N62-14471

LIFE SCIENCES ACTIVITIES ASSOCIATED WITH PROJECT MERCURY

Stanley C. White, M.D.
Chief, Life Systems Division
NASA Manned Spacecraft Center

C. Patrick Laughlin, M.D.
Assistant Resident in Internal Medicine
University Hospitals of Cleveland, Cleveland, Ohio
(Formerly with NASA Manned Spacecraft Center)

Introduction

Fifteen years of speculation and study concerning the problems of placing man into space flight produced a mass of reports which contemplated the hurdles and suggested solutions needed to permit safe flight. The accumulation of problems occurred in all disciplines. This could have been expected because the area of study was in the unknown, and speculation and calculation were the only methods of attack until flight data could be obtained.

The Life Sciences community was as prolific in the identification of potential problem areas as the other scientific disciplines. The arrival of the era of manned space flight offers the opportunity to assess the problems directly and to define what is speculation and what is problem.

This paper will discuss two areas of life sciences activities during the Project Mercury program. The first area will review the life-support activities associated with the spacecraft development and the provisions for the astronaut. The second area will present a summarization of the data concerning man's ability to live and work in this new environment and will attempt to present an analysis of the significance of the findings in light of future flights.

Life-Support Activities on the Spacecraft

Early in the development program of Project Mercury, the decision which established the astronaut as a vital and functioning segment of the spacecraft systems and flight plan was made. This decision affected the entire life support effort more than any other single event. The required provisions within the spacecraft were able to be defined. All systems which had the astronaut as an integral link were designed and tested to provide a reliable astronaut in the system. The crew station was provisioned to complement the expected capabilities of the astronaut. A full display of cockpit instruments was incorporated. The concept of using a full cockpit of instruments was considered to be a better procedure than one which called for refitting the spacecraft after the capability of man was demonstrated. If flight experience demonstrated that instruments were not needed or could not be used dependably by the astronaut, they would be easily removed or inactivated. The associated controls to permit the astronaut to backup the systems manually or to select an alternate system were provided. Their orientation was such that the relationship of one to another allowed natural operation by the astronaut while he was restrained within his couch and harness. Additional study was made to assure normal function of the pilot while wearing the full pressure suit. Logical grouping of the instruments and their placement in the panel were determined through repeated operational flight simulations. These test simulations used the most up-to-date flight procedures to represent the data needed and astronaut action required during each phase of flight. Controls were moved when more positive availability for operation was shown to be needed. Sizing of the switches, spacing of one control from the other, color coding of the groups of instruments, and selection of the calibration on the face of the instruments were studied to permit efficient action by the astronaut while using the pressure suit in both uninflated and inflated states. Couch, suit, and crew station were treated as an integral problem. One or all were modified as necessary to provide a more efficient astronaut.

The design criteria for the life-support systems aboard the spacecraft provided a sea-level equivalent man, as far as function was concerned, under normal flight operations. The environmental system provided an atmosphere of 5 psia consisting of nearly 100 percent oxygen partial pressure. The proposal to use this atmosphere raised the question of man's tolerance to such an oxygen-rich atmosphere. Earlier studies had been made which demonstrated that oxygen toxicity would not produce difficulty for the durations of flight proposed in the Mercury program.[1] However, the problem of atelectasis associated with prolonged 100 percent oxygen exposure was found in early test programs. This problem was due to the lack of the normal atmospheric nitrogen within the small alveoli of the lung and was aggravated by the position of the astronaut in the couch and the compression of the chest associated with launch and entry acceleration. During the early studies on a centrifuge, the lung areas affected were visualized through chest X-rays and the methods of resolving this problem were studied. It was found that scheduled deep inhalations and periodic voluntary coughs were adequate for the prevention of alveolar collapse and would permit reinflation after collapse. This easy solution for the problem permitted the continued use of a 100 percent oxygen system. Therefore, the most simple and reliable closed environmental system could be used in the Mercury spacecraft.

