SPECIAL ARTICLE

NAZI SCIENCE — THE DACHAU HYPOTHERMIA EXPERIMENTS

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IT is widely recognized that the experiments performed on prisoners in German concentration camps during the Second World War were in fact brutal crimes committed under the guise of medical research. There is controversy, however, about the use of the results obtained from those studies. Among the approximately 30 known projects, the controversy has focused most intensely on the experiments involving hypothermia in humans that were performed at the Dachau concentration camp.[1] The debate among scientists and ethicists has spread to the public through the print and broadcast media.[2-6] Positions range from a total ban to advocacy of the uninhibited use of the material. At one pole, Arnold Relman, editor-in-chief of the *Journal*, has noted that the Nazi experiments "are such a gross violation of human standards that they are not to be trusted at all" and said that the *Journal* would not allow citations of the Nazi work.[1] In contrast, Robert Pozos, a physiologist specializing in hypothermia, has advocated the free use of the results, believing that they can advance contemporary research on hypothermia and save lives.[2,7] By 1984 more than 45 publications had made reference to Dachau experiments.[1] A much larger body of literature on hypothermia, however, has not referred to these controversial studies.

In the immediate postwar period, Andrew Ivy, a physician-scientist and American Medical Association representative at the Nuremberg war-crimes trials, declared that the Nazi experiments on humans were of no medical value.[8] Leo Alexander, a psychiatrist and consultant to the American Chief of Counsel for War Crimes, reported at first that the Dachau study had produced credible data, but he subsequently reversed his position and concluded that the results were not dependable.[9,10] More recently, several investigators have endorsed the data from the Dachau experiments either explicitly or implicitly by citing the results.[2,7,11-13] According to these sources, the study generated data unavailable elsewhere about the response of unanesthetized persons to immersion hypothermia, providing particularly important information on lethal temperatures, specific reactions to cooling, and methods of rewarming. These endorsements contributed to an impression that the Dachau hypothermia project represents good science despite its offensive ethics. There are doubts, however, about the scientific integrity of the work.[1] An evaluation of its scientific rigor is needed to shed light on the reliability of the results and on the need to pursue the ethical debate about their use. This paper presents a critical analysis of the experimental protocol and the results reported, and an examination of the credentials and reliability of the investigators.

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THE DACHAU HUMAN HYPOTHERMIA STUDY

The immersion-hypothermia project was conducted at the Dachau concentration camp between August 1942 and May 1943. Its purpose was to establish the most effective treatment for victims of immersion hypothermia, particularly crew members of the German air force who had been shot down into the cold waters of the North Sea.[14] The subjects in the experiment were male civilian prisoners belonging to various religions and nationalities, as well as Russian prisoners of war. Their participation was usually forced, but occasionally it was "voluntary" in response to promises, rarely fulfilled, of release from the camp or commutation of the death sentence.[14]

During the experiments, the subjects were immersed in a tank of ice water. Some were anesthetized, others conscious; many were naked, but others were dressed. Several different methods of rewarming the subjects were also tested. Responses of body temperatures, clinical manifestations, and selected biochemical and physiologic measurements were purportedly monitored, and autopsies were performed. (Rectal measurements of temperature are given throughout this paper.)

In an attempt to conceal the atrocities, the original, incriminating records of most of the concentration-camp studies of humans were destroyed before the camps were captured by the Allied forces. A large body of information was later recovered, however, pertaining to the extensive communications between the investigators and Heinrich Himmler, the Reichsführer of the SS (Nazi special police). Immediately after the war, Leo Alexander investigated the Dachau hypothermia experiments and prepared a 228-page report that included 68 pages of personal commentary about the background and substance of the study and a reproduction of a 56-page comprehensive report to Himmler on the Dachau experiments, signed by Drs. Holzloehner, Rascher, and Finke and dated October 21, 1942.[9] A separate communication notes that the report, referred to in this paper as the Dachau Comprehensive Report, had been prepared by Rascher for presentation at a medical conference for military personnel on hypothermia.[15]

Although the Dachau Comprehensive Report does not report on all the immersion experiments per-

formed at Dachau, it is the only original account available about the project, and it includes sufficient information to evaluate the work. Indeed, the Alexander report containing the Dachau Comprehensive Report is essentially the only primary reference cited in the literature on the Dachau study. It also served as the main source of material for the present analysis, in addition to relevant information from other documents and sources. This discussion highlights representative data from the Dachau Comprehensive Report. I will have more to say later about Dr. Rascher, Reichsführer Himmler, and the others involved in directing the experiments.

