Heat and Cold in Medicine

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Specialist in physical medicine and physical therapy probably used heat and cold the most. Other medical specialists, including family practice physicians, often prescribe heat or cold for therapeutic purposes. Surgeons sometimes use extreme cold (cryosurgery), and radiologists are often involved in interpreting thermographic images.

Physical basis of heat and temperature

Matter is composed of molecules that are in motion. In a gas or liquid the molecules move about, hitting one another or the walls of container; even in a solid the molecules have some motion about the sites that they occupy within the crystal structure. The fact that the molecules move means that they have kinetic energy, and the kinetic energy is related to the temperature.

The average kinetic energy of the molecules of an ideal gas can be shown to be directly proportional to the temperature; liquids and solids show similar temperature dependence. In order to increase the temperature of a gas it is necessary to increase the average kinetic energy of its molecules. This is can be done by putting the gas in contact with a flame. The energy transferred from the flame to the gas causing the temperature rise is called *heat*.

***Heat**: is the total energy of molecular motion in a substance.*

***Temperature**: is a measure of the average energy of molecular motion in a substance.*

If enough heat is added to a solid, it melts, forming a liquid. This liquid may be change to a gas by adding more heat. Adding still more heat converts the gas to ions. While adding heat to a substance increase its molecular kinetic energy, thereby increasing its temperature, the reverse is also true: heat can be removed from a substance to lower the temperature. Low temperatures are referred to as the cryogenic region. The ultimate in cold is "absolute zero" (-273.15°C), a temperature that is experimentally unattainable.

Temperature Scales

Temperature is difficult to measure directly, so we usually measure it indirectly by measuring one of many physical properties that change with temperature. We then relate the physical property to temperature by a suitable calibration.

There are three types of Temperature Scales

- *Fahrenheit* (°F) scale.

In United States the most common temperature scale is the Fahrenheit. Water freezes at 32°F and boils at 212°F, and the normal body temperature (rectal) is about 98.6°F.

- Celsius (°C) scale.

Most scientists in the United States used the Celsius (°C) scale (formerly called the centigrade scale), which is in common use throughout most of the world. Water freezes at 0°C and boils at 100°C, and the normal body temperature (rectal) is about 37°C.

- Kelvin (°K) scale.

Another important temperature scale used for scientific work is the Kelvin (°K), or absolute scale, which has the same degree intervals as the Celsius scale; 0°K (absolute zero)

is -273.15°C. On the absolute scale, water freezes at 273.15°K and boils at 373.15°K, and the normal body temperature (rectal) is about 310°K. This temperature scale is not used in medicine.

The relationships between the different temperature scales are: -

°K = 273.15+°C	**°C = (5/9)×(°F-32)**	**°F = (9/5) ×°C+32**

Example:-

The temperature of the human body is normally about 98.6°F.calculate the temperature of the body in °C and °K?

°C = (5/9)×(°F-32) =5/9(98.6-32)=37 °C

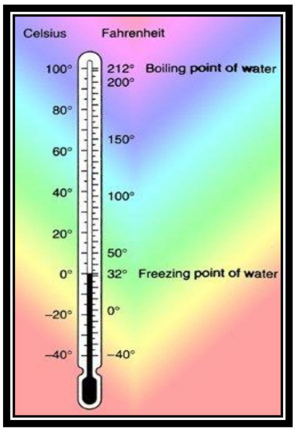
°K = 273.15+°C =37+273=310.15 °K

Temperature Measurement

Thermometer is a device used to measure the temperature. For the medical and biological purposes, there are several important types of thermometers are:-

1) *Glass-liquid thermometer*

The most common way to measure temperature is with a glass fever thermometer containing mercury or alcohol. The principle behind this thermometer is that an increase in the temperature of different materials usually causes them to expand different amounts. In a fever thermometer, a temperature increase causes the alcohol or mercury to expand more than the glass and thus produces an increase in the level of the liquid. If the liquid expanded the same amount as the glass, the level of the liquid in the stem would remain constant with temperature.



