N76 12669

CHAPTER 1
CLINICAL ASPECTS OF CREW HEALTH

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Introduction

While the primary goal of the Apollo Program was to land men on the moon and return them safely to Earth, there were other very important medical objectives. The earlier Mercury and Gemini programs had raised some concerns about the health and safety of future crews. For example, the high metabolic energy expenditure of extravehicular activity during the Gemini missions was unexpected. Before Apollo astronauts could safely explore the lunar surface, reliable predictors of energy cost and real-time monitoring techniques had to be developed. Physiological changes were noted in individual crewmen, some more consistently than others. The most important of these changes was in cardiopulmonary status demonstrated by decreased exercise capacity, loss of red blood cell mass, and cardiovascular deconditioning demonstrated by a decrease in the effectiveness of antigravity cardiovascular responses during postflight stress testing.

At the end of the Gemini program, with 2000 man-hours logged in space, it was clear that man could engage in relatively long space flight without any serious threat to health. However, clarification was still required in many areas. First of all, because of the small number of individuals who flew in space and because of the variability of their responses, it was impossible to distinguish between space-related physiological changes and individual physiological variations. Secondly, for those changes which were directly related to space flight, the relatively short mission durations precluded the identification of trends.

In view of the foregoing considerations, four medical objectives were specified for the Apollo Program:

1. Ensuring crew safety from a medical standpoint. This objective required that every effort be made to identify, eliminate, or minimize anything which posed a potential health hazard to the crew.

2. Improving the probability of mission success by ensuring that sufficient medical information was available for management decisions.
3. Preventing back-contamination from the lunar surface.
4. Continuing to further the understanding of the biomedical changes incident to space flight. This objective was formulated to detect, document, and understand changes occurring during space flight.

The program to ensure crew safety commenced long before the Apollo Program itself with the development and implementation of the medical selection and screening program for astronauts. Apollo astronauts were drawn from a pool of individuals who were thoroughly screened to preclude any physical or physiological problems which would jeopardize either the mission or the astronaut candidate. Later, special measures were taken to further protect the health and enhance the safety of those astronauts chosen for specific Apollo missions. These included preflight medical examinations, a health stabilization program, drug sensitivity testing of astronauts for all medications aboard the spacecraft, and other measures.

The preflight medical program was designed to preclude, as far as possible, the development of any clinical medical problems during space flight. Since no preventive medicine program, however carefully conceived, can ever guarantee the absence of illness or disease, medications were carried onboard the Apollo spacecraft. The contents of the medical kit were revised as need indicated throughout the Apollo Program. Onboard bioinstrumentation was provided to monitor vital signs for rapid diagnosis of any physiological difficulty in a crewmember and to provide medical information required for mission management. Additional information was transmitted via voice communication between the crew and the ground-based flight surgeons. During extravehicular activity, methods were added to provide metabolic rate assessment. In addition to heart rate, oxygen consumption was monitored along with inlet/outlet temperature of the liquid cooled garment worn by the crewmen.

Opportunities for inflight medical investigations were severely restricted on the Apollo missions because of conflict with the principal operational objectives. Furtherance of the understanding of the effects of space flight on human physiological functioning had to rely almost exclusively on comparison of preflight and postflight observations. These were carefully selected to focus attention on the areas which appeared most likely to be affected, for example, cardiovascular function. Other areas were also investigated for unforeseen changes and corroborative information.

The sections which follow describe medical procedures and findings for Apollo astronauts in the preflight, inflight, and postflight phases of the Apollo missions.

Preflight Procedures and Findings

The procedures implemented in the preflight period for Apollo missions had five major objectives. These were:

1. The discovery of latent illnesses during the process of selection of astronauts and preparation for missions.

2. The implementation of the health stabilization program and other preventive measures.
3. Determination of individual drug sensitivity to the contents of the Apollo medical kits.
4. Providing baseline data against which to compare postflight data for determination of space flight effects.
5. Prevention of any situations which might delay or otherwise interfere with operational aspects of the missions.

The procedures performed in the preflight period ensured improved performance of flight tasks and, with rare exceptions, prevented the outbreak of illness inflight. This outcome was, in part, the result of medical screening and selection programs designed to provide physically competent crews. Observation and semi-isolation programs also helped to detect latent ailments which might have produced frank symptoms during flight. Finally, a training course was presented to astronauts to acquaint them with stresses of space flight and their effects upon the human organism.

Medical Screening/Examinations

Preventive health care in a population which has been chosen for a particular job begins with the medical selection of that population. Rigorous astronaut selection standards were established to identify:

1. Individuals who were physically capable of performing astronaut duties; specifically those possessing the necessary physical and psychomotor capabilities and not subject to incapacitating physiological disturbances when exposed to the various stresses of space flight.

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

Apollo astronauts were initially medically screened by techniques which varied only in minor degree from those applied to the first seven Mercury astronauts. The standards used closely approximated U. S. Air Force Flying Class I Standards, except in the selection of scientist-astronauts where visual standards were relaxed to qualify a sufficient number of candidates. These examinations were performed at the U. S. Air Force School of Aerospace Medicine, with final review and medical acceptance of candidates by the NASA Lyndon B. Johnson Space Center medical staff. Listed below are the components of the examination used for medical selection.

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 Master 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 Alpha 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. A urine 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, and 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.

22. Electroencephalographic studies.

23. Centrifuge testing.

The preflight medical examinations for Apollo crewmembers included detailed physical examinations and special studies. The physical examinations commenced 30 days prior to launch and ended on the day of lift-off. The special studies involved collection of baseline data for comparison with postflight findings. The areas of particular interest were microbiology, immuno-hematology, clinical chemistry, and cardiopulmonary function. Baseline data collection in each of these areas, of course, had bearing on crew health, but was additionally obtained in order to answer the following critical questions:

1. Did a change take place in a particular dependent variable?

2. Was the change significantly different from that occurring in a control group?
3. What was the extent of the change?
4. What was the time course of the observed change?
5. Was it possible to provide causal interpretations?

The following sections provide details concerning the preflight physical examinations and special baseline studies.

Physical Examinations. The physical examinations of Apollo crewmembers were intended to document the crewmenbers' physical qualifications for the mission, to detect any medical problems which might require remedial or preventive intervention, and to provide baseline data for postflight comparison. Physical examinations were conducted in the following manner:

1. *Preliminary examination at F-30 days.* At this time, interval history, vital signs, and a general physical examination were conducted.

2. *Interim examination at F-15 days.* General physical examination, dental examination, and monitoring of vital signs were accomplished.

The preliminary and interim examinations included the following procedures:

- An interval history and detailed review of systems, vital signs – to include oral temperature, blood pressure, and pulse rate.
- ENT examination to include visual inspection of the external ears, auditory canals, and tympanic membranes, the nose and nasal passages, transillumination of the frontal and maxillary sinuses, and visual inspection of the anterior and posterior middle pharynx.
- Examination of the eyes to include visual inspection and palpation of the lids and lacrimal apparatus, visual inspection of the conjunctiva, sclera, and cornea, and ophthalmoscopic examination of the lens, media, and fundus.
- Examination of the heart to include palpation, percussion, and auscultation.
- Examination of the lungs to include palpation, percussion, and auscultation.
- Examination of the abdomen to include palpation, percussion, and auscultation.
- Examination of the genitalia and anal regions.
- Examination of the extremities for recent trauma or limitation of function.
- Neurological examination to include a brief examination of the cranial nerves and motor, sensory and proprioceptive modalities.
- Skin, visual inspection.
- Lymph nodes, by palpation.
- Dental examination (interim examination only).

3. *Comprehensive examination at F-5 days.* The comprehensive examination consisted of the procedures on the following page.

- Interval history, vital signs, including height, weight, oral temperature, pulse rate, and blood pressure.
- ENT Examination:
  - a. Ears: Visual inspection of external ears, auditory canals and tympanic membranes, screening Rudmose audiometry.
  - b. Nose: Visual inspection, sinus transillumination, if indicated by recent history.
  - c. Throat: Direct examination of middle pharynx.
  - d. Eyes: Same as for preliminary examination, plus distant and near visual acuity, near-point of accommodation, phorias, and visual fields.
- Heart: Palpation, percussion, and auscultation, plus standard twelve-lead EKG.
- Lungs: Palpation, percussion, and auscultation, plus PA chest film.
- Abdomen: Palpation, percussion, and auscultation, plus abdominal scout film.
- Genitalia and anus: Inspection, plus digital rectal examination.
- Extremities: Examination for recent trauma, range of function.
- Neurological examination: Detailed examination of cranial nerves, motor, sensory, and proprioceptive modalities.
- Skin: Visual inspection, plus photographs of any areas of significant interest.

4. *Cursory examination – F-4 to F-0 days.* Brief physical examinations and histories were conducted in the last four days before flight. These included recording of vital signs, oral temperature, pulse, blood pressure, weight, plus a brief examination of the ears, nose, throat, heart, and lungs. Other signs and systems were examined as indicated by the medical history.

The scheduled physical examinations varied slightly with mission requirements. However, these had to commence not earlier than 30 and not later than 21 days prior to lift-off in order to provide sufficient time to diagnose and treat any illnesses of recent onset. Some of the significant medical findings that occurred during the 30-day preflight period are listed in table 1. The comprehensive examination performed five days prior to launch was intended to accurately document the physical status of each crewmember at the outset of the mission. The final examination prior to flight involved last minute recordings of critical parameters to provide the most reliable basis that could be obtained for postflight comparisons.

The following paragraphs provide some detail on various aspects of the physical examination.

Dental Examinations. Dental care was provided as a regular part of the ongoing health care program of astronauts. However, special measures were taken prior to missions to preclude, wherever possible, dental problems during flight. All crewmen were evaluated at or about F-15. Because of the relatively short duration of the Apollo flights, emphasis was placed on general observation rather than definitive quantitative research.