Because the Dachau hypothermia experiments were performed almost 50 years ago, I have exercised care in this analysis to avoid judging them by contemporary standards. It is noteworthy, however, that despite the explosive growth of medical science during the second half of the century, the basic principles of scientific investigation have not changed appreciably.

Experimental Design

The descriptions in the Dachau Comprehensive Report of the design, materials, and methods of the experiments are incomplete and reflect a disorganized approach. Only an impression of the scope of the study can be formed from the fragmentary information provided. The size of the experimental population and the number of experiments performed are not disclosed. Only from postwar testimony do we learn of 360 to 400 experiments conducted on 280 to 300 victims — an indication that some persons underwent more than a single exposure.[16,17] Such basic variables as the age and level of nutrition of the experimental subjects are not provided, and the various study subgroups are not segregated. The numbers of subjects who underwent immersion while naked, clothed, conscious, or anesthetized are not specified. The bath temperatures are given as ranging between 2 and 12°C, but there is no breakdown into subgroups, making it impossible to determine the effect of the different temperatures. The end points of the experiment — time spent in the bath, specific body temperature, subject's clinical condition, death, and the like — are not stated.

At least seven different methods of rewarming the subjects after immersion were tested. No information is available about the physical characteristics of each heat source, the initial body temperature of the victims, or the elapsed time between the cessation of cooling and the start of rewarming. For one method tested, the temperature of the warm bath was specified for only two experiments. One assistant later testified that some victims were thrown into boiling water for rewarming.[18]

The frequency and timing of data collection are not stipulated in the report. Postwar testimony revealed that whenever possible, some assistants and victims altered the temperature readings and changed the timing of blood sampling in the attempt to save lives. The frequency of such laudable alteration of the data is unknown.[19]

Blood pressure was not measured. Cardiologic monitoring was limited to heart sounds and electrocardiography, but in the shivering victims no tracings were obtained during immersion or after removal from the bath. Therefore, dangerous or even fatal cardiac arrhythmias escaped detection during the unmonitored periods.

In summary, the basic information essential for documenting an orderly experimental protocol and evaluating the results is not provided. We know enough, however, to conclude that the methods of study were clearly defective.

Analysis of Reported Results

According to the Dachau Comprehensive Report, anesthesia and bath temperatures ranging from 2 to 12°C had no demonstrable effect on the rate of cooling. These surprising observations are at variance with generally accepted concepts and raise strong doubts about the experimental approach. For example, Keatinge noted that immersion in water at 5°C is tolerated by clothed men for 40 to 60 minutes, whereas raising the water temperature to 15°C increases the period of tolerance to four to five hours.[20] Moreover, the report contains no specific information about the effects of age, clothed as compared with unclothed immersion, or nutritional state on the rate of body cooling.

Cardiac arrhythmias are described in the Dachau Comprehensive Report as being slow, fast, or irregular, without reference to standard nomenclature. Ventricular fibrillation, known to be a common cause of death from hypothermia, and atrial fibrillation, the most frequent cardiac irregularity from hypothermia, are not even mentioned. The term atrial flutter, the only conventional designation mentioned, is used to label a tracing of atrial fibrillation. The unusual characterization of common cardiac arrhythmias and their misinterpretation suggest a lack of expertise in cardiac physiology.

According to the Dachau Comprehensive Report, the subjects' body temperatures continued to fall after they were removed from the cold bath, and it was postulated that this "after drop" might be responsible for death after rescue from cold water. The temperature curves in the Dachau Comprehensive Report, however, show the presence of the "after drop" to be variable.