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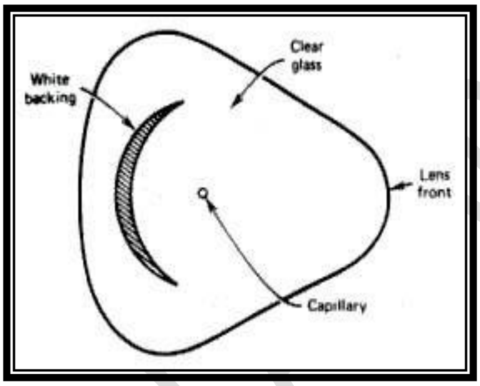

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Figure1: a- a glass liquid thermometer. b-cross section of glass liquid thermometer

In order to show this expansion, thermometers are designed so that the mercury is forced to rise from the bulb in a capillary tube with a very small diameter. The smaller the diameter of the capillary, the greater is the sensitivity of the thermometer.

Two things increase the visibility of the capillary: -

- The glass case acts as a magnifying glass.
- An opaque white backing is used.

The capillary of a fever thermometer has a restriction just above the bulb so that after the liquid is forced into the stem by expansion it does not return when the temperature falls. In order to return the mercury to the bulb it is necessary to take advantage of some elementary physics involving centrifugal forces or by giving the thermometer a sharp jerk.

2)Thermistors

Thermistors rely on their change of electrical resistance as means of measuring temperature. They are semiconducting devices and have negative temperature coefficients of resistance. The resistance decrease approximately exponentially with increasing temperature. Those used in medicine normally consist of a small bead of semiconducting material, a few tenths of a millimeter in diameter, encapsulated in a thin glass envelope and attached to two connecting wires. They can detect temperature changes of as a little as a 0.01°C. They have rapid response times because they have small heat capacities. Their small size allows them to be inserted into blood vessels to monitor blood temperature. More routinely, they are used to measured core temperature (the temperature of the deep tissues of the body). A thermistor is essentially an electrical device and therefore its output can be fed to a chart recorder to provide a continuous recording of temperature.

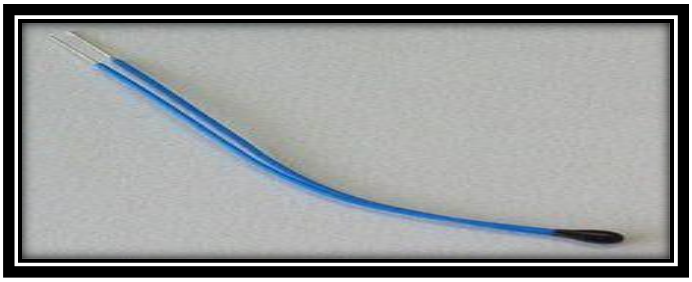

Figure2: Thermistors(bead type).

3) Thermocouple

A thermocouple consists of two junctions of two different metals. If the two junctions are at different temperatures, a voltage is produced that depends on the temperature difference. Usually one of the junctions is kept at a reference temperature such as in an ice-water bath. The copper-constantin thermocouple can be used to measure temperatures from (-190 to 300 °C). For a 100°C temperature difference, the voltage produced is only about 0.004V (4mV). Thermocouples can be made small enough to measure the temperature of individual cells.

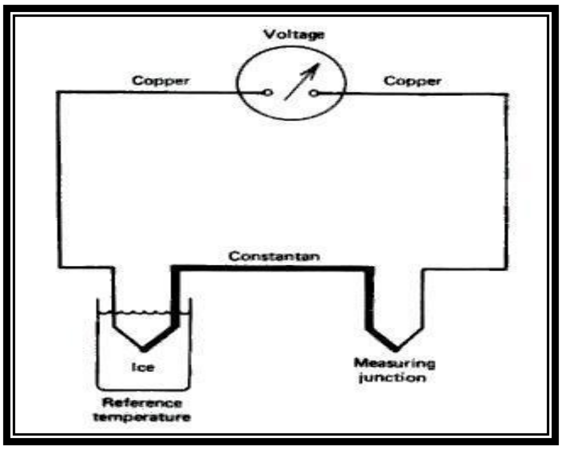

Figure3: Schematic diagram of Thermocouple.

3) Thermopile

It can be used to detect the heat radiate by the skin and consisted of a number of thermocouples connected in series .One set of thermocouple junctions (A) is exposed to the radiation and is heated by it, the other set (B) is shielded from the radiation, a highly polished metal cone concentrates the radiation on the exposed junction, and these junctions are coated with lamp-black to enhance the efficiency with which the radiation is absorbed. The meter reading depends on the rate at which heat energy enters the cone and this in its turn depends on the temperature of the skin. Thermopiles are normally calibrated to read skin temperature directly.