Table 1
Preflight Medical Findings in Apollo Mission Crews

Diagnosis	Number of Occurrences
Pressure suit abrasions	2
Blister, left toe	1
Pressure suit callouses, scapulae and iliac crests	1
Carious lesion, mesial	1
Cellulitis of the hand secondary to laceration	1
Conjunctival injection	3
Dermatitis	3
Dermatophytosis, feet	2
Folliculitis, abdomen	1
Furunculosis	2
Gastroenteritis	7
Gingival burn	1
Hematomas, secondary to trauma	3
Inflammation, medial canthus, right eye	1
Influenza syndrome	3
Keratosic plaque	1
Traumatic lesion of the right buccal mucosa	1
Viral lesion of the buccal mucosa	1
Viral lymphoid hyperplasia of the postpharynx	3
Pyuria	4
Papules/pustules	5
Paronychia	1
Viral pharyngitis	3
Pulpitis, tooth No. 31	1
Prostatitis	1
Tinea crura	1
pedis	1
Viral tympanic membrane infection	1
Seborrhea	2
Viral rhinitis	3
Ringworm, arm	1
Beta-hemolytic pharyngitis	1
Sunburn, face and torso	2
Ulcer, aphthous	2
Urinary tract infection	8

Again, because mission duration was short, no special inflight dental treatment capability was provided for Apollo. It was felt that the risk of a problem occurring was slight and, when weighed against limitations of weight, space, and training time, providing an inflight treatment capability was not indicated. Analgesic and antibiotic drugs were provided for symptomatic treatment of any dental problems. As a further precaution, restorative dental treatment was avoided in the three-month period prior to launch. The object of this measure was to minimize the possibility of barodontalgia, a sudden, severe toothache which can occur when barometric pressure is reduced as a result of expansion of air entrapped in a dental restoration. When a dental problem arose in the three-month period prior to flight and a restoration became necessary, the astronaut in question was subjected to reduced barometric pressure to ascertain the condition of the tooth.

Dental problems that occurred among crewmembers during the Apollo Program resulted in no appreciable mission impact. During the 90-day preflight period, five of the thirty-three Apollo crewmen had dental problems requiring treatment. One preflight and one postflight occurrence of pulpitis could have caused significant crewmember impairment if the pulpitis had occurred during a flight. Pulpitis, an inflammation of the dental pulp, causes severe pain that usually can be stopped only by root-canal therapy, performed by a skilled dentist in a fully equipped dental suite, or by extraction. Prediction of such occurrences is virtually impossible, although the preventive treatment of known causative factors can lower the risk of occurrence. The only other preflight problems were minor fractures of previously placed restorations or minor fractures of part of a crown of a tooth. Inflight, no problems were experienced. No case of barodontalgia ever occurred, although some astronauts had experienced this discomfort during their flying careers.

Experience with Apollo astronauts in an intensive preventive dentistry program led to the conclusion that the probability of a disabling dental emergency in the astronaut population is one occurrence in 9000 man-days. The probability of dental problems of lesser severity, but associated with significant discomfort, is one in 1500 man-days. These figures are comparable to those recorded for Navy personnel on long submarine patrols. From these estimations, it is obvious that a provision for emergency inflight dental care must be made only for very long-duration missions.

Visual Function Testing. Visual function testing was a part of the pre- and postflight physical examination of Apollo astronauts. Ten visual parameters were tested during the Apollo Program:

- Unaided visual acuity, 7 m (20 ft)
- Amplitude of accommodation
- Near point of convergence
- Fusional amplitudes, base-in and base-out
- Horizontal phorias, 7 m and 33 cm (20 ft and 13 in.)
- Refraction
- Intraocular tension
- Color perception
- Depth perception
- Visual fields

One of the major considerations in flight was the amount of harmful ultraviolet (UV) radiation to which the crewmen would be subjected during extravehicular activity. Prior to Apollo missions, the UV threshold of the eye was unknown. Over a three-year period, NASA-sponsored research determined these levels. The problem was, however, subsequently resolved with the development and use of Lexan in the extravehicular visor assembly, since Lexan was opaque to UV radiation. A minimum of 2000 hours of exposure would be required to produce a corneal "burn" through this plastic.

Table 2 gives the data ascertained for ocular thresholds to UV radiation.

Table 2

Ocular Thresholds for Ultaviolet Radiation

Waveband (nm)	Solar Flux ($J/cm^2/sec \times 10^{-4}$)	Relative Effectivity	Effective Flux ($J/cm^2/sec \times 10^{-4}$)
215 – 225	0.2644	0.40	0.1058
225 – 235	0.5288	0.31	0.1639
235 – 245	0.5288	0.53	0.2803
245 – 255	0.6610	0.50	0.3305
255 – 265	1.4542	0.53	0.7707
265 – 275	2.1152	1.00	2.1152
275 – 285	2.5118	0.68	1.7080
285 – 295	4.7592	0.57	2.7127
295 – 305	5.9490	0.57	3.3909
305 – 315	7.1388	0.29	2.0703

Total ultraviolet effective flux : 13.6483×10^{-4} J/cm²/sec
Ocular burn threshold for ultraviolet : 40×10^{-4} W/cm²
Ultraviolet band threshold time : 2.93 seconds

The harmful effects of UV radiation extend over an area slightly greater than the 215 to 315 nanometer range noted above; however, the relative effectivity outside these extremes is very low. Summating these slight effects into the flux listed above could possibly lower the total UV band threshold time to about two and one-half seconds in a Zero Air Mass environment.

Special Studies. A number of special preflight examinations were conducted and measurements made to provide a baseline against which to compare postflight findings in the areas of microbiology, immuno-hematology and clinical chemistry, and cardiopulmonary function. Details of each of these studies are provided in the related chapters in Section III of this book. The preflight examination procedures required for each are discussed only briefly here.

In order to study any microflora alterations which could have occurred in space flight, preflight samples were taken to catalog the microorganisms found on the crewmembers and their clothing, and on spacecraft surfaces. Samples collected for culture included swabs of various parts of the body, throat gargle, and urine and fecal samples. These were collected on four occasions in the month prior to flight. Blood samples were also collected on three occasions in this same time frame.

Baseline data were obtained on the cellular elements of the blood, the chemical constituents of the blood and urine, and the humoral and cellular factors involved in immunity. The hematological and chemical measurements of various blood constituents were one portion of comprehensive examinations designed to disclose the state of well-being or the presence of occult disease in the crews. Blood analyses furnished data which, when integrated with facts obtained from histories and physical examinations, permitted an objective assessment of the physical status of the astronauts and allowed for remedial action if required. However, no values outside of the normal range were observed.

Biochemical and hematological baseline information was obtained, in part to quantitate the effect of the stresses inherent in space flight, and in part to aid medical personnel in medical management of crews in the postflight period.

Cardiopulmonary evaluations and findings are discussed at length in Section III, Chapter 4 ***Apollo Flight Crew, Cardiovascular Evaluations***, and Chapter 5, ***Exercise Response***. Preflight orthostatic tolerance tests and exercise response tests were performed to provide baseline information to facilitate assessment of space flight effects.

Cardiopulmonary data were obtained to develop heart rate versus metabolic rate calibration curves that would be used for estimating real-time work output during extravehicular activity. Utilization of Douglas bags, a Tissot spirometer, and an oxygen consumption computer or metabolic rate meter also made determination of cardiopulmonary efficiency possible. Evaluation of cardiopulmonary data was accomplished by observing how the dependent variables – workload, oxygen consumption, blood pressure response, respiratory response, and EKG – changed in response to the independent variable, heart rate.

The extent of cardiovascular system "deconditioning" was assessed also by comparison with preflight baseline responses to the application of negative pressure to the lower half of the body by means of the lower body negative pressure (LBNP) device. Preflight evaluations were made at least three times in the month preceding flight. The test procedures involved five minutes with the subject at supine rest in the LBNP device, a total of fifteen minutes at negative pressures ranging from $-40 \times 10^2 N/m^2$ to $-67 \times 10^2 N/m^2$ (-30 to -50mm Hg), and five minutes of recovery. Because missions involving postflight quarantine could not accommodate the size of the LBNP device in the Mobile Quarantine Facility, a static stand-type of orthostatic tolerance testing was substituted. This involved obtaining five minutes of electrocardiographic data while the crewman was standing still with his back to the wall and his feet apart. Test conditions were controlled and standardized to exclude unnecessary variables such as environmental temperature, time of day, food intake, physical exertion, or venipuncture.

Health Stabilization

The problem of communicable disease exposure prior to flight, with subsequent development of symptoms in flight, was recognized as a potential hazard from the beginning of the United States space program. Total isolation of flight crews for a period of time prior to launch offered indisputable advantages but was initially thought to be infeasible because of the operational difficulties involved. Flight crews were 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.

When clinical illnesses impacted preflight mission operations during Apollo 9 and 13, it became apparent that some type of preflight health stabilization program was imperative. Prior to Apollo 14, 57 percent of the Apollo crewmembers experienced some illness of varying degrees of severity at some time during the 21 days before launch. Based on observations of the first several flights and on the observation of crewmember activities during earlier manned Mercury and Gemini missions, the Flight Crew Health Stabilization Program was developed and implemented for the Apollo 14 mission and subsequent missions. Such a program, rigorously enforced, can result in a significant reduction of infectious disease hazard, although the hazard cannot be eliminated completely.

Table 3 lists the illness events in Apollo crewmen and shows the dramatic reduction in illness following the implementation of the health stabilization program.