The acceleration-protection system, through the development of the contoured couch and the extension of the astronaut's tolerance to the levels of the anticipated emergency accelerations, permitted the safe removal of the astronaut from a failing booster under all flight emergencies. The advances in the couch and tolerance data did more to make manned flight possible, during the early phases of the Mercury program, than any other area of work. Early studies had shown that emergency acceleration profiles would double the known acceleration tolerance levels. The contoured couch permitted manned centrifuge flights to reach acceleration of 21g.[2] Even though physiological changes were seen during the high levels of exposures, the changes were reversible and no residual damage could be found. With this new level of demonstrated tolerance, man could accept all normal and emergency flight accelerations. The solution of this part of the problem left only the landing-impact forces to be studied. The impact tolerance of man was established through the data from the rapid deceleration tests performed by Colonel John P. Stapp. His final series of tests[3] gave the upper limits for injury with the ability for full recovery. The design of the crushable structure for use under the couch kept the emergency landing loads imposed upon the astronaut to within these tolerance levels. However, the anticipated rate of onset of the landing accelerations exceeded the known tolerance data. Programs were carried out to demonstrate that these rates of onset were acceptable for water landings.[4] The required provisions for land landings dictated the need for the addition of the impact skirt in order that the multidirectional lateral loads could be kept within the known data limits. The test programs and measured landing loads from flight vehicles have been assessed by Mr. Peter Armitage at the Manned Spacecraft Center and the results have demonstrated that the acceleration protection system is safe for water and land.

The prime requirement established for the biomedical data-gathering system was the provision of instruments for the assessment of the astronaut status as part of the flight safety program. After this requirement had been met, the remainder of data collection was directed toward answering the many biomedical questions which had been raised concerning man in the new environment. The data indicating the adequacy of the operation of the environmental system were invaluable because it complemented the information gathered from the astronaut directly. The correlation of system information and information provided by the man was possible through the provision of a normal sea-level functioning man. The data collected plus the astronaut's voice reports have given an excellent profile of the astronaut's status throughout the flights. The clear, concise, and accurate reports have confirmed that man and his spacecraft did well while operating in the new environment.

The astronauts assigned the responsibility for surveillance of the life-support areas were valuable in providing the technical and operational transition needed to assure that the systems were adequate for flight. Their experience in aircraft was made available to the bioscientist and engineers working on the life systems area. They frequently participated in the testing of equipment and offered guidance on further improvements. As the specific astronaut was chosen for a flight, the relationship on the flight readiness of the life-support system became more personalized and minor changes were incorporated in the equipment which would aid the accomplishment of the flight plan. Postflight critiques of the life-support systems were made, and new changes such as the addition of wrist bearings and the fingertip lights on the gloves of the full pressure suit were incorporated after the astronaut had recommended their incorporation. New ideas and the prototype units were discussed and demonstrated to the astronauts. Their representative solicited the group astronaut opinion and then worked toward the integration of the desired changes into the system.

Each decision concerning the addition of support for man was based upon comprehensive discussions before it was implemented. Where conflict between further automatic or manual equipment was encountered, the functioning man won. As the program progressed, more backup devices became manual. Through the combined effort of all of the disciplines required for the development of the spacecraft, man has been placed into the space vehicle, and the vehicle has been ready to receive him.

Summary of Mercury Manned Flight Medical Data and Implications for Future Flight

Detailed medical data resulting from the manned flights in Project Mercury have been presented in Government technical documents and conferences following each of the flights.[5,6,7,8] The purpose of this discussion is to review the medical information and, more importantly, to discuss the implications of this experience on life-science planning and future activities.

As a matter of convenience the medical data have been divided into two source areas: (1) the preflight and postflight physical and laboratory examinations, and (2) the physiological information from the countdown and flight, which includes the astronauts' voice reports and the spacecraft bioinstrumentation. Comparative control data were obtained from prior clinical examinations, centrifuge training sessions, procedure trainers and launch countdown practices.

