Medical Physics

Heat and Cold in Medicine

Lecture Two

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1. Physical basis of heat and temperature

As molecules of all materials are moving, so they have kinetic energy. The movement of **gas** molecules are freer than **liquid** and liquid molecules are more free than **solid**.

There are three temperature scales:

1-Fahrenheit scale (°F): in this scale the freezing temperature of water is 32°F and the boiling point is 212°F, and normal body temperature is about 98.6°F.

2-The Celsius (°C): the freezing point of water is 0°C and the boiling point is 100°C and the normal body temperature is about 37°C.

3-The Kelvin scale (°K): or the absolute scale, this scale has the same divisions as the Celsius but takes the 0°K at the absolute zero which is -273.15 ℃. **This temperature scale is not used in medicine.**

To change °C to °F

°C = {(°F - 32) 5/9}

Or °F to °C

°F = {°C (9/5) +32}

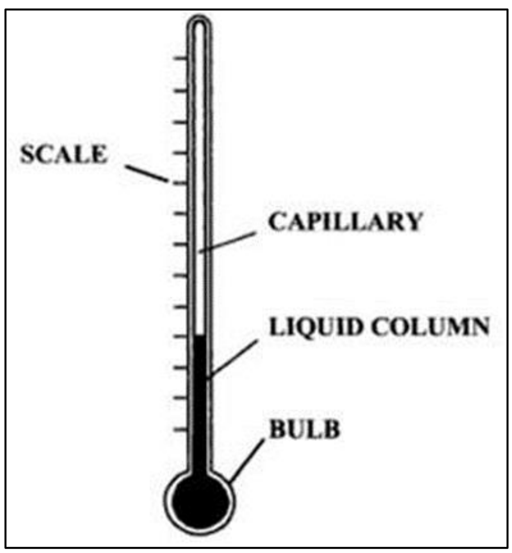
There are different types of temperature-sensitive devices:

1. Glass-liquid thermometer:

This thermometer is composed of glass capillary tube ends with a bulb a store for liquid, the liquid can be mercury or alcohol.

The principle behind this thermometer is that an increase in temperature of different materials usually causes them to expand in different amounts.

When the thermometer is heated the liquid inside will expand more than the glass causing the liquid to rise in the capillary.



The smaller the diameter of the capillary, the greater is the sensitivity of the thermometer, a fever thermometer, which needs to show fractions of degrees, requires a capillary so small-less than 0.1 mm in diameter**.**

The thermometer is taken from the mouth it shows the maximum temperature it reached underneath the tongue.

2. Thermistor

A thermistor is a special resistor that changes its resistance rapidly with temperature.

Thermistors are used quite often in medicine because of their sensitivity, with a thermistor it is easy to measure temperature changes of 0.01°C.

Thermistors are occasionally placed in the nose to monitor the breathing rate of patients by showing the temperature change between inspired cool air and expired warm air. An instrument of this type is called an **anemograph.**

3. Thermocouple:

A thermocouple consists of two junctions of two different metals. If the two junctions are at different temperatures, 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-constantan thermocouple can be used to measure temperature from - 190 to 300°C.

Thermograph-mapping the body's temperature:

All objects regardless of their temperature emit radiation.

We use the Stefan-Boltzmann law to describe the radiation emitted by the body.

$W = e\,\sigma\,T^4$

Where

W: is the total radioactive power per surface area.

T: is the absolute temperature of the body.

e: is the emissivity.

The emissivity depends upon the emitter material and its temperature.

For radiation from the body, **e is almost 1**.

σ: is the Stefan-Boltzmann constant = 5.7×10^{-12} W/cm^2 °K^4

Example:

What is the power radiated per square centimeters from the skin at a temperature of 306°K?

Sol:

$W = e\,\sigma\,T^4$

W = (1) (5.7×10^{-12}) $(306)^4$ = 0.05 W/cm^2

4. Heat therapy:

The heat was recognized as a therapeutic agent several thousand years ago.

In this section, we briefly consider the physical methods of producing heat in the body.

1- Heat conductive:

This is based on the physical fact that if two objects at different temperatures are placed in contact, heat will transfer by conduction from the warmer object to the cooler one.

The total of heat transferred depends on:

- The temperature difference.
- The time of contact.
- The area of contact.
- The thermal conductivity of the materials.

This can be done by several ways such as hot bath, hot packs, and electric heating pad.

This will lead to local surface heating conductive heating is used in the treatment of arthritis, strains, and back pain.

2- Radiant heat (IR):

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 Watts incandescent lamps.

The waves penetrate about 3mm in the skin. An excessive exposure can cause reddening and sometimes swelling (edema).

It is considered more effective than conductive heating because it can penetrate deeper.

3. Radio wave heating (diathermy):

Short wave diathermy utilizes electromagnetic waves in radio range (wavelength≈10m).

Heat from diathermy penetrates deeper into the body than radiant and conductive heat, it used in the treatment of inflammation of skeleton, bursitis, and neuralgia.

4-Ultrasonic diathermy:

These waves are completely different from electromagnetic waves. They produce mechanical vibration inside tissue.

They are the same as the sound waves but they have much higher frequencies about 1MHz.

In ultrasonic diathermy, power levels of several watts per square centimeter are usually used and the sound source is directly in contact with body.

Ultrasonic heating is used for **reliving tightness** and **scarring occurring in joint disease**.

5. Use of cold in medicine:

Cryogenics is the science and technology of producing and using very low temperatures. It is used in biology and medicine and called cryobiology.

Low temperature can be produced by liquefying gases. It was succeeded to produce liquid air (-196 ℃) in 1877 and liquid helium (-269 ℃) in 1908. For liquid nitrogen it is (-196°C). These cold liquids have many medical and biological advantages.

The storage of liquefied gases is rather difficult because it can absorb heat rapidly from the environment by conduction, convection, and radiation.

A special container has been designed by Dewar (1892) and named after him.

One goal of cryonics is to preserve people with fatal diseases at a low temperature with the hope that in the future, they could be revived and their diseases cured.

Some successful work has been done with cooling hamsters down to (5°C) by freezing 50 to 60 % of the water in their bodies, and then reviving them. Some simpler human biological systems such as blood, semen and tissue have successfully been cooled, stored and revived.