Table 3
Effect of Flight Crew Health Stabilization Program (FCHSP) on the Occurrence of Illness in Prime Apollo Crewmen

Mission	Illness	Number of Crewmen Involved	Mission Phase
Before Implementation of FCHSP			
Apollo 7	Upper respiratory infection	3	Preflight, inflight
8	Viral gastroenteritis	3	Preflight, inflight
9	Upper respiratory infection	3	Preflight
10	Upper respiratory infection	2	Prefgiht
11	None	–	–
12	Skin infection	2	Inflight
13	Rubella infection	1	Preflight
After Implementation of FCHSP			
Apollo 14	–	–	–
15	–	–	–
16	–	–	–
17	Skin infection	1	Preflight

Drug Sensitivity Testing

Drug sensitivity testing was performed to determine the response of flight crewmembers to each item in the medical kit to preclude allergic reactions and other undesirable side effects in flight. Each Apollo crewmember was tested under controlled conditions to determine his response to medical kit items carried onboard the spacecraft. (The medical kit is described later in this chapter in the section concerning Inflight Procedures and Findings.) After a medical history was obtained by a physician regarding the experience of each crewmember with each medication under test, and it had been determined that (1) no adverse reaction had been experienced, and (2) there was no evidence of impaired health at the time of testing, the medication was administered to the astronaut. The crewmember was observed by the physician for an appropriate period of time following administration of the medication and was queried about subjective responses. If positive subjective findings were reported, the test was either repeated with a double-blind placebo method, or an appropriate drug was substituted for which no undesirable side effects had been reported. Individuals were additionally tested for any allergic reaction to the electrode paste.

Table 4 indicates the drug administration and observation constraints applied. All medications used were treated in a similar fashion.

Medical Training

To perform their inflight tasks optimally, Apollo crewmen required an understanding of the interaction of space flight stresses and their effects on the human organism, including the manner in which the body adapts to space flight factors. Further, these crewmen had to recognize any abnormalities in their health status and understand the therapeutic measures which might have been prescribed for inflight problems. Medical training began shortly after astronaut selection with a series of lectures concerned with space flight physiology and therapeutics. The curriculum encompassed about 16 hours of didactic instruction provided by experts in each area. The principal elements were as follows:

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 programs scheduled for Apollo and Skylab Programs, illustration of the need to establish good baseline data, controls, and possible expansion of the present program.

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.

Table 4
Typical Pharmacological Agent
Administration and Observation Constraints

Item	Route of Administration	Frequency of Observation by Physician	Constraints
Meperidine HCl (Demerol)	I.M. 1/4 dose (25 mg)	0-15 min; 2nd hour; 4th hour	No flying, driving, or other hazardous pursuit for 8 hours
Hyoscine and D-amphetamine sulfate (Dexedrine)	0.3 mg (Hyoscine) and Oral 5.0 mg (Dexedrine)	1 hour and 4 hours or immediately on development of any reaction	Not within 4-6 hours of planned sleep
Propoxyphene HCl (Darvon)	Oral (65 mg)	One time within 4 hours or immediately on development of any reaction	No flying or driving within 6 hours
Acetylsalicylic acid (ASA)	Oral (300 mg)	One time within 4 hours or immediately on development of any reaction	None
Tetracycline	Oral (250 mg)	Within 4 hours or immediately on development of any reaction	Not within 24 hours of stool collection for microbiology
Diphenoxylate HCl with atropine sulfate (Lomotil)	Oral (0.025 mg)	One time within 4-8 hours or immediately on development of any reaction	None
D-amphetamine sulfate (Dexedrine)	Oral (5 mg)	2nd hour, 4th hour or immediately on development of any reaction	Not within 4 to 6 hours of planned sleep. Heart rate to be recorded
Skin cream	Topical	Within 4-6 hours or immediately on development of any reaction	None
Methylcellulose eye drops	Topical	On application	None
Polymycin B-bacitracin-neomycin sulfate (Neosporin) ointment)	Topical	On application	None

Table 4 (Continued)
Typical Pharmacological Agent
Administration and Observation Constraints

Item	Route of Administration	Frequency of Observation by Physician	Constraints
N-benzhydryl-N-methylpiperazine monoHCl or lactate (Marezine)	Oral (50 mg)	Within 4 hours or immediately on development of any reaction	No flying, driving, etc. for 8 hours
Proparacaine HCl (Opthaine)	Topical	On application	None
Simethicone (Mylicon)	Oral	Within 4 hours	None
Oxymetazoline HCl (Afrin)	Topical	(1) On application (2) 8-12 hours or immediately on development of any reaction	None
Electrode paste	Topical	At 48 and 72 hours following application	None
Ampicillin	Oral (250 mg)	0-15 min; within 4 hours or immediately on development of any reaction	Not within 24 hours of stool collection for microbiology
Triprolidine HCl and pseudoephedrine HCl (Actifed)	Oral (60 mg)	One time within 4 hours or immediately on development of any reaction	No flying driving, etc. for 8 hours

Description of Vestibular System. 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 System. Brief description of anatomy and physiology, relationships to other sensory 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 were required of each astronaut every three years in the technical and practical aspects of altitude physiology and the medical aspects of survival.

Before each mission, a detailed medical briefing was provided by staff members of the Johnson Space Center approximately one month before launch. The purpose of the briefing was as follows:

1. To acquaint the crewmembers with the pre- and postflight medical procedures planned for their mission.
2. To discuss with the crew preventive medicine measures (related to diet, potential sources of infection, and physical conditioning) recommended for their health and comfort.
3. To acquaint the crew with the Apollo medical kit and its uses.
4. To review with the crew the flight food and hygienic supplies selected for their flight.
5. To demonstrate the configuration and operation of the biomedical harness.
6. To achieve final coordination of procedures for logging or communicating medical data during flight.
7. To familiarize the crew with toxicological considerations.

The Astronaut Health Care Program

Once selected, retention of space crewmen on flying status assumes great importance for a number of reasons, not the least of which is the cost of training such individuals. Consequently, comprehensive health care is provided all astronauts and their families through a preventive, diagnostic, and therapeutic program managed by the National Aeronautics and Space Administration, with aid from many civilian and military consultants. Care of families by the same physicians rendering care to the astronauts provides an understanding of the total milieu in which the astronaut lives and functions.

Astronauts must 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. Preventive dental care is also rendered. All patients are seen by a dentist at least once every six months and their conditions evaluated at that time. Emphasis is placed on a home care program. During these periodic examinations, care is taken to minimize ionizing radiation exposure during the use of diagnostic X-rays. 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, the astronaut population represents the opportunity for a unique longitudinal study which should yield invaluable information for selection of future space flight crews.

Listed in tables 5 through 11 are examples of significant medical problems detected during the annual physical examination. These tables serve to highlight the types of medical findings contained in the past histories of the astronaut crews. The findings are invaluable to the mission flight surgeon as background information in the real-time assessment of inflight medical problems and in pinpointing potential problems that may arise. It is vital that all inflight signs and symptoms be evaluated in the context of past medical findings such as are enumerated in these tables.

Inflight Procedures and Findings

During the inflight phase of Apollo missions, medical care was limited to long-distance biotelemetry monitoring, diagnosis, and treatment with the appropriate onboard drugs. This treatment was carried out by the space crewmen themselves under the direction of ground-based flight surgeons. The weightless flight phase of Apollo missions was characterized by certain transient adaptational difficulties, by a few clinical illnesses, and by a limited number of physiological phenomena apparently related largely to space flight factors. The following sections describe the clinical and medical aspects of the inflight portion of Apollo missions.

Table 5
Infectious Diseases

Infection	Number of Cases
Upper respiratory	133
Influenza	33
Pneumonia	7
Sinusitis	19
Otitis media	1
Otitis externa	6
Gastroenteritis	29
Genitourinary	30
Bacterial dermatitis	9
Superficial fungal dermatitis	20
Conjunctivitis	3
Blepharitis	1
Chalazion	3
Herpes zoster	1
Herpes hominis, recurrent	1
Cellulitis and lymphangitis	1
Rubella	1
Tuberculin skin test conversion	2
Total	301

Table 6
Neoplasms

Neoplasm	Number of Cases
Basal cell carcinoma	2
Epithelioma	2
Polyp, colon	1
Adenoma, thyroid	1
Fibroma	1
Squamous papilloma, eyelid	1
Total	8

Table 7
Hereditary and Metabolic Diseases

Disease	Number of Cases
Plasma thromboplastin antecedent deficiency	1
Gout	1
Abnormal glucose tolerance	2
Hypercholesterolemia	1
Hyperlipemia	1
Idiopathic hyperbilirubinemia	1
Total	7

Table 8
Degenerative Disorders

Disorder	Number of Cases
Hearing loss	6
Presbyopia	6
Lenticular opacities	3
Vertebral degenerative changes	4
Cervical spondylosis - Brown-Sequard syndrome *	1
Degenerative disc disease, early	1
Total	21

* Not detected during annual physical examination.

Table 9
Allergic Problems

Allergic Response	Number of Cases
Angioneurotic edema	1
Urticaria	7
Asthma secondary to aspirin hypersensitivity	1
Skin hypersensitivity, ant bite	1
Allergic vasculitis and synovitis	1
Contact dermatitis	3
Drug rash	2
Total	16

Table 10
Traumatic Injuries

Trauma	Number of Cases
Muscle strain	9
Sprains	9
Torn meniscus (knee)	2
Fractures	11
Dislocation - shoulder and phalanges	2
Lacerations	10
Bursitis or synovitis (elbow)	2
Burns	3
Contusions	3
Eye injuries	9
Dog bite	1
Peripheral compression neuropathy	1
Concussive labyrinthitis	1
Laryngitis (excessive speaking)	1
Total	64

Table 11
Miscellaneous Problems of Medical Significance

	Number of Cases
Cholecystitis or cholelithiasis	2
Hernia	2
Sperm granuloma	1
Hemorrhoids, symptomatic	5
Renal calculus	1
Ménière's syndrome	1
Thrombophlebitis	1
Migraine equivalent	1
Congestive prostatitis	2
Rectal fissure	1
Abdominal pain, unknown etiology, severe	1
Atrial fibrillation	1
Dysbarism, bends	1
Barotitis media	5
Total	25

Monitoring

When the United States space program first began, the concept of obtaining continuous physiological data by instrumenting the human operator was a new one. No sufficiently reliable off-the-shelf hardware was available. Since that time, sophisticated and highly reliable biotelemetry devices have been developed.

