Theodor Benzinger, German Pioneer in High Altitude Physiology Research and Altitude Protection

VIKTOR HARSCH

HARSCH V. *Theodor Benzinger, German pioneer in high altitude physiology research and altitude protection.* **Aviat Space Environ Med 2007; 78:906–8.**

Theodore Benzinger was a pilot-physician who performed pioneering research—often involving self-experimentation—in areas related to flight at high altitude during World War II. Of greatest historical interest to those of us in aerospace medicine is his work on the effects of rapid decompression and related oxygen equipment. Benzinger was born in Stuttgart, Germany, on 28th August 1905. He studied medicine and natural sciences at the universities of Tuebingen, Munich, and Berlin. From 1934 to 1944, Benzinger headed the aeromedical laboratory "EMed" in Rechlin, where he was instrumental in conducting studies related to stratospheric flight, including self-experimentation with rapid decompression up to 19,000 m (62,320 ft). His Rechlin experiments made an important contribution to understanding the physiology and life- support requirements for high-altitude aviation and later work under space-equivalent conditions. Following World War II, Benzinger joined the staff of the U.S. Army Air Force Aeromedical Center in Heidelberg. In 1947 he was recruited by "Operation Paperclip" to work at the U.S. Naval Medical Research Institute (NMRI) in Bethesda, MD, where he worked on various aspects of human physiology. He died as a U.S. citizen in Bethesda, MD, on 26th October 1999.

Keywords: Theodor Benzinger, German aviation medicine, rapid decompression, altitude physiology, EMed, Rechlin.

THEODORE JOHANNES BENZINGER was a pilot-physician who performed pioneering research—often involving self-experimentation—in areas related to flight at high altitude during World War II. Of greatest historical interest to those of us in aerospace medicine is his work on the effects of rapid decompression and related oxygen equipment. Born in Stuttgart, Germany, on 28th August 1905, Benzinger (**Fig. 1**) studied medicine and natural sciences at the universities of Tuebingen, Munich, and Berlin, following which he assisted renowned physiologists Siegfried Thannhauser and Hans A. Krebs with their work (13).

In 1933, Benzinger was recruited by acceleration physiologist Heinz von Diringshofen to direct the Aeromedical Laboratory at the Testing Centre in Rechlin, which was operated by the undercover Luftwaffe. As part of this assignment, he conducted advanced studies in respiratory physiology under the leading German physiologist Hermann Rein at the University of Goettingen. In that program Benzinger developed early methods for continuous, direct recording of O_2 and CO_2 tensions in alveolar air and of metabolic O_2 consumption and CO_2 production, methods that were of considerable value for later respiratory research at Rechlin (15,22).

The Luftwaffe's Test Centre Rechlin was responsible for testing all aircraft types, motors, weapons, and equipment related to aviation, and products of the German aviation industry and research. Its Aeromedical Laboratory, "EMed" (Erprobungsstelle Medizin), was established on March 15th, 1934, to investigate physiological problems associated with the technical development of aviation (17). For example, in 1936 the overpressure principle was applied to demand respirators at Rechlin, following which a more advanced adjustable-demand regulator was designed by Seeler. Various masks were tested for their ability to support positive pressure breathing and to prevent the inboard leak of cockpit air. Systems were devised to minimize requirements for stored oxygen during parachute jumps from very high altitudes (4).

The laboratories of EMed were situated close to the engineering department and the altitude and climatic chambers were used jointly by both departments. As is still the tradition in today's aeromedical laboratories, medical staff flew as pilots or observers in all phases of flight testing (4). Benzinger himself was trained as a test pilot for many aircraft types in Germany's Luftwaffe. He joined the high-altitude reconnaissance Squadron 4F-121 for high-altitude reconnaissance flights over the British Isles during the Battle of Britain, thus gaining valuable practical experience for his work in the field of high altitude physiology research and altitude protection. Benzinger and a colleague introduced the term

From the History and Archives Committee of the German Society for Aviation and Space Medicine (DGLRM), Neubrandenburg, Germany.

This manuscript was received for review in October 2006. It was accepted for publication in June 2007.

Address reprint requests to: Dr. med. Viktor Harsch, M.D., Aviation Medical Center Trollenhagen, Suedstrasse/Fliegerhorst, Neubrandenburg, Mecklenburg-Vorpommern 17034, Germany; FUNeubrandenburg@web.de.