Physical Examination Data

Extensive clinical examinations were accomplished on the flight astronauts by a medical specialty group during the final days prior to launch. A preflight physical evaluation was made by the astronauts' Flight Surgeon on launch morning just prior to suiting. The postflight examination consisted of two parts, a cursory checkout on the recovery ship as soon as the astronaut was aboard and a detailed appraisal at a down-range debriefing site (either Grand Bahama or Grand Turk Island) by the initial medical specialty group. All of these examinations included the collection of blood and urine samples.

MR-3 Flight.- Astronaut Alan B. Shepard, who made the MR-3 flight, had a preflight physical examination at Cape Canaveral approximately T-8 hours. (T represents launch time.) His postflight examinations were at T+45 minutes (shipboard) and T+3 hours (Grand Bahama Island). Positive findings were limited to a 3-pound weight loss, and a few rales heard at the base of both lungs which cleared with coughing. His general condition was excellent. The physical findings and laboratory studies were all within the control clinical observations made in association with Astronaut Shepard's centrifuge training.

MR-4 Flight.- Astronaut Virgil I. Grissom was examined for the MR-4 flight at approximately T-7 hours (Cape Canaveral), T+30 minutes (shipboard) and T+2 hours (Grand Bahama Island). A 3-pound weight loss was recorded. The sinking of the spacecraft and his subsequent exertion in the sea during recovery were reflected in the fatigue and elevated pulse and respiration rates observed aboard the recovery vessel. All vital signs had returned to normal at the Grand Bahama debriefing site examination. No other significant physical findings were observed.

MA-6 Flight.- Astronaut John Glenn's final preflight physical examination for the MA-6 flight was completed at approximately T-6 hours, 30 minutes (Cape Canaveral). Postflight examinations were at approximately T+6 hours (shipboard) and T+12 hours (Grand Turk Island). The recovery physicians reported a clinical impression of mild dehydration and fatigue. An approximate 5-pound weight loss was recorded. Vital signs (temperature, blood pressure, pulse, and respiration rates) were all within prelaunch values. There were superficial abrasions on the second and third fingers of the right hand caused by recoil of the explosive hatch actuator plunger. The remainder of the physical examination was unremarkable.

In summary, the preflight clinical examinations revealed no abnormalities. The postflight examinations all disclosed a healthy astronaut with no findings that could be specifically attributed to space flight. Certain of the comparative preflight and postflight blood and urine data were interpreted as consistent with the occurrence of stress while other values were believed to be normal fluctuations.

Physiological Data

Physiological data were available from the time of astronaut insertion into the spacecraft until he disconnected the biosensor plug from the suit as part of the landing procedure. Bioinstrumentation utilized in all flights consisted of two electrocardiograph leads, a respiration rate thermistor, and a rectal temperature thermistor. A blood pressure measuring system, similar to the clinical (indirect auscultatory) method, was added to the MA-6 spacecraft. The countdown and flight records were generally of excellent quality with the exception of the respiration rate trace. In addition to the biosensor data, the pilot's subjective evaluation of body sensations and the film from the pilot-observer camera provided important sources of information.

MR-3 Flight.- In the MR-3 suborbital mission, the total biosensor monitoring time was approximately 4 hours and 30 minutes. The actual flight duration from lift-off to water landing was 15 minutes and 22 seconds.

Pulse rates during countdown were well within expected ranges. A high of 138 beats per minute was recorded at spacecraft separation and a downward trend ensued during the following 5 minute zero-gravity interval. Pulse rate rose to a high of 132 beats per minute during reentry and was 111 beats per minute at loss of telemetry signal. The electrocardiogram waveform showed no significant variation during the countdown and flight. Body temperature remained near 99° F for the entire countdown and flight. Respiration rate during the countdown and flight was similar to rates noted at centrifuge training runs.

Astronaut Shepard reported no disturbing sensations with zero-gravity and both launch and reentry accelerations were well tolerated.

