CLASSICS IN SPACE MEDICINE

Graybiel A, Holmes RH, Beischer DE, Champlin GE, Pedigo GP, Hixson WC, Davis TRA, Barr NL, Kistler WG, Niven JI, Wilbarger E, Stullken DE, Augerson WS, Clark R, Berriaqn JH. ***An account of experiments in which two monkeys were recovered unharmed after ballistic space flight.*** **J Aviat Med 1959; 30: 871-931.**

This Classic paper is a detailed account of data from suborbital spaceflights by monkeys aboard Jupiter missiles in the earliest days of the U.S. space program. Following launch from Pad 5 at Cape Canaveral, FL, the rockets flew a 15-min ballistic trajectory 483 km (300 miles) in altitude and 2400 km (1500 miles) downrange, landing in the Atlantic Ocean. The animals experienced a peak acceleration of +10 Gx during launch followed by 8.3 min of weightlessness at altitudes well above the internationally accepted "threshold of space," 100 km. Re-entry used a newly developed ablative heat shield for thermal protection and was spin-stabilized prior to a parachute landing in the Atlantic Ocean. Re-entry deceleration forces were as high as +38 Gx. The first flight on December 13, 1958, carried a squirrel monkey called Gordo. Telemetry indicated no physiological abnormalities, but failure of the parachute prevented capsule recovery and planned post-flight studies. On May 28, 1959, a rhesus monkey, Able, and a squirrel monkey, Baker, were launched together on another Jupiter and were recovered alive, the first reported living beings that had been launched to greater than 100 km altitude and survived re-entry.

The squirrel monkeys (Gordo and Baker) were small (500 g) and by nature of the species very excitable and physiological labile. Heart rate, respirations, and temperature rapidly rose with any physiological or emotional stress and so they were sensitive indicators to the effects of spaceflight. Fifteen animals were trained to tolerate restraint and confinement, and the flight animals were selected for their performance quality. Gordo was called "Old Reliable" for his stable responses during training. The capsule for a squirrel monkey, including life support and telemetry equipment, weighed just 14 kg and occupied a volume of 0.013 m^3 (750 cu inches). It provided life support for 24 h including 12 h before launch and was oriented so that its occupant would experience acceleration in the Gx axis.

The rhesus monkey, Able, weighed 3 kg and belonged to a species known to display stable responses to experimental research. His capsule measured 0.16 m^3 (10,000 in^3), weighed 117 kg, and had more sophisticated life support equipment with a 72-h capability, as the animal had to be placed in the capsule 64 h before launch. It has been suggested that the pre-launch experience was probably a larger physiological stress on Able than the actual spaceflight. The capsule was also oriented for Gx acceleration.

Capsule atmospheric pressure was equivalent to sea level. Life support included O_2 supply, CO_2 and humidity absorption, cabin pressure and temperature control, and waste containment. The cabin atmosphere began as air but gradualy became O_2-enriched as pressurization was maintained by replacement with 100% O_2. No food or water was provided, but Able was given an intra-peritoneal infusion of D5W. The cabin pressure and temperature were monitored by telemetry downlink, while a radiation dosimeter was designed for retrieval after recovery. Telemetry included EKG, respiration, chest sounds, and temperature. In addition, a movie camera recorded Able's activity at a rate of 16 frames/s for later study. Able was also instrumented with two electromyography telemetry sensors to monitor motion and shivering. Control animals similarly restrained and monitored were studied at the same time at Cape Canaveral.

Capsule life-support conditions remained stable and all phases of the flights and were well tolerated physiologically by the animals. Transient elevations of heart rate and respiration occurred during startling events (lift off, engine cut off, and spin-up just prior to re-entry); Baker exhibited episodes of profound bradycardia and elevated respiration rates during the startle events, which probably represented anxiety-induced vasovagal effects. However, all variables returned to baseline values in space and there were no indications that weightlessness was physiologically stressful. Prolonged cardiopulmonary responses at the end of the boost phase and during re-entry were as expected due to the acceleration forces. There were no telemetry indications of disorientation or neurovestibular dysfunction, a finding confirmed by later analysis of the camera images of Able. Unfortunately, Able died four days after landing during anesthesia to remove a monitoring electrode; the authors discounted the possibility that the effects of spaceflight might have contributed to this event. Baker lived a long life and died of natural causes in 1984.