Each Apollo crewman wore a biosensor harness which provided a means of transmitting critical physiological data to the ground. Through this system, medical personnel were able to evaluate physiological status during such critical phases as launch and docking, extravehicular activity, and lunar explorations. This real-time telemetry of vital biomedical information was also available for monitoring Apollo crewmen in the event of inflight illness.

The operational bioinstrumentation system was designed as an individually adjustable unit worn under the flight clothing. The biobelt assembly was an electronic system that included sensors, signal conditioners, and telemetry interfaces. The system returned electrocardiogram, heart rate, and respiratory pattern and rate data. A two-lead EKG with synchronous phonocardiography provided an index of cardiac activity. Cardiotachometer equipment made monitoring of instantaneous and average heart rate information possible. Voice communications and real-time television observations, coupled with monitoring of the vital signs, provided the medical basis for an inflight clinical profile of the Apollo astronauts.

Data from the biotelemetry of the spacecraft were displayed at consoles at the launch and mission control centers. The consoles were manned continuously by medical personnel during the course of each mission. Heart and respiration rates were displayed in digital form; electrocardiogram and impedance pneumogram data were presented on a cathode ray oscilloscope.

In general, the equipment worked well, although some minor losses of data were experienced throughout the program. Problems with breakage of bioharness leads and pin connectors encountered on the Apollo 7 mission were corrected for subsequent flights. Some degradation of physiological data was caused by loose biosensors, but restoration of good data was usually obtained by reapplication of the sensors. Sponge pellet electrodes were used in the biosensor harness for the first time on the Apollo 15 mission. This modification reduced skin irritation that had earlier resulted from continuous wearing of the electrodes.

The quality of the data obtained with the new electrodes was excellent. Some data loss resulted because air became trapped under the electrodes during the Apollo 15 mission, but this was easily corrected by modifying the electrodes with small vents.

Additional data were telemetered during lunar surface extravehicular activity to permit assessment of the portable life support system and, additionally, the determination of the metabolic activity during lunar excursions. Metabolic rate was approximated by monitoring the inlet and the outlet temperatures of the liquid cooled garment. Heart rate and oxygen usage were also monitored as metabolic rate indices. Of the three methods, the thermal data and oxygen use methods proved to be reasonably accurate and significantly more reliable as a means for determining metabolic rate than did heart rate data.

Further documentation of the Apollo bioinstrumentation system is reported in Section VI, Chapter 3, *Bioinstrumentation.* Additional information concerning monitoring during extravehicular activity is contained in Section II, Chapter 4, *Metabolism and Heat Dissipation During Apollo Extravehicular Activity Periods.*

Inflight Medications

The initial philosophy regarding use of medication precluded usage except in a medical emergency. Additional experience and the confidence gained thereby permitted some alteration of this philosophy to the extent that certain drugs were prescribed during Apollo missions when indicated. For example, hypnotics were prescribed when adequate rest could not be obtained, particularly when sound sleep was important prior to critical mission phases.

Medical Kit. The contents of the Apollo medical kit (figure 1) were selected based on experience gained during earlier missions. The drugs were intended to treat the contingency situations most likely to arise. As noted previously, crewmembers were tested for sensitivity to all drugs in the medical kit and substitutions were made when necessary.

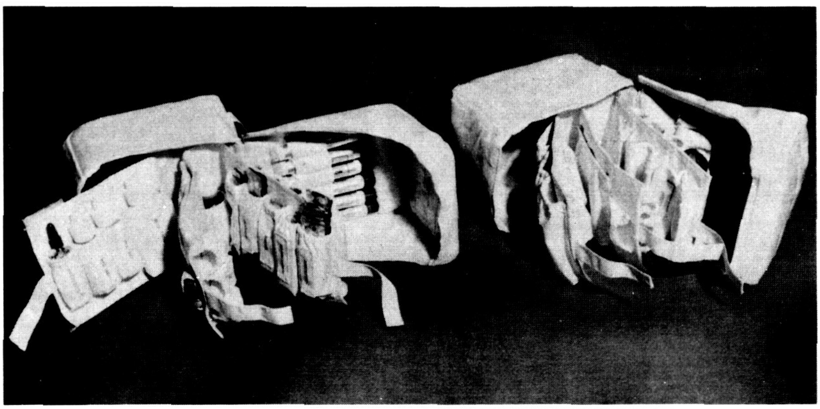

Figure 1. Typical Apollo medical kit.

Table 12 lists drugs and drug stowage and usage aboard the Apollo Command Module. The contents of the medical kits were changed as more effective medications were identified. For example, the combination scopolamine/Dexedrine was substituted after Apollo 11 for the previously stowed Marezine after ground-based tests indicated it was more effective for the treatment of motion sickness. Likewise, a short-acting barbiturate, Seconal, was added after reports of sleep difficulties by the Apollo 7 crew. The cardiac arrhythmias experienced during the Apollo 15 mission dictated the addition of Pronestyl, Lidocaine, atropine, and Demerol in missions subsequent to Apollo 15. Each Apollo vehicle also carried a medical accessory kit in a compartment behind the Lunar Module Pilot's couch. Its contents are listed in table 13. An abbreviated version of the Command

Table 12

Command Module Medical Kit

	7	8	9	10	11	12	13	14	15	16	17
	Stowed/Used										
Methylcellulose eye drops (1/4%)	2/1	2/2	2/0	2/0	2/0	2/0	2/0	2/0	1/0	2/10	1/0
Tetrahydrozoline HCl (Visine)	—	—	—	—	—	—	—	—	—	—	1/1
Compress - bandage	2/0	2/0	2/0	2/0	2/0	2/0	2/0	2/0	2/0	2/0	2/0
Bandaids	12/2	12/0	12/0	12/0	12/0	12/0	12/0	12/0	12/0	12/0	12/0
Antibiotic ointment	1/1	1/0	1/0	1/0	1/0	2/0	2/0	2/0	2/0	2/1	2/1
Skin cream	1/0	1/1	1/1	1/0	1/0	1/0	1/0	1/0	1/0	1/1	1/0
Demerol injectors (90 mg)	3/0	3/0	3/0	3/0	3/0	3/0	3/0	3/0	3/0		
Marezine injectors	3/0	3/0	3/0	3/0	3/0	3/0	3/0	3/0	3/0		
Marezine tablets (50 mg)	24/3	24/1	24/4	12/0	—	—	—	—	—	—	—
Dexedrine tablets (5 mg)	12/1	12/0	12/0	12/0	12/0	12/0	12/1	12/0	12/0	12/0	12/0
Darvon compound capsules (60 mg)	12/2	18/0	18/0	18/0	18/0	18/0	18/0	18/0	18/0	18/0	18/0
Actifed tablets (60 mg)	24/24	60/0	60/12	60/2	60/0	60/18	60/0	60/0	60/0	60/0	60/1
Lomotil tablets	24/8	24/3	24/1	24/13	24/2	24/0	24/1	24/0	24/0	24/0	48/5
Nasal emollient	1/0	2/1	2/1	1/0	1/0	1/0	1/0	1/0	1/0	1/0	1/0
Aspirin tablets (5 gr)	72/48	72/8	72/2	72/16	72/Unk	72/6	72/30	72/0	72/0	72/0	72/0
Tetracycline (250 mg)	24/0	24/0	24/0	15/0	—	—	—	—	60/0	60/0	60/0
Ampicillin	—	60/0	60/0	45/0	60/0	60/0	60/0	60/0	60/0	60/0	60/0
Seconal capsules (100 mg)	—	21/1	21/10	21/0	21/0	21/6	21/0	—	21/0	21/3	21/16
Seconal capsules (50 mg)	—	12/7	—	—	—	—	—	—	—	—	—
Nose drops (Afrin)	—	3/0	3/1	3/0	3/0	3/1	3/1	3/1	3/0	3/0	3/3
Benadryl (50 mg)	—	8/0	—	—	—	—	—	—	—	—	—
Tylenol (325 mg)	—	14/7	—	—	—	—	—	—	—	—	—
Bacitracin eye ointment	—	—	1/0	—	—	—	—	—	—	—	—
Scopolamine (.3 mg) - Dexedrine (5 mg) capsules	—	—	—	—	12/6	12/0	12/2	12/0	12/0	12/0	12/1
Mylicon tablets	—	—	—	—	40/0	40/0	40/0	40/0	40/0	40/0	40/0
Opthaine	—	—	—	—	—	—	1/0	1/0	1/0	1/0	1/0
Multi-Vitamins	—	—	—	—	—	—	—	20/0	—	—	—
Auxiliary Medications for Apollo 16 & 17											
Pronestyl	—	—	—	—	—	—	—	—	—	80/0	80/0
Lidocaine	—	—	—	—	—	—	—	—	—	12/0	12/0
Atropine	—	—	—	—	—	—	—	—	—	12/0	12/0
Demerol	—	—	—	—	—	—	—	—	—	6/0	6/0

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Table 13
Apollo Medical Accessories Kit Contents

Item	Apollo Mission										
	7	8	9	10	11	12	13	14	15	16	17
Constant wear garment harness plug	–	–	–	–	–	–	–	–	3	3	3
ECG sponge packages	–	–	–	–	–	–	–'	–	14	14	14
Electrode bag	1	1	1	1	1	1	1	1	1	1	1
Electrode attachment assembly	12	12	12	12	20	20	20	20	100	100	100
Micropore disc	12	12	12	12	20	20	20	20	50	50	50
Sternal harness	1	1	1	1	3	3	3	3	3	3	3
Axillary harness	1	1	1	1	1	1	1	1	1	1	1
Electrode paste	1	1	1	1	1	1	1	1	1	1	1
Oral thermometer	1	1	1	1	1	1	1	1	1	1	1
pH paper	1	1	1	1	1	1	1	1	1	None	None
Urine collection and transfer assembly roll-on cuffs	3	3	6	6	6	6	6	6	6	6	6

Module medical kit was carried in the Lunar Module (table 14). The adequacy of the kits was reviewed after each flight, and appropriate modifications were made for the next flight. The basic contents of the medical kits remained the same for each mission, but there was no "standard" kit.