The data for one of the more crucial aspects of the project, the assessment of the lethal temperature level, are incomplete and inconsistent. An assistant testified that the victims were cooled to 25°C.[14] In a short Intermediate Report, Rascher noted that all those whose temperatures reached 28°C (an undisclosed number) died.[21] However, the postscript to the Dachau Comprehensive Report maintains that "with few excep-

tions" the lethal temperature was 26 to 27°C. In a further inconsistency, the Dachau Comprehensive Report notes that in six fatal experiments the terminal temperature ranged between 24.2 and 25.7°C. Even more puzzling is the claim in the table cited to support this point that in these victims death was observed to occur between 25.7 and 29.2°C. The mortality rate for this fatal range of hypothermia is not supplied, so the lethality of the lethal temperature remains undefined. The temperatures reached in the majority of the 80 to 90 victims who died are not reported. Moreover, because the demographic characteristics, nutritional state, and general health of this cohort are not described, it is impossible to determine whether the results apply to populations outside a concentration camp.

The Dachau Comprehensive Report states that in seven experiments the victims died 53 to 106 minutes after the start of cooling. Alexander reports, however, that a review of Rascher's experimental records and statements by his close associates disclosed that it took between 80 minutes and six hours of immersion to kill the naked victims, whereas the clothed men died after six to seven hours of cooling.[10]

The information on the lethality of the experiments is also inconsistent. In the Dachau Comprehensive Report, Rascher writes in one place that the hypothermia study was not designed to produce fatalities, and in another presents data on seven lethal experiments, and he refers to 13 deaths. In fact, two assistants testified that at least 80 to 90 victims died during the experiments, and only two were known to have survived the war, both of whom became "mental cases."[16,17] The sequence is reminiscent of Rascher's disclosures on mortality in another study, on high altitude, which contained a similar chain of discrepancies.[9]

Firm conclusions about the efficacy of several techniques of rewarming are offered, despite a paucity of supporting data. Detailed results presented in the form of time-based temperature curves are reported for only three groups of experiments. The graphs reveal that body-temperature recovery was fastest with immersion in warm water, but that rewarming and presumably survival were achieved with the other methods, too. The description of one set of experiments and the accompanying temperature curve in the Dachau Comprehensive Report show the quality of the reporting (Fig. 1). The text states that a method of rewarming with a combination of a warm bath and a body massage was tested, but in the supporting figure treatment with a light box is added at the end of the study. The number of experiments and the demographic characteristics of the victims in this subgroup are not specified. Nor are the temperature of the bath and the intensity of the electric heat source, or the frequency and timing of the measurements of temperature. Although no warming was instituted for approximately 12 minutes after the victims were removed from the ice-water bath, the temperature curve

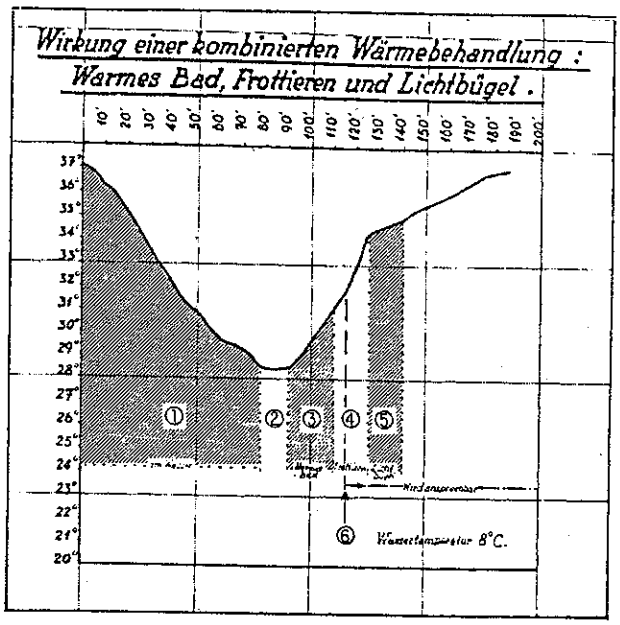

Figure 1. Reproduction of Figure 10 from the Dachau Comprehensive Report.