In conclusion, the first reported ballistic flight into space followed by survivable re-entry demonstrated spaceflight was physiologically tolerable. The authors considered their greatest achievement to be a feasibility demonstration of sustained life support and continuous biomedical monitoring with down-linked telemetry.

Background

Beginning in June 1948, the USAF Aeromedical Laboratory used facilities at White Sands, NM, to launch a series of ballistic flights with animal payloads. As described in an earlier Classics article (1), eight primates were flown on short suborbital flights using V-2 or Aerobee rockets. During the same period, the Soviet Union flew a series of rockets carrying dogs; they reported finding no physiological problems with suborbital spaceflight and noted that animals flown repeatedly seemed to display adaptation (5), although details of the flights were not provided until 30 yr later. It is now known that the Soviets made many successful dog ballistic suborbital flights beginning in 1951, with several over 450 km (310 mi) in altitude during 1958 before the Able-Baker flight. The series of successful suborbital flights by animals was a necessary prerequisite for space medicine experts to gain the confidence to proceed to manned spaceflight (2–4, 6).

Comment by Dr. William Augerson

This was a very complex project made more difficult by demands for secrecy. During flight preparations at the Cape, the primates were kept in unmarked trailers and I wore my old Army Signal Corps insignia. I was assigned to Walter Reed Army Institute of Research (WRAIR) as a part of the NASA Space Task Group (STG) working on Project Mercury.

The schedule of the Jupiter missile tests was the main determinant around which we worked. Although the Able-Baker flight was not a NASA project, the STG tolerated my involvement, and I was able to introduce some features that we were interested in for manned flight—contoured couches, semi-supine orientation, physiologic telemetry, performance assessment, and photo observation. At the time we had not developed reliable cutaneous EKG sensors, so the decision was made to use surgically implanted subcutaneous electrodes. I designed the couch and restraint system and worked with Joe Brady at WRAIR on performance hardware and related training of the monkeys.

I discussed in a previous article how political considerations drove a last-minute substitution of an untrained U.S. rhesus monkey (Able) for our trained Indian rhesus monkey, preventing us from obtaining any performance data (2). Later in Project Mercury we had some additional experience with high level Washington anxiety impacting project schedules, all part of the complexity of getting off the planet. There was some anxiety about the delayed arrival of the animals at Cape Canaveral. Two monkeys escaped into trees in the parking lot

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during a refueling stop in Atlanta. Intrepid Army aviation personnel got fruit at a nearby grocery store and enticed the monkeys back into captivity and later fame.

The project gave me a lot of practice in medical monitoring and life support arrangements on the pad, which continued to be problems in later manned Mercury flights. The time Able was confined in the capsule was very long. We were aware of circadian variations in physiology and were also very concerned about hypo/hyperthermia and maintaining fluid balance. Monitoring was very tedious with anxious moments assessing decline in temperature and startle reactions to launch pad events. Telemetry let us see much of the flight in real time and redundancy of sensors fortunately maintained heart rate information. We did get a rather long “weightless” period, with results reassuring for our upcoming Mercury-Redstone suborbital manned flights and also encouraging for near future orbital flights. Apart from scientific information we also learned a lot operationally about interfacing spaceflight and life science projects. I was back at STG when Able had the fatal anesthetic event and have no direct knowledge of events, although I may have seen the necropsy report later.

None of us were prepared for the media circus which ensued postflight, with cartoons showing Able briefing the astronauts about spaceflight. The Mercury astronauts were not amused but eventually forgave me for my role in the project.

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