Reprint & Copyright © by Aerospace Medical Association, Alexandria, VA.

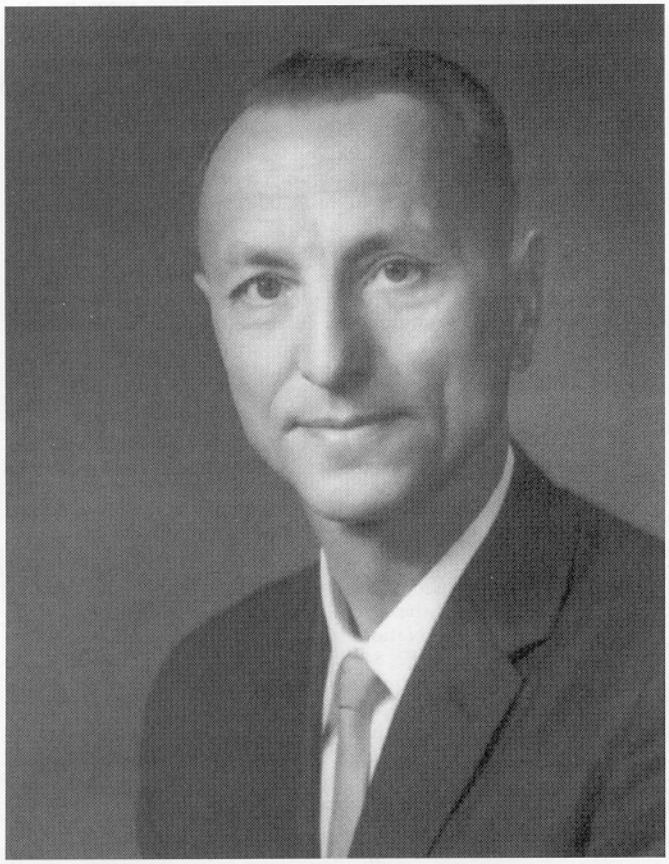

Fig. 1. Theodor Benzinger (1905–1999). Courtesy of the German Society for Aviation and Space Medicine (DGLRM), History and Archives Committee.

"altitude sickness" with respect to aviation in 1941 (Benzinger M. Personal communication; 2000*)(9).

During World War II several nations introduced cabin pressurization to support high-altitude flight above enemy interceptors and ground-to-air fire. As the risk of rapid decompression (RD) was higher in pressurized cabins, studies on the effects of RD and the countermeasures were intensified in Germany, the United States, and the UK (1,6,16). Benzinger and his staff established that the effects of RD are determined principally by the ultimate altitude attained rather than the pressure differential or the rate of pressure change. Similar results were proven by tests in Farnborough, Berlin, and Rechlin (11,17). A systematic investigation of the problems of RD was started in Germany in the late 30s. In RD self-experiments in 1937, Benzinger's subjects, breathing oxygen, reached a simulated altitude of 15,000 m (49,200 ft) in 66 s (14). That altitude was reached 2 yr later with a 6-s decompression in the laboratory of Clamann and his team at the Berlin Luftfahrtmedizinische Forschungsinstitut (5,8), but most of the RD work was done at Rechlin. Simulated altitudes up to 17,000 m (55,777 ft) and decompression rates to 60,000 m $\cdot$ s^{-1} (196,860 ft $\cdot$ s^{-1}) were reached. In the course of 376 documented RDs on volunteers, 2 cases of air embolism occurred. On one occasion, Benzinger and an engineering colleague were decompressed to very high altitude, whereupon the volunteer lost consciousness and was left temporarily hemiplegic and speechless after regaining consciousness (15). In addition, three subjects were thought to have developed complications due to exacerbation of latent pulmonary tuberculosis (Benzinger M. Personal communication; 2000)(2,18). In animal experiments performed in collaboration with Doering and Roessle, Benzinger found that RD with a closed glottis produced air embolism (4).

The decompression experiments at Rechlin under Benzinger's supervision provided the basis for subsequent Luftwaffe development of aircraft with pressurized cabins and physiological training of flying personnel (5). The laboratory explored the time of useful consciousness following decompression and established standard values for emergency descents to lower altitudes ("Rettungssturz") were determined; these results formed the basis for the "Technical directions for the construction and trial of airplanes with pressurized cabins" (18,21). In addition, the Rechlin staff made a teaching film and wrote a technical manual for flying with pressurized cabins (19,20). For safety reasons, further RD experiments on human subjects were forbidden by a Luftwaffe order dated 23rd October 1941 (14). Nevertheless, in 1944 in Rechlin, Benzinger's assistant H. Halbach exposed himself to RD to 19,000 m (62,320 ft). The time of exposure was less than 10 s and no signs of bubble formation, RD atelectasis, or other irreversible injuries were observed (10).