Table 14

Lunar Module Medical Kit

Medical Package Assembly	Quantity
Rucksack	1
Stimulant pills (Dexedrine)	4
Pain pills (Darvon)	4
Decongestant pills (Actifed)	8
Diarrhea pills (Lomotil)	12
Aspirin	12
Bandaids	6
Compress bandages	2
Eye Drops (methylcellulose)	1
Antibiotic ointment (Neosporin)	1
Sleeping pills (Seconal)	6
Anesthetic eye drops	1
Nose drops (Afrin)	1
Urine collection and transfer assembly roll-on cuffs	6
Pronestyl	12
Injectable Drug Kit	Quantity
Injectable drug kit rucksack	1
Lidocaine (cardiac)	8
Atropine (cardiac)	4
Demerol (pain)	2

Pills and tablets in the medical kit were packaged in such a manner that the crewman had easy access to the medication at all times. The pills were sealed individually in cells in strips of 12 or 24 cells. Midway through the Apollo Program, the number of pills in the kit was increased. Pressure-related problems in medication packaging were resolved by puncturing each cell with a small pin; the hole made it possible for the air to vent when under reduced-pressure conditions.

The use of standard spray bottles in a weightless, reduced-pressure environment proved unsatisfactory. Sprays were therefore replaced by dropper bottles. However, the likelihood of overdosage from a dropper bottle and the need for more uniform distribution of decongestants than is possible with dropper bottles makes future development of a zero-gravity spray dispenser highly desirable.

General Adaptation

In general, Apollo astronauts adapted well to the world of zero gravity. It was, in many respects, a boon. Astronauts were able to move effortlessly about the spacecraft, and this enhanced the perceived volume of the vehicle.

The most frequently reported subjective sensation associated with initial orbital insertion was a feeling of fullness in the head. This sensation, reported by all but two crewmen, persisted for four hours to three days. Concomitantly, crewmen noticed a roundness of the face in one another and engorgement of the veins of the head and neck. One crewman reported that head fullness was similar to the feelings elicited by standing on one's head or hanging upside down.

Crews of the Apollo 7, 12, 14, and 15 missions reported some soreness of the back muscles. This condition was relieved by exercise and hyperextension of the back. No calibrated inflight exercise program was planned for any of the flights; however, an exercise device was provided. The crewmen typically used the exerciser several times a day for periods of 15 to 30 minutes when they were in the Command Module.

Insomnia was another frequent crew complaint. The principal reasons for insomnia were shifting the customary sleep time, altering circadian rhythm, and combating operational problems. When one considers the unfamiliar environment of space and the excitement this generated, as well as the onboard noise and other mission-related disturbances, it is not surprising that the astronauts in some cases failed to obtain sufficient restful sleep. Some crewmen found it was possible to obtain restful sleep with the aid of hypnotics.

The first American space crews to report any symptoms of motion sickness were the Apollo astronauts. The symptoms ranged from so-called "stomach awareness" to frank nausea and, in a few cases, vomiting. In most instances, the nausea appeared to be related to rapid body movement before adaptation to weightlessness occurred. Symptoms subsided or were absent when crewmen moved slowly during the initial period of weightlessness. Moreover, no recurrence of motion sickness symptoms was reported after this adaptation period was completed. Increased susceptibility to motion sickness is thought to be the result of the relatively enhanced effect of stimulation of the acceleration-detecting nerve ends in the semicircular canals that occurs during weightlessness. The otolith, the gravity-sensing component of the inner ear, is thought to bias the input of the semicircular canals to the brain center that controls vomiting. The removal of this bias in the weightless condition results in an alteration of the input to the brain from the semicircular canals. Then, in a susceptible individual, rapid head motions will result in motion sickness.

Adaptation of the inner ear to weightlessness, which occurs fairly rapidly in most individuals, can be hastened by appropriate head movements that produce a subthreshold stimulation of the semicircular canals. This technique was taught to all Apollo crewmen subsequent to the Apollo 9 mission. Although not all crewmen have used this technique to assist their adaptation to weightlessness, those crewmen who have used it have achieved fairly good results.

Considerable variation in susceptibility to motion sickness exists among individuals, and a prediction of individual susceptibility is not precise. A thorough understanding of the physiology of the inner ear is needed for better prediction and prevention of motion sickness.

Crew Illness and Medications

Table 15 lists medical problems experienced by Apollo crews in flight. The more important of these are discussed below.

Apollo 7. Three days prior to the Apollo 7 launch, the Commander and Lunar Module Pilot experienced slight nasal stuffiness and were successfully treated. They were medically certified fit for flight when launch day physical examinations of the crew failed to demonstrate any manifestations of illness.

Approximately 15 hours after lift-off, the crew reported that the Commander had developed a bad head cold. The flight surgeon recommended aspirin for symptomatic relief, and that one decongestant tablet (Actifed) be taken every eight hours until the Commander either felt better or had exhausted the onboard supplies. The Commander reported a normal temperature and no symptoms of sore throat, cough, or lung congestion. The Command Module Pilot and Lunar Module Pilot also experienced cold symptoms 24 hours later and the same treatment schedule was instituted.

The possibility of rupturing the eardrums during entry caused some concern because it was considered necessary for the crew to wear pressure suits during entry. With helmets on, the crewmen would not be able to perform the Valsalva maneuver and equalize pressure within the middle ear cavities. Forty-eight hours prior to entry, the crew made the decision not to wear helmets or gloves. The last nine decongestant tablets were taken during the last 24 hours of flight. The times for taking the tablets were selected so as to obtain the maximum benefit at the time of the deorbit maneuver and entry.

During entry, none of the crewmen had any difficulty in ventilating the middle ear and the Valsalva maneuver was not required. In the postflight physical examinations, the two crewmen who had experienced the most distressing inflight symptoms showed no residual evidence of their colds. The other crewman did exhibit a slight amount of fluid in the middle ear.

After the flight, the Commander stated that his cold symptoms began about one hour after lift-off (six hours after his prelaunch physical examination). In the zero-gravity environment, he reported, the drainage of nasal and sinus secretions ceases. The body's normal means of eliminating such secretions is lost because of the absence of gravity. There is no postnasal drip, and, because secretions do not reach the lower respiratory tract, they do not produce coughing. Forceful blowing is the only method available for purging nasal secretions, but blowing the nose is ineffective in removing mucoid material from the sinus cavities.

Apollo 8. After the Apollo 8 Commander's symptoms of motion sickness dissipated, he experienced additional symptoms of an inflight illness believed to be unrelated to the adaptation syndrome. When the Commander was unable to fall asleep two hours into his initial rest period, he took a sleeping tablet (Seconal) which induced approximately five hours of sleep, described as "fitful." Upon awakening, he felt nauseated and he had a moderate occipital headache. He took two aspirin tablets and then went from the sleep station to his couch to rest. The nausea, however, became progressively worse and he vomited twice. After termination of this first sleep period, the Commander also became aware of some increased gastrointestinal distress and was concerned that diarrhea might occur.

Table 15

Inflight Medical Problems in Apollo Crews

Symptom/Finding	Etiology	Number of Cases
Barotitis	Barotrauma	1
Cardiac arrhythmias	Undetermined, possibly linked with potassium deficit	2
Eye irritation	Spacecraft atmosphere	4
	Fiberglass	1
Dehydration (Apollo 13)	Reduced water intake during emergency	2
Flatulence	Undetermined	3
Genitourinary infection with prostatic congestion	Pseudomonas aeruginosa	1
Headache	Spacecraft environment	1
Head cold	Undetermined	3
Nasal stuffiness	Zero gravity	2
Pharyngitis	Undetermined	1
Rhinitis	Oxygen, low relative humidity	2
Respiratory irritation	Fiberglass	1
Rash, facial, recurrent inguinal	Contact dermatitis	1
	Prolonged wearing of urine collection device (Apollo 13)	1
Skin irritation	Biosensor sites	11
	Fiberglass	2
	Undetermined	1
Seborrhea	Activated by spacecraft environment	2
Shoulder strain	Lunar core drilling	1
Subungual hemorrhages	Glove fit	5
Stomach awareness	Labyrinthine	6
Nausea, vomiting	Labyrinthine	1
	Undetermined (possibly virus-related)	1
Stomatitis	Aphthous ulcers	1
Excoriation, urethral meatus (Apollo 13)	Prolonged wearing of urine collection device	2
Urinary tract infection	Undetermined	1
Dysbarism (bends) *		1

* Also occurred during Gemini 10; later incidences were reported by the same crewman five years after his Apollo 11 mission.

As the mission progressed, the flight surgeon had the impression that the Commander was experiencing an acute viral gastroenteritis. This tentative diagnosis was based upon the delayed transmission of a recorded voice report that the Commander had a headache, a sore throat, loose bowels, and had vomited twice. A conversation between the Senior Flight Surgeon and the Commander verified that the previous report was correct, but that the Commander was feeling much better. The Commander also stated that he had not taken any medication for his illness, which he described as a "24-hour intestinal flu." (Just prior to the Apollo 8 launch, an epidemic of acute viral gastroenteritis lasting 24 hours was present in the Cape Canaveral area.)

The Commander's temperature was 309°K (97.5°F) on two occasions subsequent to his nausea and vomiting. The Commander was advised to take one Lomotil tablet and to use Marezine if the nausea returned. Complete remission of the illness, however, made the use of further medications unnecessary.

Apollo 9. Three days before the scheduled Apollo 9 launch, the Commander reported symptoms of general malaise, nasal discharge, and stuffiness. These common cold symptoms were not present at the physical examination performed on the previous day. The Commander was treated symptomatically and his temperature remained normal throughout the course of the illness. Two days before the scheduled launch, the Command Module Pilot and the Lunar Module Pilot also became ill with common colds and were treated symptomatically. However, because the symptoms persisted, the launch was postponed for three days. The crew responded rapidly to rest and therapy and were certified fit for flight the day prior to the rescheduled launch.