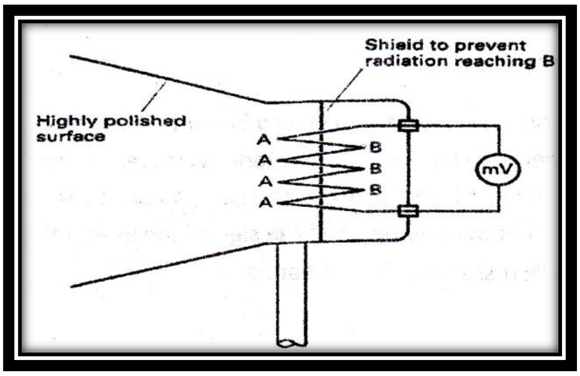

Figure4: Schematic diagram of Thermopile .

Thermograph-mapping the body's temperature

Thermography: Process to measure the body surface temperature, indicate that the surface temperature various from point to another depend on:

1) External physical factors

2) Circulatory process near the skin-blood flow near the skin is the dominant factor.

Measurement of surface temperature is thought to be useful in diagnoses of some diseases, which may change locally the skin temperature. All objects regardless of their temperature emit heat radiation. The body heat can give (IR) infrared radiation of long waves, which are not visible unlike the red-hot object, which is visible. Thermograph is the process in which the infrared radiation emitted by the body is used to produce a (thermal image) or (temperature map) of the surface of the body. The images are called Thermograms and are normally displayed on a TV screen. Different temperatures are represented by different colors, in a black and white display by different shades of gray.

Figure5: Technician used the thermograph instrument

Heat radiation power can be measured by:

W= $\sigma e T^4$

- T temperature of the body
- e emissivity which depends upon the emitter material
- **σ** constant= 5.7×10^{-12} W/cm^2 °K

For radiation from the body e is almost 1

Example:-

1. *What is the power radiated per square centimeter from skin at a temperature of 306°K (33°C)?*

   $W= \sigma e T^4$

   $W = (5.7 \times 10^{-12})\ (306)^4 = 0.05\ W/cm^2$

2. *What is the power radiated from a nude body $1.75m^2 (1.75\times 10^4\ cm^2)$ in area?*

$W= (0.05)\ (1.75\times 10^4\ cm^2) = 875W.$

Thermograph uses:

A-Cancer detection: Breast cancer could be characterized by an elevated skin temperature in the region of the cancer. The surface temperature above a tumor was typically about 1 °C higher than that above nearby normal tissue, and it was thought that this will be a good procedure for early breast cancer detection.

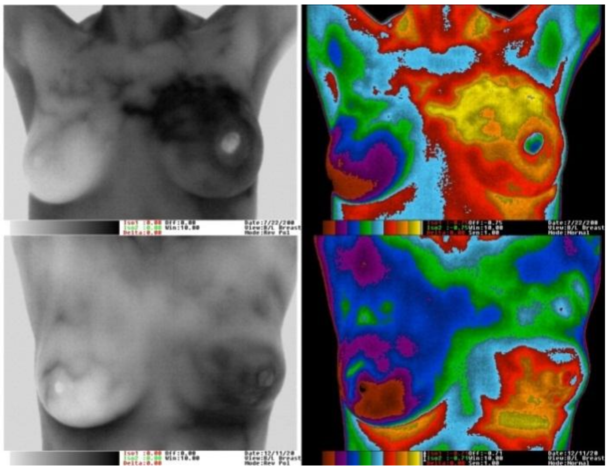

Figure6: picture of normal breast compare to the breast cancer.

B- Thermograph used to study the circulation of blood in the head, differences in the blood supply between left and right sides can indicate circulatory problems. In diabetic patients: Thermograph has had considerable success in reducing leg amputation in diabetic. The blood supply in diabetic's leg is usually adequate, but if the tissues break down and an ulcer is formed, the need for blood in the leg may double. The circulation problems of the diabetic then become evident: the ulcer dose not heals and often becomes infected .With thermograph, the presence of a hot spot on the foot can be determined before an ulcer forms.

C-In the Dentistry

Dentists recommend the use of medical thermograph in monitoring control in the inflammation process into oral cavity and reaction of the regional lymphatic nodes, maxillary joint disease and other chronic disease of the bones, nerves located in the maxilla facial area.