The RD experiments performed at Rechlin under Benzinger's guidance formed a substantial contribution to the understanding of and development of countermeasures for air operations under space-equivalent conditions, and later for space operations, including development of pressure suits. Though ebullism was expected to occur at an ambient pressure of 47 mmHg (63,000 ft) or less, in 1944 it was demonstrated at Rechlin that brief exposure to space-equivalent pressure and hypoxia was survivable without a pressure suit (7,10,17). Much of the important RD work accomplished by Benzinger and his team was originally published only in restricted-access or secret reports, in service manuals of the Luftwaffe, and in technical regulations edited at Rechlin (14,18–20). In his Paperclip file at the National Archives, 69 reports from Benzinger's laboratory are documented, covering the years 1934 until 1944 (13). However, some unclassified experimental work was published in journals and manuals of physiology and aviation medicine. Furthermore, results of aeromedical research were discussed at the meetings of the German Academy of Aeronautical Research and of the Lilienthal Organization of Aeronautical Research (12,14). The most influential publications were those on decompression sickness and the medical recommendations for the construction and operation of pressurized airplanes (2,3).

The Rechlin Test Centre was destroyed in a U.S. bombing raid in August 1944, after which Benzinger relocated the laboratory on a reduced scale to southwest Germany at the Group Zeppelin Research Institute

* Benzinger T. Oral history, Dr. Benzinger's autobiographical sketch (handwritten). Presented to author by Dr. Maria Benzinger during an interview on 04.04.2000 in Bethesda, MD.

in Schopfloch, close to Stuttgart. After the end of the war, Detlev Bronk, Coordinator of Research for the Air Surgeon U.S. Army Air Force, brought Benzinger and part of the Institute's equipment to the newly established Heidelberg Aeromedical Centre, where he worked from 1945 until 1947 (5). In the cited documents it remains unclear who was in charge of the recruitment of other Rechlin specialists, such as K. Buettner. In Heidelberg, Benzinger conducted research on high-altitude oxygen equipment, human oxygen consumption, heat exhange, and psychomotor activities (13). Benzinger's wartime activites were questioned by Allied authorities during the Nuremberg trials, but no charges were ever made (8). He was subsequently recruited by "Operation Paperclip" to relocate to the U.S. Naval Medical Research Institute (NMRI) in Bethesda, MD, on the advice of Albert R. Behnke, a pioneer in underwater physiology (15).

Benzinger provided major contributions to the the USAF's 1950 classic text, "German Aviation Medicine in World War II," including chapters on blast effects, RD, and hypoxia at extreme altitudes (7,13). At NMRI in the 1960s and 1970s, he helped extend the fundamental equation of chemical thermodynamics, and in 1964 demonstrated the feasibility of measuring the temperature of the tympanic membrane as an index of core temperature. In recognition of his work, Benzinger was honored with the Golden Scheele Medal of the Chemical Society in Stockholm in 1963, by membership of the Claude Bernard Colloquium on Experimental Medicine in Paris in 1965, and by an Alexander von Humboldt Prize of the Federal Republic of Germany in 1980. Benzinger was responsible for 40 inventions and patents, and he wrote more than 130 scientific papers as well as chapters in 12 books. He died in Bethesda, MD, on 26th October 1999 (Benzinger M. Personal communication; 2000)(21).