The horizontal axis shows minutes, and the vertical axis temperature (°C). The German title may be translated as "Effect of combined rewarming treatment: warm bath, massage and light box." The water temperature was 8°C. The arrows and numbers (1 to 6) were superimposed by the present author. Translations of the corresponding notations from the German are: 1, in water; 2, period out of bath (no German notation); 3, warm bath; 4, massage; 5, light box; and 6, response to speech (regaining of consciousness).

shows no "after drop" such as that previously described as being regularly observed. The duration of resuscitation in a warm bath is 10 minutes, according to the text, but it lasts 20 minutes in the figure.

The conclusion is drawn that immersion in a warm bath for rewarming is the best method of treatment, and preferential use of this technique is recommended. However, since survival rates — the ultimate criterion of the effectiveness of a rewarming technique — are not given in the Dachau Comprehensive Report, no judgment about the merits of the various resuscitative techniques is warranted, and the recommendation that a warm bath is the best therapy cannot be justified on the basis of the data. The credibility of the results has been compromised further by the postwar disclosure that most victims who were thrown into a tub of boiling water for rewarming died, making it probable that in fact rewarming in a warm bath had the highest mortality.[18] Incidentally, the role of immersion resuscitation remains controversial to this day.[22]

The Dachau Comprehensive Report maintains, without any supporting data, that warm-bath rewarming had no undesirable side effects. With the grossly inadequate techniques of hemodynamic and electrocardiographic monitoring used at Dachau, circulatory failure and cardiac arrhythmias, the two

most likely untoward reactions, could not be evaluated accurately. Therefore, the statement about the lack of harm is not justified.

According to the Dachau Comprehensive Report, death from cooling was caused by heart failure due to peripheral vasoconstriction and cold-induced structural myocardial injury. However, there is no mention of clinical signs of cardiac failure or evidence of myocardial damage at autopsy. Extensive experimental and clinical experience has clearly shown that contrary to the claim from Dachau, death from hypothermia is usually due to ventricular fibrillation, and cold does not injure the heart but instead protects it. Indeed, selective myocardial cooling is routinely used to preserve the myocardium during cardiac surgery. Appropriate electrocardiographic monitoring and histologic examination of myocardial tissue in the Dachau victims could have identified the true mechanism of death.

To support the concept that death invariably resulted from cardiac and not respiratory failure, the report advances the claim that breathing continued for as long as 20 minutes after "clinical standstill of the ventricle." This sequence of events is at variance with the time-honored observation that spontaneous respiration does not continue for long after the cessation of cardiac function, and it suggests that the investigators lacked the means or competence to recognize cardiac arrest. Another possibility is that the phenomenon of persistent breathing after cardiac arrest was fabricated.

The concept that local application of cold to the occiput and dorsal neck accelerates cooling was advanced by Himmler and is demonstrated convincingly in the Dachau Comprehensive Report with temperature curves from one set of experiments. Rascher also maintained that death and cerebral bleeding occurred only when the occiput and neck were submerged in the ice water, implying that immersion hypothermia does not result in death if the structures above the neck are kept out of the water. Although the scalp is an efficient heat-exchanging surface,[23] I could find no evidence in the rich literature on induced or accidental immersion hypothermia that this relatively small area has such a pivotal role in the cooling response. The observation was probably fabricated; Gagge and Herrington remarked that the Dachau results may have been "exaggerated" to support Himmler's theory.[24]

The statement in the Dachau Comprehensive Report that cooling was complicated by cerebral edema and hemorrhage is at variance with the vast experimental and clinical experience on record. In animals, hypothermia shrinks rather than swells the brain.[25] Cerebral edema has not been observed in cases of accidental hypothermia or surface or core-induced hypothermia for cardiac surgery.[26] The last of these techniques is used in more than 250,000 operations annually in the United States alone without concern about the development of cerebral edema from hypothermia. Similarly, cerebral hemorrhage has not been observed as a result of experimental or clinical hypothermia. Thus, this report from Dachau probably represents a fabrication of data. It is also possible that brain injuries were inflicted by beatings or were sustained during the desperate struggles of the victims in the ice tank.