The Lunar Module Pilot experienced motion sickness and vomited twice, once while preparing for transfer to the Lunar Module, and again after transfer. After about 50 hours of flight, he was still not feeling well but had experienced no further vomiting. He reported that his motion sickness symptoms subsided when he remained still. He was advised to take a Marezine tablet one hour before donning his pressure suit for extravehicular operations that were to be conducted at approximately 73 hours. The nominal plan called for the Lunar Module Pilot to spend two hours and 15 minutes outside the spacecraft, but, because of his symptoms, the plan was revised so that only the tasks having the highest priority were to be performed. The principal objectives were successfully accomplished in approximately 45 minutes. The Lunar Module Pilot took Seconal several times during the mission to induce sleep.

Apollo 10. All three crewmen experienced irritation of the skin, eyes, and upper respiratory passages when the fiberglass insulation in the Command Module tunnel became loosened and particles of fiberglass became suspended in the cabin air. This was treated symptomatically with good results. This crew complained of abdominal rumblings caused by the ingestion of hydrogen gas present in the potable water. Since they were concerned that diarrhea might develop, they decided on their own initiative to take Lomotil tablets. Medically, the use of the drug was not indicated.

Lomotil decreases the activity of the lower intestinal tract and reduces the amount of gas that can be expelled. Aspirin was taken occasionally by all crewmen.

Apollo 11. The Apollo 11 Commander and Lunar Module Pilot each took one Lomotil tablet to retard bowel movements before Lunar Module operations. They each carried extra Lomotil tablets into the Lunar Module but did not use them. Four hours before entry, and again after splashdown, the three crewmen each took scopolamine/dextroamphetamine (antimotion sickness) tablets. Aspirin tablets were also taken, but the number of tablets per individual was not recorded. The Lunar Module Pilot recalled that he had taken two aspirin tablets almost every night to aid his sleep. One interesting medical event that occurred on this flight was reported by the Command Module Pilot in his account of the Apollo Program.* He revealed that he had experienced dysbarism (bends) on his first space flight (Gemini 10) as well as on his second (Apollo 11). He described symptoms involving the left knee as a sharp, throbbing ache which gradually worsened and leveled off at a moderate, but very uncomfortable level of pain. The symptomatology was less painful on Apollo 11 than it had been on Gemini 10. Unfortunately this information was not made available to the medical team during either the Gemini or Apollo Programs.

Apollo 12. The Commander developed a mild contact dermatitis from the biosensor electrolyte paste. An analysis performed postflight on the batch of paste applied to the affected skin areas during the mission failed to identify any constituent not present in nonoffending batches of the electrolyte paste. To avoid similar occurrences, subsequent Apollo crewmen were tested with all materials of known allergenic potential, as has always been done with medical kit drugs. As a further precaution, the identical materials to be used in flight were used in training to provide for scrupulous observation and reporting of any skin reactions.

All three crewmen used Actifed decongestant tablets to relieve nasal congestion at various times throughout the flight. The Lunar Module Pilot also took Seconal throughout most of the mission to aid sleep. Aspirin was taken occasionally by all the crewmen. No motion sickness medications were taken prior to entry.

Apollo 13. The Lunar Module Pilot awoke on the second day of the mission with a moderately severe headache. He took two aspirin tablets with only fair results. After eating breakfast and engaging in physical activity, he became nauseated and vomited. His symptoms began to subside over the next 12 hours as adaptation to weightlessness took place. All crewmen took scopolamine/dextroamphetamine antimotion sickness medication prior to entry.

A urinary tract infection in one of the crewmen could have resulted in a serious inflight illness if the mission had lasted 24 hours longer. During the return flight following the inflight accident, the combined stresses of cold, dehydration (caused by voluntary rationing of water), and prolonged wearing of the urine collecting device (UCD) were

*Collins, Michael: Carrying the Fire: An Astronaut's Journeys. Farrar, Straus and Giroux (New York), 1974.

contributing factors. The other two crewmen had less serious problems, but the UCD was not designed for prolonged wearing.

Apollo 14. No medications were used during the Apollo 14 mission other than nose drops to relieve nasal stuffiness caused by the spacecraft atmosphere. On the third day of flight, the Commander and the Lunar Module Pilot used one drop in each nostril. Relief was prompt and lasted approximately 12 hours. The Command Module Pilot used the nose drops three hours prior to entry.

Apollo 15. The Commander developed a dermatitis from the deerskin lining of a communication carrier. This sensitivity was not recognized before the mission because a concomitant skin disorder (seborrhic dermatitis) existed.

Aspirin and nose drops were the only medications used during Apollo 15. The Commander took a total of 14 aspirin tablets over a period of days to relieve pain in his right shoulder that developed after difficult deep core-tube drilling on the lunar surface. The Command Module Pilot used nose drops just prior to Earth entry to prevent possible middle ear blockage.

Apollo 16. The Lunar Module Pilot used three Seconal capsules for sleep induction during the Apollo 16 mission. One capsule was taken on the night prior to lunar descent and the other two capsules were used for the first and second lunar surface sleep periods, respectively. In the postflight medical debriefing, the Lunar Module Pilot reported that the Seconal was effective in producing a rapid onset of good sleep.

Apollo 17. More medications were taken on Apollo 17 than on any of the previous missions. The intermittent use of Seconal for sleep by all three crewmen and the daily use of simethicone for symptomatic relief of flatulence by the Commander were the principal factors contributing to the high intake of medications. The Commander also took a scopolamine/dextroamphetamine capsule on the second day of flight for "stomach awareness."

The Command Module Pilot and the Lunar Module Pilot experienced one loose bowel movement each, on the eleventh and twelfth days of flight, respectively. In each case, Lomotil was taken and was effective.

Cardiac Arrhythmias

Apollo 15 was the first manned space flight in which cardiac irregularities other than occasional benign premature ventricular contractions were observed. A historical account precedes discussion of possible etiology and mechanisms.

An isolated premature ventricular contraction was observed on the Lunar Module Pilot 41 minutes prior to launch. Subsequently, while the Lunar Module Pilot was being monitored during the translunar coast phase of the mission, only infrequent premature ventricular contractions (approximate rate one to two per hour) were observed. These events were not considered significant since the Lunar Module Pilot had demonstrated occasional premature ventricular contractions during all of his ground-based altitude chamber tests and training sessions. The frequency of the Lunar Module Pilot's premature ventricular contractions remained constant at the same rate throughout the three periods of extravehicular activity, Lunar Module ascent, and docking.

Shortly after docking with the Command Module at 178 hours ground elapsed time (GET), the Lunar Module Pilot experienced five ventricular prematurities in a 30-second period. Approximately one hour later at 179:07 GET, while the crewmen were observing the Lunar Module tunnel leak rate in their couches, the Lunar Module Pilot suddenly converted from normal sinus rhythm to a nodal bigeminal rhythm. During the 14 seconds in which the abnormal rhythm persisted, a total of eleven coupled beats were observed. The Lunar Module Pilot's heart rate preceding and during the arrhythmia was approximately 95 beats per minute. One and one-half minutes prior to onset of the bigeminal rhythm, his heart rate had peaked at 120 beats per minute for a 20-second period. Following this bigeminal episode, the Lunar Module Pilot experienced approximately ten additional premature atrial contractions during the time he was monitored over the next 60 hours of the mission. The last atrial prematurity in the Lunar Module Pilot was observed at 240:24 hours GET. The Lunar Module Pilot's premature ventricular contractions, however, persisted at the previously cited rate of one to two per hour.

The Commander was completely eurhythmic until 286:22 hours GET, when he suddenly began to experience occasional supraventricular prematurities. The first of these occurred while the Commander was sound asleep and continued through the first hour after awakening. The Commander's heart rate at the time of onset was approximately 30 beats per minute. Approximately 30 aberrant beats occurred during a one and one-half hour period. No further prematurities were observed on the Commander after 288 hours GET.

Throughout the entire mission, no ectopic heart beats or arrhythmias were observed on the Command Module Pilot.

When questioned during the postflight medical debriefing, the Lunar Module Pilot recollected experiencing the sensation of extreme fatigue during the time when the bigeminal rhythm was noted. In fact, he required a short period of rest before he was able to carry on his assigned duties. Furthermore, the Lunar Module Pilot stated that he was puzzled about this feeling of extreme fatigue which he experienced and considered inappropriate; however, he did not express his concern to the flight surgeon in the Mission Control Center during the flight. Throughout the flight, the Lunar Module Pilot did not experience any symptoms referable to his heart, such as palpitations, sternal pressure or pain, and he was completely unaware that an arrhythmia had occurred.

The Commander also was unaware he had experienced ectopic heart beats during the last day of the mission and was unable to recall experiencing any cardiac symptoms inflight.

The etiology of episodic cardiac arrhythmias recorded on the two Lunar Module crewmen during this mission is unclear; however, a number of possible factors, acting independently or in concert, are considered to have predisposed the myocardium to ectopic behavior. Of principal interest is the magnitude of the total body potassium deficit and hypokalemia measured postflight. Whether the potassium concentrations recorded in the immediate postmission examination represented the true state of potassium balance at the time of the episodes of arrhythmias inflight cannot be determined. However, salt-wasting mechanisms predictably would have been at their peak during that period of the flight, thereby suggesting a total body potassium deficit considerably greater than that registered postflight.

While salt-wasting compensatory mechanisms operate to reestablish fluid and osmotic equilibrium in the adapted crewman, several other factors probably were operative which could upset this balance and lead to transient states of decompensation. For example, heavy workloads and the attendant heat stress could easily exacerbate the electrolyte deficit experienced by the lunar surface crewmen. Emotional stress, altered work/rest cycles, and fatigue are known to increase adrenal medullary activity and liberate large quantities of epinephrine which further aggravate the salt loss. Commensurate with the catecholamine-potentiated electrolyte loss, the resultant high epinephrine blood levels would exert a positive inotropic effect on the myocardium. Furthermore, these decompensating factors probably occurred in the presence of a marginal dietary intake of mineral which resulted in a clinical deficit of total body electrolyte.

