POSTOPERATIVE HEAT STROKE *

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ALTHOUGH the literature in industrial medicine covers the subject of heat sickness fairly adequately, a survey of recent medical literature lists 28 cases occurring as a complication of surgery. Gibson (1), addressing a meeting of the New York Academy of Medicine in 1900, first reported this surgical complication, and Moscowitz (2) discussed it at some length in 1916, but it remained for Cutting (3) in 1931 to summarize the 20 cases reported up to that time. Duncan (4) in 1934 and Everett and Whitham (5) in 1937 reported 8 more cases, all occurring in Nebraska. I wish to describe 2 more occurring in 1945, and to discuss means of preventing this rarely diagnosed, but probably not too infrequent complication.

Heat-sickness has been described in the literature under a multiplicity of names, including among others such familiar ones as heat disease, heat stroke, heat exhaustion, sunstroke, thermic fever and heat cramps. Though each describes a different group of symptoms, clinicians discuss them together because all occur as a result of some disorder of the heat-balancing mechanism. What is more, one clinical type may change into another, and several types may be seen as a result of the same insult. Duncan (4) cited the report of a Lt. Comdr. Bloedorn, USN, which described an accident involving the draught ventilator aboard the USS Pennsylvania in 1918, resulting in 20 officers and enlisted men succumbing to the intense heat. Of these, 15 became cold and clammy, with weak pulses and subnormal temperatures, a picture clinically resembling heat exhaustion. The 5 remaining victims became delirious or unconscious, with extremely high temperatures, unquestionably cases of heat stroke.

Ordinarily, man can combat heat satisfactorily, but when patients in operating rooms are subjected to high temperatures such as are produced by excessive drapes, instrument sterilizers, and overhead lights, casualties must be expected. In the cases presented in this report, the multibeamed surgical lamp raised the temperature on the operating room table from 88 to 114, a rise of 26 degrees. These factors, then, are all conducive to producing hot, moist air, which invariably prevents adequate evaporation of sweat, and heat dissipation.

* The opinions or assertions contained herein are the private ones of the writer and are not to be construed as official or reflecting the views of the Navy Department or the Naval Service at large.

Undoubtedly many deaths from heat sickness have gone unrecorded as such. Cases of sudden high postoperative temperatures with resultant fatality have often been attributed to the so-called "liver deaths," and many cases of heat exhaustion occurring during or following an operation have been classified as postoperative shock. Heat stroke must be considered in any differential diagnosis when hyperpyrexia exists on otherwise unexplained basis, especially if the condition occurs during hot weather.

PHYSICS

The maintenance of body comfort depends on the response of the body mechanism to such external stimuli as motion, temperature and humidity of the air. When body physiology is unable to cope with altering atmospheric conditions, discomfort to the extent of heat sickness may ensue. How the body reacts to these stimuli is essentially a matter of elementary physical laws.

Motion.—We are all familiar with the fact that moving air is necessary for the maintenance of health and comfort. Even such minimal motion as to be barely perceptible may be sufficient. "Crowd poisoning" is nothing more than a condition resulting from poorly circulating air. It is for air motion that people seek the popular mountain and seashore resorts where cooling, soothing breezes may be found. Despite the heat or even the humidity which might exist at these resorts, comfort produced by air motion can be maintained under most circumstances.

Temperature.—Within certain ranges, other factors remaining the same, the higher the temperature of the air, the greater will be the degree of body discomfort. How this is brought about will be described later.

Humidity.—We are all familiar with the terms "absolute humidity," which is the actual weight of water contained in a unit volume of air, and "relative humidity," which is the ratio of the amount of water in the air to the amount it might hold, if saturated, at that particular temperature. Yet relative humidity in itself does not measure the dryness or wetness of a climate. It has been demonstrated that, given the same degree of relative humidity, different amounts of water can be absorbed by the atmosphere, depending on the temperature of the latter. Generally speaking, every 27° rise in Fahrenheit reading doubles the amount of water the air can be made to hold.