Background and Organization

The hypothermia project was proposed by Air Force Field Marshal Erhard Milch and approved by Himmler.[14] Because Rascher's qualifications as an investigator were limited, two presumed experts, Drs. Holzloehner and Finke, were recruited to help with the experiments.[9,14,27] However, Rascher took charge of the project despite his lack of qualifications, whereas the two experienced investigators functioned essentially as part-time consultants, apparently without the power to ensure acceptable scientific standards.[9,14] Two months after the start of the project, Holzloehner and Finke thought that the work had been completed and withdrew. Rascher continued alone, directing another 350 experiments with the explanation that he needed additional material to complete a thesis required to support his application for a university appointment.[16]

Reichsführer Himmler, the other principal behind the project, had absolute authority over the concentration camps. Although educated in agriculture, the Reichsführer fancied himself a medical scientist and was intimately involved in the administrative and scientific aspects of the studies of humans. All human experimentation within the concentration-camp system required Himmler's approval.[9] He outlined the objectives of the projects and at times even the experimental approach.[19] When his scientific suggestions were not pursued, Himmler pressured the investigators into carrying out his proposals.[9,14,28,29] The Reichsführer expressed special interest in the hypothermia project and traveled to Dachau several times to witness experiments.[9,18] Thus, the study represents a private venture by two unqualified ideologues, conducted in a prison setting quite alien to the standards of an academic environment. With Himmler's aid, Rascher thwarted repeated attempts by the medical establishment of the military to influence, participate in, or wrest control of the project.[14]

The Principal Investigator

Sigmund Rascher was born in 1909. He started his medical studies in 1930 and joined both the Nazi party and the storm troopers (the SA) three years later. After a volunteer internship, Rascher served for three years as an unpaid surgical assistant. He was barred temporarily from the University of Munich for suspected Communist sympathies.[9,19] In 1939, the young doctor denounced his physician father, joined the SS, and was inducted into the *Luftwaffe*.[19,29] A liaison with and eventual marriage to Nini Diehl, a widow 15 years

his senior who was a one-time cabaret singer but also the former secretary and possibly mistress of the Reichsführer, gained Rascher direct access to Himmler. A strange partnership evolved between the junior medical officer and one of the highest officials of the Third Reich. One week after their first meeting, Rascher presented a "Report on the Development and Solution to Some of the Reichsführer's Assigned Tasks During a Discussion Held on April 24, 1939."[19] The title of this paper foretold the character of the ensuing relationship between the two men. Because of Rascher's servile and ingratiating approach to Himmler, his "connections were so strong that practically every superior trembled in fear of the intriguing Rascher who consequently held a position of enormous power."[14]

Rascher's short investigative career included a leading role in the infamous high-altitude experiments on humans at Dachau, which resulted in 70 to 80 deaths.[8,9] He was also involved in testing a plant extract as a cure for cancer. The genesis of this project illustrates Rascher's style and influence. Professor Blome, the deputy health minister and plenipotentiary for cancer research, favored testing the extract in mice. Rascher insisted on experiments in humans. Himmler sided with Rascher. A Human Cancer Testing Station was set up at Dachau. The deputy health minister collaborated on the project, held approximately 20 meetings with Rascher, and visited the junior officer at Dachau several times.[30]

Another of Rascher's major research efforts focused on the introduction of a pectin-based preparation, Polygal, to promote blood clotting. He predicted that the prophylactic use of Polygal tablets would reduce bleeding from wounds sustained in combat or during surgical procedures. The agent was also recommended for the control of spontaneous gastrointestinal and pulmonary hemorrhages. Combat wounds were simulated by the amputation of the viable extremities of camp prisoners without anesthesia or by shooting the prisoners through the neck and chest.[18]

Rascher also claimed that oral premedication with Polygal minimized bleeding during major surgical procedures, rendering hemostatic clips or ligatures unnecessary and shortening operating times.[31] He published an enthusiastic article about his clinical experience with Polygal, without specifying the nature of some of the trials in humans. The paper concluded, "The tests of this medicine 'Polygal 10' showed no failures under the most varied circumstances."[32] Rascher also formed a company to manufacture Polygal and used prisoners to work in the factory.[33] A prisoner who was later liberated testified that Rascher's enthusiasm for Polygal's antiinfectious properties was probably sparked by news of the introduction of penicillin by the Allies and by his eagerness to reap fame and receive the award established for inventing a German equivalent. He initiated experiments in humans apparently without any preliminary laboratory testing. In one experiment, pus was injected into the legs of prisoners. The experimental group was given Polygal. The controls received no treatment. Information filtered to Dr. Kurt Plotner, Rascher's physician rival, that the controls were given large, deep subcutaneous inoculations, whereas the victims in the experiments received smaller volumes of pus injected intracutaneously. Plotner reportedly investigated the matter and discovered that the Polygal used was saline colored with a fluorescent dye.[9]