MR-4 Flight.- Physiological data for the MR-4 suborbital flight were recorded for approximately 3 hours and 35 minutes; 15 minutes of which was flight time. Pulse rates averaged 80 beats per minute during countdown, 138 beats per minute at lift-off, and increased to 162 beats per minute at spacecraft separation. A high of 171 beats per minute was recorded at retrofire, declining gradually through reentry to 137 beats per minute at loss of telemetry signal. The electrocardiogram revealed only sinus tachycardia. Rectal temperature did not fluctuate significantly during the flight. Respiration rates varied from 12 to 24 breaths per minute during countdown, but because of poor trace quality in-flight data were not obtained.

Astronaut Grissom reported no unpleasant feelings while weightless. A brief tumbling sensation was felt at booster engine cutoff which lasted only a few seconds. Hearing and visual acuity remained undisturbed.

MA-6 Flight.- The total monitoring time for the MA-6 orbital flight was 8 hours and 15 minutes of which 4 hours and 53 minutes was actual flight time. Pulse rate during countdown varied from 56 to 86 beats per minute with a mean of 68 beats per minute. At lift-off, the pulse rate was 110 beats per minute, rising to 114 beats per minute at spacecraft separation, then apparently stabilized through weightlessness with a mean of 86 beats per minute. The highest pulse rate, 134 beats per minute, occurred during reentry at the time of maximum spacecraft oscillation.

Analysis of the electrocardiogram showed some variation in the origin of the heartbeat during the countdown which was not present during flight. These findings were believed to be within the range of normal physiological stress responses. Respiration rates were within expected values throughout the countdown and flight. Body temperature declined during the countdown as a result of external cooling of the suit circuit. There was a gradual rise after lift-off, increasing about 2° F for the entire flight, reflecting normal body temperature regulation.

Astronaut Glenn's in-flight commentary and postflight debriefing remarks indicated that vision, hearing, food chewing, swallowing, and urination were normal during flight. Deliberate attempts to stimulate the vestibular system did not produce any disturbing symptoms.

As pointed out in prior reports, the Mercury Redstone suborbital flights did not provide enough time to establish physiological trends, and no observed medical data could be specifically attributed to weightlessness. However, the Mercury Atlas orbital flight of Astronaut Glenn provided sufficient time for physiological responses to apparently stabilize, and trend information was obtained. Perhaps the most valuable medical observation made from each of the manned flights was that all the physiological and clinical examination data were consistent with normal function. This finding was supported by the competent performance displayed by each of the astronauts during space flight.

Discussion

As observed from the United States flights to date, no specific medical problems peculiar to weightlessness have been defined. No difficulty has been experienced by the astronauts in tolerating the acceleration associated with launch and reentry. Available Russian cosmonaut data[9] indicate similar observations with the exception of the symptomatology reported by Titov after about 6 hours of weightlessness. Although not definite, the Russian reports suggest that some disturbance in vestibular function did occur. This disturbance apparently did not interfere with operational performance of the spacecraft. Whether this disturbance is a consequence of extended exposure to weightlessness or represents an idiosyncratic response of Titov is not known. There are several possibilities which might explain the relative lack of physiological changes during weightlessness as observed in our flights. These include:

(1) Physiologic response mechanisms adapt quickly and no functional disturbances are produced.

(2) The bioinstrumentation utilized and the astronaut's subjective evaluation are not sufficient to detect subtle transient changes associated with short exposures.

(3) The exposure durations have been too brief to elicit physiologic changes.

(4) The combination of brief exposure and the restrained position are sufficient to curtail the appearance of adverse effects.

Additional space flight experiences will determine eventually which of the above explanations or combinations thereof are correct.

The effects of weightlessness on human physiology will continue to be a primary objective in early space flight programs. Planning and direction of ground-based and in-flight medical research relating to zero-gravity will be influenced by observations obtained from longer missions in the Mercury spacecraft. Plans for the two-man Gemini spacecraft are to provide an increased flight time, and thus to permit extended investigations. This exposure to increased space flight (up to 2 weeks) will be approached with essentially the same bioinstrumentation and technique as used in the Mercury program. Should physiologic problems arise which result in crew performance decrement, then detailed in-flight medical investigations, including the use of animals, might become necessary. If function abnormalities appear when the crew is unrestrained, then the Apollo earth-orbiting spacecraft or an earth-orbiting laboratory might be required for more detailed experiments. This approach then would utilize the flexibility inherent in the Gemini and Apollo designs, with the capability of earth-orbital flights carrying medical research equipment. Whenever valid, ground-based medical investigations would be applied to the solution of weightlessness problems.