To illustrate, let us assume that the relative humidity of a certain town remained constant at 60 per cent for an entire day. The amount of water that could be held by the atmosphere at 6 a.m. if the temperature was 32 F. would be 1.95 Gm. per cubic meter of air, whereas at noon, if the temperature rose to 86 F., the amount of water that could be taken up by that same volume of air would be 12.0 Gm. Thus, health is affected not so much by the amount of moisture, either relative or absolute, that is present in the air as it is by the amount that may still be taken up by it.

Humidity, temperature, and air motion all bear a definite relationship to health. Rosenau (6) discussed these factors both individually and collectively. With respect to humidity, moist air is depressing and enervating; whereas dry air is apt to be tonic and stimulating. With respect to temperature, cold air is invigorating; whereas hot air is enervating. With respect to motion, static air is enervating; whereas moving air is stimulating and refreshing. From these observations, it can be seen that the most mischievous combinations are cold, damp air, and hot moist air. The ideal conditions for health, comfort, and efficiency are those in which dry bulb temperature readings vary from 68 to 70 F., and relative humidity determinations range from 40 to 50 per cent.

Humidity influences the dissipation of heat by the body by increasing the conductivity of the atmosphere for heat. Thus cold damp air produces a loss of heat by means of conduction, and this cooling influence is the reason for cold moist air being chilling. On the other hand, humidity may interfere with evaporation of sweat, and thus exercises a heating influence. Blood flows to the surface of the body, thereby reducing physical and mental capacity, and it is for this reason that warm moist air produces a general enervation. If the air is 88 per cent saturated, evaporation no longer compensates for the decreased radiation, resulting in an increase of body temperature with the ensuing of heat stroke.

The effect of changes in temperature and humidity on health is brought about by the response of the body's heat regulating mechanism to these changes. With moderate temperatures, heat dissipation is brought about by radiation, convection and conduction. When higher temperatures prevail, humidity becomes an important factor in heat dissipation. Here the skin is covered with perspiration, and heat may then be dissipated from the body by means of evaporation.

Air motion, too, is absolutely necessary for comfort. The physiology is not quite clear, but cutaneous fibers for pressure and temperature are probably stimulated, resulting in local or general vasodilation or vasoconstriction as the case may demand. Sensations may be deadened by a steady flow of air, and for this reason currents of air from windows would appear to be more efficacious than those produced by a steady mechanical system. Air motion aids heat loss by enhancing convection and evaporation.

PHYSIOLOGY

The process of maintaining heat is governed by the heat regulating mechanism of the body which, as Ranson (7) described, consists of two centers located in the hypothalamus at the base of the brain. The heat producing center is located posteriorly in the hypothalamus near the medullary bodies, and the heat dissipating center is located anteriorly in the hypothalamus, above and forward of the optic chiasma. These centers receive their stimulation to function not only from the circulating blood temperatures acting directly on them, but also from external skin stimuli.

From a physiologic point of view, heat sickness may be viewed as a state resulting from the breakdown of either the heat producing or heat dissipating center of the brain, or both. Actually there are three definitely recognized disease entities: heat exhaustion, heat cramps and hyperpyrexia, but because of their common etiology and common seat of abnormal physiology, they will be considered here as an all-inclusive disease group.

Dill (8), in discussing the source of energy and heat derived from food, stated that only 20 per cent of the calories thus obtained is expended as work energy, whereas as much as 80 per cent is utilized in the maintenance of body heat. Heat production in the body is a chemical phenomenon brought about by the digestion and combustion of food. Energy thus produced manifests itself by movement of muscles either voluntary, in the form of active work, or involuntary, in the form of chills. Heat loss, on the other hand, is physical and follows the laws of radiation, convection and evaporation. As the atmospheric temperature approaches that of the body, the amount of heat lost through radiation, convection and conduction becomes correspondingly less, and the amount of sweating required to keep the body comfortable becomes increasingly important. Thus the mechanism of evaporation is called into function, and this produces heat loss via the skin, numerous sweat glands and the lungs. It has been shown that 400 cc. of water is lost by way of the lungs in twenty-four hours, and the amount lost by way of the skin and sweat glands may be as much as 1800 cc. each day. Heat loss through evaporation depends in a large measure on the humidity of the atmosphere. If the air is hot, the discomfort of patients exposed to high humidities becomes insufferable compared to the discomforts when lower humidities prevail.