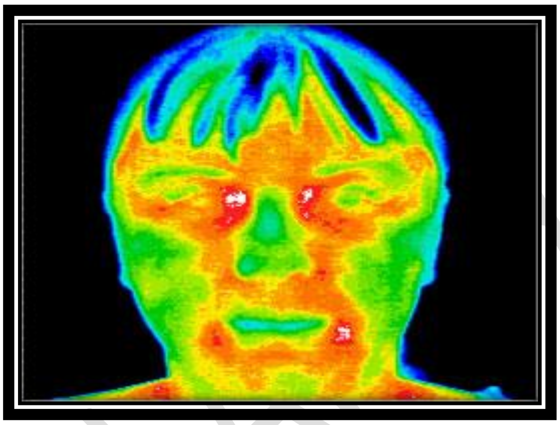

Figure7: focal tooth infection picture.

Heat therapy

The primary therapeutic effects take place in the heated area

1-There is an increase in the metabolism resulting in a relaxation of the capillary system.

2-There is an increase in the blood flow, as blood moves into cool the heated area.

The physical methods of producing heat in the body;

1) *The conductive method:*

The conductive method is based on the physical fact that if two objects at different temperatures are place in contact, heat will be transfer by conduction from the warmer object to cooler one. The total heat transferred will depended upon:

1- The area of contact
2- The temperature difference
3- The time of contact
4- The thermal conductivity of the materials.

Hot baths, hot packs, electrical heating pads, and occasionally hot paraffin applied to the skin heat the body by conduction. Conduction heat transfer leads to local surface heating since the circulating blood effectively removes heat that penetrates deep into the tissue. Conduction heating is used in treating conductions such as arthritis, neuritis, contusions, sinusitis, and back pain.

2) *Radiant (IR) heat:*

Radiant heat is also used for surface heating of the body. This is the same form of heat we feel from the sun or from an open flame. Man-made sources of radiant heat are glowing wire coils and 250 W incandescent lamps. The IR wavelengths used are between 800-40,000nm (1nm=10^9m).The wave penetrate the skin about 3mm and increase the surface temperature.

Excessive exposure causes reddening (erythematic) and sometimes swelling (edema).Very prolonged exposure cause browning or hardening of the skin. Radioactive heating is generally used for the same conditions as conductive heating, but it considered being more effective because the heat penetrated deeper.

3) *Radiowave heating (Diathermy):*

Short wave diathermy utilizes electromagnetic waves in the radio range(wavelength~ 10m),and microwave diathermy uses waves in the radar range (wavelength~ 12cm). Heat from diathermy penetrates deeper into the body than radiant and conductive heat. It is useful for internal heating and has been used in the treatment of inflammation of the skeleton, bursitis, and neuralgia.

Different methods are used for transferring the electromagnetic energy into the body in short wave diathermy:-

A) By using capacitor plates: - the part of the body to be treated is placed between two metal plate-like electrodes energized by the high-frequency voltage. The body tissue between the plates acts like an electrolytic solution. The charged particles are attached to one plate and then the other depending upon the sign of the alternating voltage on the plates; this results in resistive (joule) heating. Different body materials react differently to the waves, and this effect provides some selectively in treatments.

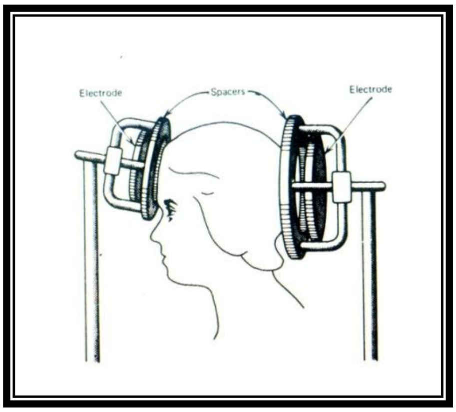

Figure8: Capacitance method of short wave diathermy.

B) Magnetic induction method:- It is considered one of the methods that are used for transferring the electromagnetic energy into the body in short-wave diathermy. In this method, either a coil is placed around the body region to be treated or a "pancake" coil is placed near the part of the body. The alternating current in the coil results in an alternating magnetic field in the tissues. Consequently alternating (eddy) currents are induced, producing joule heating in the body region being treated. This method is used in relieving muscles spasms and degenerative joints disease.

