinesia in humans (23). Paradoxical reactions can and do occur in humans even without the superimposition of special stresses. Benzedrine, which stimulates the central nervous system in most individuals, depresses it in others. During the action of overloads, an injection of adrenaline increases, and then decreases, the pressor effect . During overloads too, vasoconstrictors (adrenaline, noradrenaline) and vasodilators (nitroglycerine, papaverine) produce a longer increase in blood pressure (30) than under normal conditions.

Further regarding vasodilators, several Soviet authors (31) have suggested that those with brief action (nitroglycerine, isadrine) should be administered periodically for training the baroreceptors of the vessels in a state of weightlessness. This proposal is, however, under dispute.

It must be borne in mind that during flight there may be a reduction of the effectiveness of stimulating preparations and an increase in the activity of preparations that inhibit central nervous system function.

Soviet space medical experts endorse the use of soporifics. Krupina et al. (22) feel these medications are absolutely necessary in flight, especially in the event that insomnia develops. They caution against the use of meprobamate, however, because it produces an undesirable weakening effect on the muscles. Some of the soporifics (phenobarbital, for example) should not be used in space flight because of the extreme length of the sleep which they produce (up to 12 hours) and the pronounced posthypnotic effect and other side effects (31). Some other soporifics (for example, chloral hydrates) have hypotensive effects.

For prophylaxis of muscular atrophy and stimulation of the neuromuscular periphery, it is recommended by the Soviets that the food ration include alphatocopherol and pantothenic acid (29).

In finding ways to ensure prolonged prophylaxis of vestibular disturbances, a combination of drugs has been used with success in U.S. crews. A combination of Dexedrine-hyoscine has proved more effective than various drugs used alone. Parin (31) suggests that the combination of scopolamine-dexedrine not be repeatedly used because it produces a number of undesirable side effects (dryness of the mouth, disruption of accommodation, insomnia).

The problem of finding effective methods of protection against radiation damage to the crew and the entire biocomplex during space flights is a timely and very complex problem (40). A number of radioprotective chemicals is known at the present time. Some preparations (mercamine hydrochloride, mercamine salicylate, mercamine disulfide, aminoethylisothiruonium) have proved to be highly effective for human beings in clinical tests (35). However, while much work is being done in this area, there is no wholly acceptable drug available. The energy sinks(e.g., sulfhydryl drugs) have proved toxic in doses large enough to afford protection (4). Furthermore, almost nothing is known about chemical protection against radiation under space flight conditions. On long space flights, the doses of cosmic radiation may exceed permissible limits for man. Some Soviet authors (12) feel the use of cystamine and strychnine is justified in this case. Such drugs are believed to be too toxic for consideration in the U.S. program.

Diagnosis and Treatment

Diagnosis of medical status on space missions has been made possible through information provided by biotelemetry devices and through voice communication between space crews and ground-based medical personnel. During one flight of the Voskhod spacecraft, the presence of a doctor in the crew made it possible to expand the range of medical tests and to measure such things as arterial pressure, gas exchange, and so forth (30). The first U.S. Skylab mission will also include a physician in the crew.

The medical problems which have occurred inflight during the U.S. Apollo mission series are enumerated in Table 16, which also Table 16 indicates the etiology of each disorder, where identifiable, and the number of occurrences.

The need for clinical medical care inflight becomes more pronounced as mission durations increase. For long term missions, it is desirable to have a physician onboard as a crewmember and to include diagnostic machinery among spacecraft systems. Should surgical intervention be required and mission profile preclude returning a stricken crewmember to Earth for treatment, the presence of a physician becomes imperative.

Efforts are underway in the United States to develop an integrated medical/behavioral laboratory measurement system to provide clinical medical support for space crews. In the Soviet Union, the possibility of performing surgery during flights has been tested aboard aircraft in Keplarian parabolas. In these studies, special transparent containers have been used to perform surgical operations on rabbits, notably laprarotomy, under local anesthetic (the preferred approach in zero-g) (47). While cutting of the mesentry of the small intestine was accompanied by vigorous blood flow, the blood did not spurt out and scatter into the atmosphere, but flowed around the injured vessels in the form of puddles. Greater care must be taken when arterial blood flow is expected because, as might be anticipated, droplets form and tend to scatter. Contamination of the cabin atmosphere can be prevented when cutting tissues rich in blood by applying clamps beforehand to stop blood flow and using cloth dressings. Should it be necessary to open the chest, incisions should be made in stages with the length of the cut limited since there tends to be an increase in eventration of the intestine (40). On the positive side, the eventration eliminates the need for retractors. Such work has established that it is possible to carry out operative intervention under conditions of weightlessness.