Sweat glands are of two types: the eccrine, the principal type found nearly everywhere on the body, and the apocrine, found mostly in the groin and axilla, which work only on excessive demand. Sweat is a hypotonic solution of from 0.10 to 0.50 per cent sodium chloride. In addition, quantities of urea, sodium lactate and other substances are present in small traces. With exercise, the salt concentration and the rate of sweat excretion increases. With a decrease in plasma salt, the ability of blood to hold water decreases, and with the continued drinking of water, the amount of urine excreted increases. Under continued exposure to high temperatures, Drinker (9) observed that the amount of sweating increases from day to day while the concentration of the contained chlorides decreases, thus reflecting the adaptability of man to these adverse conditions.

Ferris (10) has observed that in a series of patients who developed heat stroke, a decreased amount of sweating manifested itself as many as one to twelve hours prior to collapse. All sweating usually stopped when the temperature of the patient reached 105 F.

PATHOLOGY

The principal pathologic change associated with heat stroke is edema of the leptomeninges, the brain, and the lungs. Cloudy swelling is present in such vital organs as the liver, kidneys and myocardium. Fatty changes are found in the liver, and petechial hemorrhages may be seen in the brain, viscera and skin.

REPORT OF TWO CASES

The following two patients were brought to the operating room on the morning of 14 August 1945. This section of the middle west had been having some hot weather for days. On the day preceding the operation the outside temperature had reached 88.5 F. On the day of operation the temperature reached only 81 F., and the humidity was recorded at 75 per cent. In the particular operating room where the operations in these cases were to be done, there are no windows. Natural light is admitted through glass brick walls, and ventilation is effected by a poorly functioning system of air ducts. On the day of operation the dry and wet bulb readings were 88 F. and 83 F., respectively, and the relative humidity was calculated to be 81 per cent. As has been mentioned previously, ideal conditions for comfort exist when dry bulb readings are 68 to 70 F. with humidity readings ranging from 40 to 50 per cent.

Case 1. Patient S., an 18 year old ship's fireman with a history of recurrent dislocations of the shoulder, was admitted to the hospital for a Nicola operation. On the operating table an intravenous saline infusion was instituted before the commencement of the surgical procedure. Under anesthesia consisting of a 2.5 per cent pentothal sodium solution, supplemented by inhalation of nitrous oxide and oxygen, operation was begun at 8:45 a.m. Because the patient seemed quite hot and had stopped sweating, a rectal temperature was taken at the conclusion of the operation while the patient was still on the operating room table. This reading at 9:45 a.m., just one hour after beginning of the operation, was found to be 105.5 F. Because it was thought that an attack of heat stroke had begun, the patient was removed to a recovery room where an ice water enema, ice packs, oxygen and intravenous saline solution were administered. Temperature readings were recorded as follows:

Time	Temperatures (rectally)
10:30 a.m.	105.6 F.
11:00 a.m.	104.6 F.
12:00 m.	106.0 F.
12:30 p.m.	105.2 F.
1:00 p.m.	104.8 F.
2:00 p.m.	103.2 F.

Sweating did not begin again until 7:50 that evening and by midnight the temperature had dropped to 100.6 F. Recovery was uneventful. Blood chlorides taken after intravenous saline infusions had been started were 617 mg. per cent. Malarial smears were negative.

This patient later told us that he had never been troubled by intense heat even though a ship's fireman, except on one occasion when, while on duty, he became dizzy. After taking a salt tablet, however, he was much relieved. He recalls vividly that he never did sweat as freely as his shipmates and that when he did, sweating was limited to his face and forehead, and never occurred in his groin or axilla. He drank a considerable amount of water in hot weather, and noticed that he passed urine more frequently than he did in cold weather.