Therefore, frank, yet transient periods of hypokalemia were considered to be of prime importance in the genesis of the observed arrhythmias. These postulates were further substantiated by the greater postflight deficits in total body and serum potassium recorded in the lunar surface crewmen and by the absence of cardiac irritability in the Command Module Pilot.

Accordingly, it is speculated that the adaptive processes alone resulted in sufficient salt loss (principally potassium) to have predisposed the crew to cardiac irritability, and that the additional stress characteristic of lunar surface operations was sufficient to enhance the electrolyte deficit and precipitate abnormal cardiac activity.

In order to prevent potassium deficits and to reduce the likelihood of inflight arrhythmias, both Apollo 16 and 17 crews were provided a high potassium diet commencing 72 hours prior to launch and continuing until 72 hours after recovery. As a precaution, antiarrhythmic medications were included in the Apollo 16 medical kit for the first time. As an added precaution, daily, high-resolution electrocardiograms were obtained for each crewman and an accurate metabolic input/output report was maintained during flight.

No medically significant arrhythmias occurred during either flight. The postflight exchangeable body potassium intake measurements indicated that a normal potassium balance had been maintained. The absence of arrhythmias in these last Apollo crews may be attributed in part to high dietary potassium intakes, but perhaps the fact that the Apollo 16 and 17 crews maintained a better fluid and electrolyte balance, obtained more adequate sleep, and experienced a lower level of fatigue is of equal or greater significance.

It must be noted that one of the Apollo 15 crewmembers who experienced a cardiac arrhythmia had undetected coronary artery disease at the time of the mission. Approximately two years after space flight, this particular astronaut suffered an acute myocardial infarction from which he completely recovered. The undetected coronary artery disease almost certainly interacted negatively with potassium deficiency and fatigue to precipitate the inflight bigeminal arrhythmia experienced by this astronaut.

Antihypotensive Garment Testing

While Apollo missions indicated no need for an antihypotensive garment during reentry into Earth's gravity or in the immediate postflight period, the effects of these garments were tested on the Apollo 16 and 17 missions in preparation for the long-term Skylab flights. The Apollo 16 Command Module Pilot and control subjects were fitted with waist-length leotards designed to produce gradient positive pressure along the lower half of the body. The Apollo 17 Command Module Pilot wore a lower body garment using the capstan principle to apply a gradient pressure to the lower limbs. Both garments appeared to furnish some protection against orthostatic hypotension following weightless flight. The capstan-type garment, however, proved to be considerably easier to don in flight. Section 3, Chapter 4 presents details of the antihypotensive garment experiment.

Postflight Procedures and Findings

Comprehensive medical examinations similar to the preflight F-5 exam were conducted immediately after recovery of the astronauts to document the physiological changes resulting from space flight and to detect and treat any medical problems. These medical evaluations included physical examinations, microbiology and blood studies, orthostatic tolerance tests, exercise response tests, urinalysis, and chest X-rays. Postflight testing was modified in those missions requiring postflight quarantine because of limited space in the Mobile Quarantine Facility.

Although all crewmen were in good health, they exhibited varying degrees of fatigue and weight loss. Functional tests consistently showed evidence of cardiovascular deconditioning.

Physical Examinations

The postflight physical examination involved obtaining a careful inflight history and a complete review of body systems. Laboratory studies included the following:

1. Urine culture and sensitivity
2. Complete blood count
3. Urinalysis
4. Serum electrolytes

Characterization of viral and mycoplasma flora was initiated with Apollo 14. State-of-the-art procedures were utilized. These included challenging tissue cultures, embryonated eggs, suckling mice, and mycoplasma media with specimens obtained at various times in preflight and postflight periods.

The detailed results of microbiological studies are presented in Section II, Chapter 2. In summary, considerable variation in the microfloral response was observed. *Staphylococcus aureus* increased in number in some crewmen and transfers were effected between crewmen. The variables of host susceptibility, external environmental factors, and ecological relationships between competing species of microorganisms were undoubtedly responsible for these findings. In one mission, an increase in the number and spread of *Aspergillus fumigatus* and beta hemolytic streptococci were found. Microbial analysis of samples obtained in the Command Module showed a loss of organisms during the course of the mission. Intracrew transfer of microbes appeared to be a regular occurrence. Finally, there was a buildup of medically important species, particularly *Proteus mirabilis* on the urine collection device. Contamination of the urine collection devices with this organism represented a significant medical hazard.

Clinical Findings

Weight loss was a consistent postflight finding for all crewmen except the Apollo 14 Commander and Lunar Module Pilot. These weight losses are shown in table 16. The major portion of these weight changes was attributed to loss of total body water; the remainder, to tissue mass loss.

Table 17 presents postflight medical findings and the following chronological list provides details concerning these findings.

Apollo 7. The residual effects of an inflight upper respiratory infection was definitely present in one of the Apollo 7 crewmembers at recovery.

Apollo 8. Six days after recovery, the Lunar Module Pilot developed a mild pharyngitis which evolved into a common cold and nonproductive cough. He recovered completely after six days of symptomatic therapy. The Commander developed a cold twelve days after the flight.

Apollo 9. The Commander suffered from bilateral barotitis media. This condition responded rapidly to decongestant therapy and cleared after two days. Four days after recovery, the Apollo 9 Lunar Module Pilot developed an upper respiratory infection with a secondary bacterial bronchitis. He was treated with penicillin and was well seven days later. The Commander developed a mild upper respiratory syndrome eight days after recovery. He was treated symptomatically and recovered four days later. The etiology of both of these cases was determined to be type-B influenza virus.

Apollo 10. The Commander and Lunar Module Pilot had mild rashes on their forearms which were caused either by exposure to the Fiberglas insulation or to the Beta cloth in their flight suits. Four days after recovery, the Lunar Module Pilot developed a mild infection in his left nasal passage which was probably caused by a small piece of Fiberglas to which the crew was exposed in flight. This responded rapidly to symptomatic therapy.

Apollo 11. The Commander had a mild barotitis media of the right ear; however, since he was able to clear the middle ear satisfactorily, no specific treatment was necessary.

Apollo 12. On initial examination, the Lunar Module Pilot had a small amount of clear fluid with air bubbles in the middle ear bilaterally. This disappeared after 24 hours of decongestant therapy. He also sustained a laceration over the right eye when a camera

Table 16

Apollo Astronaut Body Weights (kg)

Flight	Crewman	F-30 Days	F-15 Days	F-5 Days	Mean	± SD	F-0 Days	R + 0 Hr	R + 24 Hr	R + 48 Hr	R + 72 Hr
7	Schirra	87.1	88.0	88.2	87.8	0.59	88.0	86.1	86.4	–	–
	Eisele	69.4	69.4	69.8	69.5	0.23	71.2	66.7	68.3	–	–
	Cunningham	69.4	71.8	70.8	70.7	1.21	70.8	67.8	69.6	–	–
8	Borman	76.2	76.4	77.1	76.6	0.47	76.6	72.8	74.0	75.1	–
	Lovell	76.4	77.6	76.4	76.8	0.69	78.0	74.4	74.7	75.2	–
	Anders	66.0	67.1	66.0	66.4	0.64	64.4	62.6	62.8	–	–
9	McDivitt	73.5	72.8	72.8	73.0	0.40	72.1	69.6	70.9	71.7	–
	Scott	82.8	82.5	80.7	82.0	1.14	80.7	78.2	82.1	81.2	–
	Schweickart	74.7	74.5	73.7	74.3	0.51	71.2	69.4	71.3	72.3	–
10	Stafford	80.1	79.4	78.9	79.6	0.60	77.6	76.4	77.4	–	–
	Young	76.6	77.1	76.6	76.8	0.29	74.8	72.3	73.1	–	–
	Cernan	79.4	79.5	79.4	79.4	0.06	78.5	73.9	74.6	–	–
11	Armstrong	78.0	78.2	79.1	78.4	0.59	78.0	74.4	77.1	–	–
	Collins	74.4	75.3	77.1	75.6	1.37	75.3	72.1	72.1	–	–
	Aldrin	77.6	78.9	77.9	78.1	0.68	75.7	75.3	77.1	–	–
12	Conrad	66.2	–	66.9	66.6	0.49	67.7	65.8	66.7	66.7	–
	Gordon	71.0	70.3	–	70.7	0.49	70.4	67.1	68.9	68.9	–
	Bean	69.4	–	70.3	69.9	0.64	69.1	63.5	64.9	64.4	–
13	Lovell	79.8	77.8	78.5	78.7	1.01	80.5	74.2	–	–	–
	Swigert	89.1	–	89.7	89.4	0.42	89.3	84.4	–	–	–
	Haise	71.0	70.3	71.2	70.8	0.47	70.8	67.8	–	–	–

Table 16 (Continued)
Apollo Astronauts Body Weights (kg)