The frequent references to Rascher in top-level documents indicate that this junior medical officer attracted extraordinary attention from Germany's highest officials.[9,14] His work was reported even to Hitler, who was pleased with the accounts.[34] Rascher was not well regarded in professional circles,[14,19] however, and his superiors repeatedly expressed reservations about his performance.[14,19] In one encounter, Professor Karl Gebhardt, a general in the SS and Himmler's personal physician, told Rascher in connection with his experiments on hypothermia through exposure to cold air that "the report was unscientific; if a student of the second term dared submit a treatise of the kind [Gebhardt] would throw him out."[35] Despite Himmler's strong support, Rascher was rejected for faculty positions at several universities. A book by German scientists on the accomplishments of German aviation medicine during the war devoted an entire chapter to hypothermia but failed to mention Rascher's name or his work.[36]

Rascher collected human skin for making saddles, riding breeches, ladies' handbags, and other personal items. He sold the finished products to colleagues. Although Rascher's private ventures rivaled his scientific exploits in grotesqueness, the story that emerges as the most fateful deception of his life involved his claim to have had three children, who were not in fact his own. In an attempt to please Himmler by proving that the growth of the Aryan population could be accelerated through an extension of the childbearing age, Rascher made it known that his wife had given birth to three children in quick succession after turning 48 years old. During her fourth "pregnancy," Mrs. Rascher was arrested for attempting to kidnap an infant. The ensuing investigation disclosed that the other three Rascher children had not been born to Mrs. Rascher but had been bought or abducted.[34] Himmler felt betrayed, and in April 1944 his protégé was arrested. Besides complicity in the kidnapping, Dr. Rascher was accused of financial irregularities, the murder of a German assistant, and scientific fraud.[19] Dr. and Mrs. Rascher were subsequently executed, presumably on Himmler's orders.

Discussion

This review of the Dachau hypothermia experiments reveals critical shortcomings in scientific content and credibility. The project was conducted with-

ut an orderly experimental protocol, with inadequate methods and an erratic execution. The report is riddled with inconsistencies. There is also evidence of data falsification and suggestions of fabrication. Many conclusions are not supported by the facts presented. The flawed science is compounded by evidence that the director of the project showed a consistent pattern of dishonesty and deception in his professional as well as his personal life, thereby stripping the study of the last vestige of credibility. On analysis, the Dachau hypothermia study has all the ingredients of a scientific fraud, and rejection of the data on purely scientific grounds is inevitable. They cannot advance science or save human lives.

In the light of these findings, attempts to use the data from the Dachau experiments have been puzzling. The persistence of the claim that the work offers usable or valuable information is difficult to understand. One probable reason is the extremely limited availability of the Alexander report and the tendency of investigators to use secondary citations without consulting the primary source. Wider circulation of the Alexander report would thoroughly expose the true nature of the work and put an end to the myth of good science at Dachau. Future citations are inappropriate on scientific grounds.

Inferior science does not generally come to the attention of the ethicist because it is usually discarded by scientists. Ethical dialogues deal with work of sound scientific but controversial moral content, and the mere fact that a debate is conducted implies that the subject under consideration has scientific merit. If the shortcomings of the Dachau hypothermia study had been fully appreciated, the ethical dialogue probably would never have begun. Continuing it runs the risk of implying that these grotesque Nazi medical exercises yielded results worthy of consideration and possibly of benefit to humanity. The present analysis clearly shows that nothing could be further from the truth. Although the Dachau experiments opened the dialogue about an important ethical issue, the discontinuation of debate about these experiments should not bring an end to exploration of the larger subject — the implications of the use of ethically tainted data. But the Dachau study is an inappropriate example for that purpose.

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