Case 2. Patient C., a 19 year old marine, was admitted to surgery with compound fractures of the right humerus, radius and ulna. He had had numerous sequestrectomies, and was now being admitted for a bone graft of both radius and ulna. Intravenous administration of saline solution was begun on admission to the operating room, and under intravenous anesthesia with 2.5 per cent sodium pentothal, supplemented by inhalations of nitrous oxide and oxygen, operation was commenced at 11:30 a.m. After two hours it was noted that this patient was quite warm, and had ceased sweating. Because a case of heat stroke had just preceded this one, the surgeon was advised of the patient's condition, and the operation was concluded at 2:25 p.m., a total time of three hours and five minutes elapsing since commencement of operation. A temperature reading on the operating room table was 105.4 F. The rate of his pulse, which was full and strong, was 150 per minute. Blood pressure was recorded at 100 mm. systolic and 60 mm. diastolic. In the recovery room, ice cold enemas and ice sponging were instituted. A transfusion of 500 cc. of citrated blood was followed by another 1000 cc. of normal saline solution. Blood chlorides, also taken after saline solution had been given, were 624 mg. per cent. A blood smear taken on return to the recovery room was positive for malaria. Temperature readings were recorded as follows:

Time	Temperatures (rectally)
3:15 p.m.	105.2 F.
3:30 p.m.	104.4 F.
4:00 p.m.	101.8 F.
5:15 p.m.	101.6 F.

The first signs of sweating were not evident until 7:15 that evening. This patient was never troubled by excessive heat, and sweated as freely as other marines in his company.

This patient gave a history of having had 16 attacks of malaria in the past nineteen months. His last attack, which occurred two weeks before this operation, was brought under control within a very few days. He insisted that he did not have clinical malaria just before operation, explaining that prodromal symptoms which always preceded each previous attack of malaria were absent this time. Because of the positive smear, the chief of the medical service, an internist well versed in malariology, was called to see this patient in consultation. He stated that though trauma and surgical procedures often brought on a recurrence of malaria, this case was definitely not one, and that such recurrences following operation did not manifest themselves for about twenty-four hours or more. Never had he heard of a recurrence while the patient was still on the operating room table. Others concur in the opinion that chronic malaria may reappear following a surgical procedure. Cutting (11), in discussing this postoperative complication, stated that such a recurrence is very unusual before five to six days have elapsed.

An effort to find any other possible cause for this hyperpyrexia failed. The solution of pentothal could not have been responsible since a stock solution was used for all cases that morning, and patients being operated on in different rooms, where better atmospheric conditions prevailed, were unaffected. Both the cases discussed followed one another in the same room, and on the same day. The surgical team in both these cases was the same. The recoveries of these patients from the attack of heat stroke were uneventful.

PROPHYLAXIS AND THERAPY

Th following points are to be observed while operating under conditions heretofore described as unfavorable:

1. The avoidance of elective surgery, especially in older people, unless adequate conditions prevail for the prevention of heat sickness. These conditions center about the maintenance of a cool room of low humidity, in which air currents are sufficient to produce comfort.
2. The avoidance of air-conditioned rooms for the preoperative patient if the operating room is not similarly air conditioned. If the operating room is air conditioned and the patient's postoperative room is not, the latter should be made comfortable by allowing the air to circulate, in anticipation of the patient's return.
3. The reduction of coverings and drapes to a minimum both in the operating room and after the patient's return to bed.
4. The administration of increased amounts of fluid, especially saline solution, before and during operation. One should also consider the possible substitution of saline for glucose in infusions, since glucose in large amounts is a diuretic, and deprives the skin of a medium for sweating.
5. The recording of half hourly postoperative temperature readings in hot weather. These should be rectal, since with a dry oral mucous membrane, temperature bulbs have been found to record inaccurately. If temperatures should rise excessively, ice water enemas should be given.
6. The use of frequent cool spongings with either alcohol or water.
7. The possible reduction in the preoperative amounts of cholinergic drugs such as atropine or scopolamine in hot weather, since they inhibit sweating (12).

8. The possible avoidance during hot weather of inhalation anesthesias which, because of rebreathing, increase heat retention. The use of spinal, local, conduction block, or intravenous anesthesia should be increased.

SUMMARY AND CONCLUSION

1. Heat stroke as a postoperative complication probably occurs more frequently than heretofore believed. Two cases are presented for addition to a constantly growing list.
2. Methods for prevention and treatment of this complication are described.
3. The possibility of recording temperatures on a half hourly basis by the anesthetist, along with the more frequent recordings of blood pressure, pulse and respiration, is proposed. This might be of value not only in detecting impending heat stroke, but also shock.

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