REFERENCES

1. Armstrong HG. Principles and practice of aviation medicine. Baltimore: Williams & Wilkins Company; 1939.
2. Benzinger T, Hornberger W. Die Druckfallkrankheit der Hoehenflieger (High altitude flights and decompression sickness). Proceedings of the German Academy of Aeronautical Research (Schriften der Deutschen Akademie der Luftfahrtforschung). Vol. 34. Munich and Berlin: Oldenbourg; 1941.
3. Benzinger T, Kauffmann. Richtlinien für Bau und Erprobung von Hoehenflugzeugen mit Druckkabine (Guidelines for the development and operation of airplanes with pressure cabins). Rechlin, Germany: EMed Secret Report; 1942.
4. Benzinger T. The Medical Department of the Erprobungsstelle der Luftwaffe Rechlin 1934–1944. Heidelberg, Germany: HQ 3rd Central Medical Establishment, AAF Aero Medical Centre; 20th May 1946. ATI No. 58275.
5. Clamann HG. Vorlaeufiger Bericht über Drucksturzversuche. Einschl. Schreiben an S. Ruff, Berlin-Adlershof (Preliminary report on rapid decompression experiments of 6. Sept. 1939). Brooks AFB, TX: Archives, USAF School of Aerospace Medicine; 1939.
6. Gibson TM, Harrison MH. Into thin air. A history of aviation medicine in the RAF. London: Robert Hale; 1984.
7. Harsch V. German aerospace medicine from the very beginning. Aviat Space Environ Med 2000; 71:447–50.
8. Harsch V. Leben, Werk und Zeit des Physiologen Hubertus Strughold (Life, work and times of Hubertus Strughold, 1898–1986). Neubrandenburg: Rethra; 2004.
9. Heimbach RD, Sheffield PJ. Decompression sickness and pulmonary overpressure accidents. In: De Hart RL, ed. Fundamentals of aerospace medicine. Philadelphia: Lea & Febiger; 1985:132–61.
10. Hornberger W. Decompression sickness. In: The Surgeon General, ed. German aviation medicine World War II, vol. 1. Washington, DC: U.S. Government Printing Office; 1950:354–94.
11. Luft UC, Clamann HG, Adler HF. Alveolar gases in rapid decompression to high altitudes. J Appl Physiol 1949; 2:37–42.
12. Mackowski MP. Testing the limits. Aviation medicine and the origins of manned space flight. College Station, TX: Texas A & M University Press; 2006.
13. National Archives. Paperclip-file of Theodor Benzinger. Washington, DC: U.S. National Archives and Records Administration; 1947.
14. National Archives. Military Arch Freiburg i. Brsg. RL 36. Reports and documents of the Aviation Test Centre Rechlin. Freiburg, Germany: German National Archives-Military Archives; 1936-1944: 26, 29, 31, 36, 72, 84, 85, 86, 88, 447, 474, 490, 580.
15. Special Collections & Archives. Sketch of scientific autobiography. Dayton, OH: Wright State University; 1975.
16. Stepanek J, Habermann TM, Ziemer RE, Lantz JC. Images and reflections from Mayo Clinic heritage. Mayo Clinic Proc 2002; 77:613.
17. Strughold H. Development of aviation medicine in Germany. In: The Surgeon General, ed. German aviation medicine World War II, vol. 1. Washington, DC: U.S. Government Printing Office; 1950:3–51.
18. Surgeon General German Air Force, ed. Aerztliche Regeln fuer den Hoehenflug mit Druckkabinen (Medical rules for high altitude flights with pressure cabins). Berlin, Germany: German Air Force; 1940. Technical Regulations (D Luft (T) 291 1940).
19. Technical Office of the Luftwaffe, ed. Hoehenflug mit Anleitung zum Einsatz der Atemgeraete (The use of ventilators in high altitude flights). Cologne, Germany: German Air Force; 1940. Technical Regulations 1940 (D Luft (T) 291/2 01.04.1940).
20. Technical Office of Luftwaffe, ed. Sonderregeln fuer Jagdflieger zum Flug ueber 10,000 m (Special regulations for fighter pilots for flights above 10,000 m). Cologne, Germany: German Air Force; 1941. Technical Regulations 1941 (D Luft (T) 291/3 March 1941).
21. Wright State University Special Collections and Archives, Fordham Health Science Library Archives. Box 1, Folder 1 – disposition of Dr. Benzinger on November 22nd 1983 at U.S. Department of Justice, Washington, DC; Folder 2 – U.S. Department of Justice October 25th 1983; Folder 7 – Niederschrift ueber die Besprechung Trinkbarmachung von Meerwasser am 20.05.1944 (conference on the possibility of drinking sea water on 20.05.1944); Folder 9 – sworn statement of Dr. Benzinger for the U.S. Department of Justice, 22. Nov. 1983; Folder 10 – personal notes on German Aviation Medicine World War II, 1980. Retrieved 28 August 2006 from: http://www. libraries. wright.edu/special.
22. Yearbook of the German Academy of Aeronautical Research. Berlin, Germany: German Academy of Aeronautical Research; 1941–42; 2:212.