Flight	Crewman	F-30 Days	F-15 Days	F-5 Days	Mean	± SD	F-0 Days	R + 0 Hr	R + 24 Hr	R + 48 Hr	R + 72 Hr
14	Shepard	78.0	78.5	78.7	78.4	0.36	76.2	76.6	77.1	–	–
	Roosa	74.2	76.2	75.5	75.3	1.01	74.8	69.4	72.6	–	–
	Mitchell	83.5	83.1	83.2	83.2	0.21	79.8	80.3	80.7	–	–
15	Scott	80.5	81.2	81.5	81.1	0.51	80.2	78.9	–	81.0	80.7
	Worden	73.7	73.2	74.0	73.6	0.40	73.5	72.1	–	72.6	72.3
	Irwin	74.3	73.9	74.8	74.3	0.45	73.2	70.8	–	73.7	73.1
16	Young	80.8	80.5	78.9	80.1	1.02	78.9	75.5	76.6	–	76.4
	Mattingly	63.2	61.9	62.6	62.6	0.65	61.5	58.5	59.9	–	60.3
	Duke	73.1	73.8	72.6	73.2	0.60	73.0	70.5	71.7	–	71.3
17	Cernan	81.0	80.3	80.7	80.7	0.35	80.3	76.1	76.0	78.0	–
	Evans	78.2	76.6	77.0	77.3	0.83	75.7	74.6	73.9	73.9	–
	Schmitt	76.0	76.6	75.3	76.0	0.65	74.8	72.9	71.8	73.4	–
Apollo Crew Mean		75.90	75.09	76.12	75.96		75.26	72.45	73.05	73.44	72.35
Standard Deviation		5.849	5.213	5.786	5.792		5.727	5.866	5.763	4.781	6.826

Additional Postflight Weights

Apollo 15	R + 121	R + 137	R +210	R +311 hr
Scott	80.8			
Worden	72.3			73.0
Irwin		73.7	75.0	

Apollo 16	R + 162 hr
Young	75.5
Mattingly	61.2
Duke	71.9

Apollo 17	R + 90 hr
Cernan	78.5
Evans	75.8
Schmitt	72.8

F-0 Days = Launch Day

broke loose from the impact of landing and struck him. The cut was sutured onboard the recovery ship and healed normally. On the day after recovery, the Commander developed an acute left maxillary sinusitis which was treated successfully with decongestants and antibiotics.

Apollo 13. Postflight, all three crewmen showed extreme fatigue resulting from the severe environmental stresses imposed by their crippled spacecraft. The Lunar Module Pilot suffered an acute pseudomonas urinary tract infection which required two weeks of antibiotic therapy to resolve.

Table 17
Postflight Medical Findings in Apollo Mission Crews

Diagnosis	Etiology	Number of Cases
Barotitis media	Eustachian tube blockage	7
Folliculitis, right anterior chest	Bacterial	1
Gastroenteritis	Bacterial	1
Herpetic lesion, lip	Herpes virus	1
Influenza syndrome	Influenza B virus	1
	Undetermined	1
	Influenza A_2 virus	1
Laceration of the forehead	Trauma	1
Rhinorrhea, mild	Fiberglass particle	1
Papular lesions, parasacral	Bacterial	1
Prostatitis	Undetermined	2
Pulpitis, tooth No. 7		1
Pustules, eyelids		1
Rhinitis	Viral	3
Acute maxillary sinusitis	Bacterial	1
Ligamentous strain, right shoulder		1
Urinary tract infection	Pseudomonas	1
Vestibular dysfunction, mild		1
Rhinitis and pharyngitis	Influenza B virus	1
	Beta-streptococcus (not group A)	1
Rhinitis & secondary bronchitis	Influenza B virus	1
Contact dermatitis	Fiberglas	1
	Beta cloth	1
	Micropore tape	6
Subungual hemorrhages, finger nails	Trauma	3
Total		41

Apollo 14. The Commander and Command Module Pilot each exhibited a small amount of clear, bubbly fluid in the left middle ear cavity with slight reddening of the tympanic membrane. These findings disappeared in 24 hours without treatment. The Lunar Module Pilot had moderate eyelid irritation in addition to slight redness of the tympanic membranes. All crewmen showed a mild transient irritation from the micropore tape covering their biomedical sensors (figure 2).

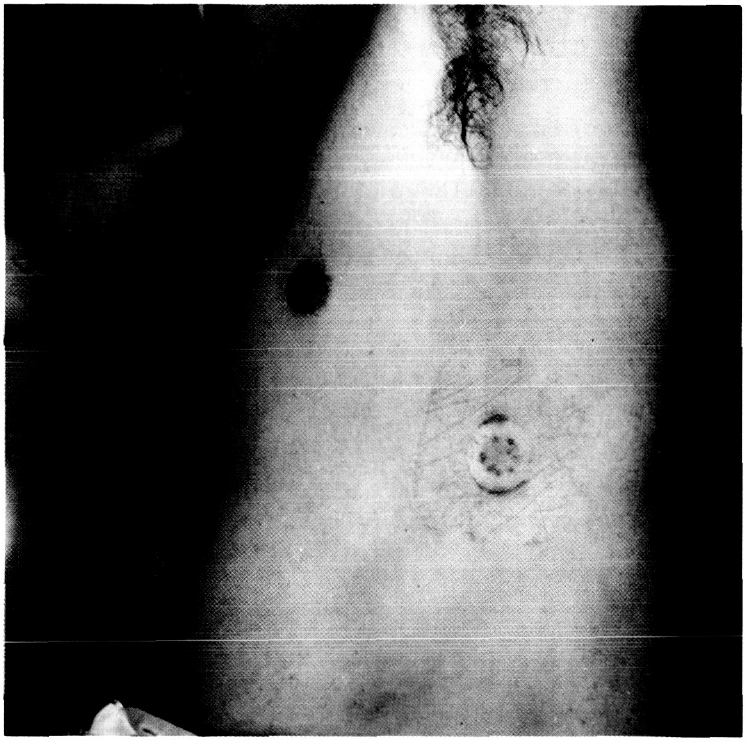

Figure 2. Example of skin irritation caused by the micropore tape covering the biomedical sensors.

Apollo 15. The Commander had subungual hemorrhages of both hands and a painful right shoulder. These hemorrhages were caused by an insufficient arm length of the pressure suit forcing the fingertips too far into the gloves during pressurized suit operation. The Commander purposely had the arm length of his pressure suit shortened preflight to permit better tactile sensation and manual dexterity during mission EVA operations. Pain in the Commander's right shoulder was due to a muscle/ligament strain which responsed rapidly to heat therapy.

Apollo 16. All three crewmen suffered varying degrees of skin irritation at the biosensor sites. This skin irritation resulted principally from the crew's desire to wear the biosensor harnesses continuously in order to save the 15 to 20 minutes required to apply these bioharnesses. The irritation subsided in 48 hours without medical treatment. The Commander had some sinus congestion which responded to medication, and also a slight reddening and retraction of the right tympanic membrane.

Apollo 17. The two lunar surface crewmen developed subungual hematomas of both hands because of insufficient arm length of their pressure suits as in Apollo 15. The Commander also had a herpetic lesion on the right side of the upper lip, which was approximately 72 hours old at the time of recovery.

Postflight Visual Findings

Although numerous trends were noted, statistically significant changes between pre- and postflight testing were found only in the superior, superior-nasal, and temporal visual fields, each of which were constricted postflight. Only one other parameter approached significance: the unaided seven-meter (20-ft) visual acuity, which also was decreased postflight. Etiology of these changes is unknown at this time.

An additional point of interest is the result of a longitudinal study of changes in intraocular tension for Apollo astronauts and astronauts participating in the Mercury and Gemini missions. In the immediate postflight period, and for a short time thereafter, a statistically significant decrease in intraocular tension was found in all astronauts, when compared with their preflight tension. The postflight intraocular tension reverted to its preflight value at a much slower rate than expected. The reason for this slow return is unknown.

After Apollo 11, all crewmen except one observed bright flashes of light while in orbit. Retinal photography was considered to determine whether the high energy particles believed to be responsible for the phenomenon produced retinal lesions.

Photographs were first made of the Apollo 15 crew. Preflight photographs were taken as part of the F-30 physical examination, and postflight photographs were made three days after splashdown. Although no lesions were noted in the eye grounds, some decrease was observed in the size of the retinal vessels. No statistical comparison could be conducted, however, due to the low resolution of the film used.

Retinal photography was again conducted on the Apollo 16 crewmen using high resolution film. Comparison of the pre- and postflight films of this crew showed no change for the Lunar Module Pilot in the size of either retinal veins or arteries at approximately three hours postflight. The Command Module Pilot exhibited a significant decrease in the size of both the veins and arteries about three and one-half hours after flight, and the Commander showed a decrease in only the veins after four hours. The degree of constriction of retinal vasculature in this crew was greater and persisted for a longer time than could be accounted for by the vasoconstrictive effect of atmospheric oxygen alone. The reason for this finding in the crew of Apollo 16 is unknown.

Retinal photographs were not taken after the Apollo 17 flight because no lesions had been found on previous missions.

Special Studies

The results of the special studies conducted in the pre- and postflight periods are detailed in Section III of this text. Only a brief summary of the significant findings in the postflight examination are presented here.

The cardiovascular system showed the most significant and consistent changes in the Apollo crews. Resting and stressed heart rates were elevated in most all crewmen when compared to their preflight baseline tests. Blood pressures were labile; and the heart size as measured by the cardiothoracic ratio was decreased by 1.02 (approximately five percent). All crewmen demonstrated some degree of cardiovascular deconditioning during the lower body negative pressure tests in the immediate postflight period as compared to preflight measurements. They likewise showed a poorer work response on the bicycle ergometer. In both instances, the time required for return to preflight baselines was usually three days, but ranged from two days to one week. The Apollo 15 Commander and Lunar Module Pilot demonstrated a different response to exercise on the bicycle ergometer than observed in previous or subsequent flight crews. Their response at low heart rate levels of work was comparable to their preflight baseline tests; but at the higher heart rate levels of work on the ergometer, they showed the typical degraded work performance capability.

Summary and Conclusions

In summary, the twenty-nine Apollo astronauts accumulated 7506 hours of space flight experience without encountering any major medical problems. Perhaps the most significant postflight medical finding of Apollo was the absence of any pathology attributable to space flight exposure. Those physiological changes which did occur were all reversible within a two- to three-day period, with the exception of the Apollo 15 crew which required two weeks for complete return to preflight baselines. The most important physiological changes observed were cardiovascular deconditioning, reduction of red blood cell mass, and musculoskeletal deterioration. Since all medical objectives of the Apollo Program were successfully achieved, a sound medical basis existed for committing man to the prolonged space flight exposure of Skylab.