Any discussion at the present time of the finer points of surgical intervention is of little more than academic interest since there is no pressing near-future need for such procedures. Rescue vehicles such as the U.S. space shuttle will be available to remove seriously ill persons from space vehicles. The problems surrounding the capability to perform surgery in weightlessness will have to be resolved for planetary missions which preclude the possibility of returning a crewmember to Earth.

Until more sophisticated treatment capabilities become available, most emergency dental problems that arise will be treated symptomatically. The onboard medical kit includes analgesics and antibiotics which can be used if necessary. Should it become absolutely necessary, future space crews will be able to pull teeth. The medical training program for Skylab crews, described earlier, includes dental training to enable crews to treat basic dental problems under the direction of the ground-based medical team. An inflight program of oral hygiene is also observed to preclude dental problems wherever possible.

Preventive Medicine

It has already become apparent, even in the relatively brief space missions which have been conducted, that a program of preventive medicine inflight is needed and will probably have to be expanded as mission lengths increase. Exercise, ideally using an exercise device such as the bicycle ergometer, is helpful in safeguarding the cardiovascular system. Exercise alone, however, is not effective in combating cardiovascular deconditioning (6) and other hypodynamic disturbances (24). It may be helpful adjunctive therapy if the technique employed raises the heart rate above 120 beats per minute. Dietary potassium supplements, mentioned earlier, appear to be helpful for preventing cardiac arrhythmias. For longer missions, other techniques may be required. The application of gradient positive pressure by means of a pressure garment has been investigated in both the U.S. and the Soviet Union. The use of the technique known as lower body negative pressure is also being examined for longer flights. This technique develops longitudinal g tolerance, that is, the ability to withstand blood shifts and ensure adequate venous return to the heart. The potential efficacy of an approach which employs lower body negative pressure application for perhaps a week prior to reentry is being investigated. Preliminary results appear promising but the establishment of a suitable LBNP profile for space flight application awaits further data. Some of this data will be provided by the LBNP experiment in the U.S. Skylab program. Provision of positive pressure by the application of an anti-hypotension garment has been investigated in conjunction with the Apollo 17 mission.

Efforts were made to counteract the effects of zero gravity on the circulatory system in the Soyuz 11 crew by a complex of techniques which included the use of a treadmill device, a gravity suit, and medication. Inflight testing indicated adequate adaptive capability of the cardiovascular system, although a possible decline in orthostatic tolerance was suggested by LBNP measures. It was, nevertheless, believed that readaptation for the Soyuz/ Salyut crew could have been less difficult than it had been for the Soyuz 9 cosmonauts, possibly as a result of the preventive measures taken (13).

Recent data from bedrest studies suggest that orally administered calcium and phosphate are more effective than exercise (no effect) or longitudinal compression (limited effect) for preventing the loss of minerals from the bones. The period of efficacy was, however, limited to ten weeks in a four month study.[1] Mineral loss was principally from weight-bearing bones, and was recoverable in the post-test period.

It is possible that in periods of prolonged weightlessness, stabilization of mineral balance may occur. Calcium balance does, for example, appear to normalize after some years in paralyzed patients (14). Nevertheless, bedrest data indicate the requirement for high calcium and phosphate intake during long-duration space flight. However, Soviet scientists have noted that calculations based on the idea of mechanical correction of calcium

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[1] Hulley et al., unpublished data.

deficit by means of its exogenic introduction under conditions of prolonged weightlessness are inadequate. We can speak only, Panov and Lobzin (29) suggest, of attempts at finding a method of regulation (possibly, hormonal) of the disturbances of the mineral metabolism in general.

Future crews may be more prone to vestibular disturbances than past crews have been. As a consequence, the possibility of pre-adapting the vestibular responses of individuals to the effects of zero gravity is being studied. Studies conducted in slow rotation rooms are expected to demonstrate the feasibility of preadaptation (3).

Terent'yev and Krupina(40) indicate that various techniques are being investigated in the Soviet Union aimed at increasing the resistance of man to various space flight factors. Trainers and physical exercise techniques have been developed and the possibility of using pharmacological preparations is under study.