Summary

The integration of the crew station with the man and his equipment was a continuous program requiring many compromises. The goal of this effort was the provision of equipment within the crew station which would permit flight control by the astronaut. The experience gained by flights to date have indicated that the provisions are adequate for the task.

The biomedical assessment program associated with flights on Project Mercury to date has produced no significant medical problems. The Russian experience with Cosmonaut Gherman Titov has shown some disturbance of the vestibular apparatus, however, symptoms were not severe enough to be incapacitating. The extension of knowledge, primarily in the prolongation of exposure to the weightless environment, is essential if the discrepancy between the United States and Soviet data is to be resolved. Presently planned programs of manned flight will yield further data in this area. The following factors will be active in the design of the medical portion of these programs:

(1) Investigation of in-flight medical responses will be extended as a function of time in zero-gravity, utilizing the Mercury, Gemini, and Apollo spacecrafts and existing techniques.

(2) Capability will continue to exist for the recognition of physiologic effects that might result in compromised crew performance. Performance must be maintained of sufficient quality to assure a safe reentry to earth from earth orbit.

(3) The design of on-going in-flight medical studies will be dependent on the interpretation of accumulated physiologic data.

(4) Ground-based medical studies will be utilized whenever possible in examining biologic responses to weightlessness.

References

1. Comroe, J. H., Jr., et. al.: Oxygen Toxicity, Jour. Amer. Med. Assoc. 128:710, 1945

2. Shepler, Herbert C.: Pilot Performance and Tolerance Studies of Orbital Reentry Accelerations Rep. #11; Letter Rep. concerning Bur. Aero. TED ADC AE-1412. Aviation Medical Acceleration Lab., U.S. Naval Air Development Center, Johnsville, Pennsylvania, September 16, 1959.

3. Stapp, J. P.: Tolerance to Abrupt Deceleration. Collected Papers on Aviation Medicine, AGARDograph No. 6, North Atlantic Treaty Organization (Paris), 1955, pp. 122-169.

4. Brinkley, James W.: Man Protection During Landing Impact of Aerospace Vehicles. Ballistic Missile and Space Tech. vol. 1, Academic Press, Inc. (New York) c. 1960, pp. 91-105.

5. Augerson, William S., and Laughlin, C. Patrick: Physiological Responses of the Astronaut in the MR-3 Flight. Proc. Conf. on Results of the First U.S. Manned Suborbital Space Flight, NASA, Nat. Inst. Health, and Nat. Acad. Sci., June 6, 1961, pp. 45-50.

6. Laughlin, C. Patrick and Augerson, William S.: Physiological Responses of the Astronaut in the MR-4 Space Flight. Results of the Second

U.S. Manned Suborbital Space Flight July 21, 1961. Manned Spacecraft Center, NASA, pp. 15-21.

7. Laughlin, C. Patrick, McCutcheon, Ernest P., Rapp, Rita M., Morris, David P., Jr., and Augerson, William S.: Physiological Responses of the Astronaut. Results of the First United States Manned Orbital Space Flight February 20, 1962. Manned Spacecraft Center, NASA, pp. 93-103.

8. Minners, Howard A., Douglas, William K., Knoblock, Edward C., Graybiel, Ashton, and Hawkins, Willard R.: Aeromedical Preparation and Results of Postflight Medical Examinations. Results of the First United States Manned Orbital Space Flight February 20, 1962. Manned Spacecraft Center, NASA, pp. 83-92.

9. Gazenko, O. G., and Yazdovsky, V. I.: Some Results of Physiological Reactions to Space Flight Conditions. Presented at Am. Rocket Society Meeting, December 1961.