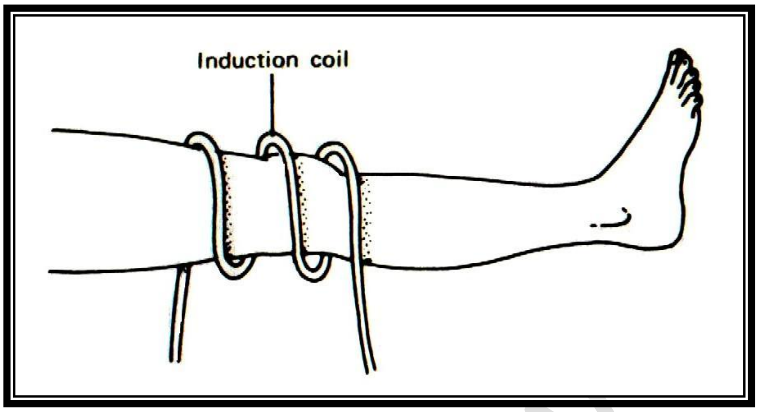

Figure9: Inductance method of short wave diathermy

Microwave diathermy:-Microwave diathermy is another form of electromagnetic energy. These waves are produced in a special tube called a *magnetron* and then emitted from the applicator(antenna)which is placed at several inches from the region to be treated .These wave penetrate deep into the tissues causing a temperature raised and deep heating. Microwave diathermy is used in the treatment of fractures, strains, bursitis, injuries to tendons, and arthritis. The frequency used is 900 MHz, which is found more effective than other frequencies in the therapy. It causes more uniform heating around bonny region.

4) *Ultrasonic Wave*:

Ultrasonic wave are completely different from the electromagnetic wave just discussed; they produce mechanical motion like audible sound wave. As the ultrasonic waves move through the body the particles in the tissues move back and forth produce heating in the tissues.

This method is useful for depositing heat in bones because they absorb ultrasound energy more effectively than dose soft tissues. Also it useful in relieving the tightness and scarring that often occur in joint disease. It greatly aids joints that have limited motion.

Heat therapy has also been used in cancer treatment in combination with radiotherapy. The tumor is heated about 42°C for approximately 30 minutes .The tumor is heated in any suitable way mentioned above.

Use of cold in medicine

Cryogenics is the science and technology of producing and using very low temperatures .The study of low-temperatures effects in biology and medicine is called cryobiology. Low temperature can be produced by liquefying gases. It was succeeded to produce liquid air (-196 °C) in 1877 and liquid helium (-269°C) in 1908.For solid CO2 it is (-79°C) and liquid nitrogen (-196°C).

For conventional blood storage it can be stored with anticoagulant at 4°C about 1% of the red blood cells hemolyze (break) each day so the blood will not be suitable for use after 21 day. For rare blood types should be stored for longer period, other procedure were used. Blood can be preserved for very long periods of time if it frozen rapidly in liquid nitrogen (-196°C)

The rate of freezing is very important to revive the cell after thawing them. In addition to that some preservation material such as glycerol and dimethy sufoxide to improve cell survival. Sometime and especially in blood these additives can present a problem to remove them from the blood.

There are two ways to freeze the blood to (-196°C):-

1) The blood sand method, in this method the blood sprayed on the surface of liquid nitrogen and then it will be frozen in small droplets in very short time forming sand like particles, and then stored at liquid nitrogen temperature.

2) The blood is kept in a container with thin metal walls and the spacing between the walls of the container is small to maintain a small thickness of blood inside the container. The container with the blood is immersed into liquid nitrogen making very rapid cooling.

Cryosurgery

The crysurgery methods are used to destroy cells called crysurgery. *It has several advantages*

1-Cause a little bleeding

2-The volume of the tissue destroyed can be controlled

3-Little pain because low temperature desensitize nerves

4-Very short recovery.

Crysurgery is used in several types of eye surgery, in

1-In retinal detachment: a cooled tip is applied to the outside of the eyeball in the vicinity of the detachment a reaction occurs that acts in weld the retina to the wall of the eyeball

2- crysurgery extract of the lens, in this procedure the cold probe is touched to the front of the lens. The probe sticks to the lens making the lens easy to remove.