Postflight Procedures

As soon as possible following the conclusion of the space flight mission, usually within the first few hours postflight, and for several weeks thereafter, space crews are closely observed by medical personnel and extensive tests are performed. A comprehensive physical examination is performed as soon as possible after recovery of the space crew in order that physiological signs with a rapidly changing time course may be detected and documented. The following are examined:

1. head
2. neck
3. eyes
4. nose, mouth, throat
5. lymphatics
6. lungs
7. heart
8. vascular response
9. abdominal area
10. genitalia
11. rectum
12. skin
13. extremities
14. mental status

In addition to the physical examination, laboratory studies are made. These include:

1. urine culture and sensitivity
2. complete blood count
3. urinalysis
4. serum electrolytes

Functional tests are also performed. Orthostatic tolerance tests and exercise tolerance tests are accomplished.

Postflight Findings and Their Implications

The systems which exhibit principal change following space flight are:

1. cardiovascular/hemodynamic
2. musculoskeletal
3. endocrine, fluid, electrolyte
4. microfloral
5. vestibular

Postflight heart rates have been elevated in most space crewmen (inflight they tend to stabilize at lower levels), and normalization is inhibited. Recent studies have also revealed a decrease in the cardiac silhouette in both U.S. astronauts (6) and Soviet cosmonauts (27). Blood pressure is labile and orthostatic stability is decreased. Further, exercise tolerance is reduced. These changes are, however, all reversible within a relatively brief period postflight.

Small but detectable musculoskeletal changes have often been noted in U.S. and Soviet crews. Slightly reduced bone optical density has been seen, as have slightly negative nitrogen balances. Bone findings, however, have not been demonstrated by all methods employed. Decreases have been found in the volume of both calf and thigh. In the Apollo 16 crew, decreased limb size persisted beyond one week postflight. In the Soyuz 9 crew, muscular pain was reported as well as measurable alterations in gait (6, 11).

Significant changes have been noted in total exchangeable potassium in the U.S. Apollo 15 and 17 crews. Table 17 indicates the Table 17 percentage change. These results show wide individual variation. Other electrolyte and hormone changes have been noted which were consistent with the pattern of rapid recovery of inflight weight loss in the immediate postflight period.

Microbiological studies during the Apollo mission series have shown that growth of opportunistic organisms appears to be favored in the space flight environment (7). Soyuz 9 cosmonauts also exhibited microfloral shifts with a number of organisms less resistant to antibiotics postflight (17). The etiology of these changes is unclear and factors other than weightlessness, confinement for example, may be involved. These changes are in contrast to the findings of earlier, very brief space flights where no significant changes were seen in immunological reactivity (43-45,19). Table 18 lists the microflora of possible significance identified postflight in Apollo space crews. Table 18

The net microbiological changes may be summarized as follows:

1. anaerobic bacteria decreased in number
2. aerobic bacteria increased in number and type
3. microorganisms were isolated at more body sites
4. organisms tended to spread across crewmembers (especially staphylococcus aureus)
5. fungal isolates decreased in number
6. higher carrier states for mycoplasma were indicated.

U.S. crews have not reported vestibular-related difficulties of the severity or with the consistency reported by Soviet cosmonauts. Gemini crewmembers reported no vestibular-related difficulties. Some Apollo crewmen have reported problems that might be related to the vestibular system but these were in all cases reversible, subsiding after two to five days into any given flight. That vestibular problems have been minimal during U.S. missions is very possibly attributable to the fact that U.S. astronauts all, so far, have had test pilot experience, and test pilots as a group suffer from a lower incidence of motion sickness than the general population. In future missions, when space crews will be drawn from a broader population including many persons who may have no aviation experience whatsoever, the incidence of vestibular symptomatology may increase (6).

Table 19 indicates the clinical medical problems experienced by Apollo crews. Table 19

The implications of cardiovascular changes were discussed in conjunction with inflight therapeutic procedures, as was the "treatment" for calcium loss. One further point might be made regarding calcium depletion from the bones. The loss of bone minerals which appears to be indicated is slight and not progressive. Moreover, it is possible that a stabilization of this mechanism may occur.

Following long flights, the question of readaptation obviously becomes more serious. It may be necessary to work out a schedule of physical stresses to be imposed in careful stepwise fashion after prolonged space flight. The changes noted in the microbiological sphere, for example, should pose no real problem for the returning space traveler, provided he is gradually reexposed to the microflora of Earth.

The problem of ensuring the medical safety of space crewmen is one of the most important ones in the conquest of space by man. Management of the principal problems has only begun. It is possible that longer duration flights may pose problems not yet seen or anticipated. Many problems are still being predicted on the basis of ground-based experiments which simulate space flight. This testing and controlled, inflight testing should yield information that will be extremely valuable in the design of medical support programs and systems which will enable man to travel safely into space on missions that could conceivably last for several years or more.

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