Hyperthermia

The word hyperthermia comes from the Greek wordshyper (excess) and thermo (heat).

- a condition in whichthere is a **non-physiological increase in the temperature of the organism** caused bydisorders of thermoregulation – in humans a temperature of 37 °C and higher
- increase in tissuetemperature induced intentionallymainly forthe purpose of **tumor treatment**
- The application of heat (or cold) to the body is also dealt with in the article thermotherapy

Hyperthermia – non-physiological increase in body temperature

Constant maintenance of **body temperature** is conditioned by the equality of heat generatedby metabolic processes and heat dissipated to the environment. This equality is maintained mainly by regulating the speed of heat dissipation – this is mainly dissipated through the skin and lungs. Inside the body, the blood flow participates in heat exchange (which also ensures the transfer of heat from the inside ofthe body to the surface). Heat exchange takes place until the equilibrium state occurs. **Physical mechanisms of heat exchange** with the environment (radiation, conduction, flow, and evaporation of water) and the effects of climatic conditionson this exchange are explained in the article -Effects of high temperatures on the body.

The percentage of individual mechanisms is given in the article - heat loss of the organism. If any of these mechanisms are disturbed,hyperthermia occurs.

How does the change in body temperature occur

When body temperature changes, there is a **change in internal energy** (denoted by ΔU, unit, ... J [joule]).

This change can occur:

- performing mechanical work

  Mechanical work depends on the force acting on the body, on thepath taken by the body, and on the angle of theforce and trajectory of the body's motion - W = F. s. cosα. But we can also express it as the change in kinetic energy – $W = Ek_2 – Ek_1$. It follows: ΔU=|ΔEk|= W

- heat exchange

  The measure ofthermal energy that gives heat to a colder body during heat exchange is the quantity **HEAT... Q=c.m.Δt [J]**
  c ... specific heat capacity = physical quantity that expresses what heat is transferred/received by 1kg of substance when cooled / heated by 1K (°C),**m** ... body mass, **Δt**... temperature change

  > **Heat capacity (C)**= physical quantity that expresses the amount of heat by which a body heats/cools by 1K; $\mathbf{C = Q.\Delta T^{-1}}$; C=c.m $\mathbf{[J.K^{-1}]}$

Different environments/bodies (e.g. air, water, ...) have a different specific heat capacity and therefore have a different warming effect on us. Hot water warms us up more than equally hot air. Therefore, for example, in the sauna we can withstand a temperature of up to 100° C, but in steam only 60° C.

substance	c [$J.kg^{-1}.K^{-1}$]
water	4 180
air 0 °C	1 003
oil	2 000

The warming effect also affects:

- Flow - flowing hot air warms us more
- thermal conductivity = ability of the environment to conduct heat
  - characterized by the coefficient of thermal conductivity (=specific thermal conductivity)
- pressure

- both events az once- mostly

The human body can be compared to the so-called **heat engine**, which works on the basis ofthe ***1st law of thermodynamics***

> *The change in the internal energy of the system/human body is equal to the sum of the work done by the surrounding bodies acting on the system by forces and the heat given to the system.* ΔU= W + Q

The system canreceive energy (W>0, Q>0) andgive energy (W<0, Q<0). If the work is performed by the system itself/ l. body, we use the formula: **ΔU = – W' + Q**

The ***2nd law of thermodynamics*** also applies – the conversion of energy cannot be complete.

Causes of hyperthermia

- **physical**
  - long-termexposureto the sun (sunstroke), stay in a hot and humid environment (hot bath, long stay in sauna) - worse heat exchange by conduction and evaporation disorder (evaporation)
  - above 60 °C particularly high risk
  - disorders of blood circulation in the body, **heart failure** – disturbed heat exchange by convection (convection)
  - physical exertion – (see introduction – heat engine)
  - dehydration – reduced possibility of evaporation
- **biological**
  - infectious diseases (colds, flu, rubella, herpes, etc.)
  - *damage tothe hypothalamus, thyrotoxicosis (thyroid disease), pheochromocytoma (a type of tumour originating from theadrenal medulla)*
  - ectodermal dysplasia *(lack of sweat glands),*cystic fibrosis
  - hypersensitivity to substances (alcohol, atropine, antihistamines, sympathomimetics...)
  - *malignant hyperthermia (skeletal muscle disease)*
  - The risk is increasedby obesity, old age, fatigue, insufficient aclimatization, more extensiveskin damage (e.g. burns)

Consequences of hyperthermia

- extreme vasodilation, decrease in blood pressure, impaired blood redistribution, decrease in brain perfusion, heart failure, pulmonary oedema
- dehydration-> hyperosmolarity *(higher amount of osmotically active particles dissolved in a liter of solvent)*
- collapses *(prolonged standing in heat and calm),* unconsciousness, brain damage, organ failure
- deep metabolic acidosis (decrease in the *concentration of standard bicarbonates*), hyperventilation (*rapid and deepened breathing*), hyperkalemia (increase in potassium in *the blood),* but in the early stages there may also be hypokalemia *(retention of potassium in cells, intestinal losses)*
- damage to tissues by heat (protein denaturation, necrosis, ...)
- inpregnancy: risk ofmiscarriage, malformations *(congenital malformations)* – at a body temperature higher by 2-2.5 °C, the duration of exposure to a higher temperature also increases the risk
  - They are not recommended:
  - hot baths (maximum 10 min)
  - saunas (up to 20 minutes for women who regularly visited the sauna before becoming pregnant)
  - very strenuous exercises up to 16 weeks of pregnancy
- sunburn: malaise, impaired concentration, headache, dizziness, nausea, vomiting, neck stiffness, cerebral sheath congestion (cerebral edema, up toserous meningitis), developmentof convulsions, deliriumtounconsciousness

Hyperthermia in oncology

- helps to increase the effects of tumor treatment
- it is beneficial only if healthy tissue is not damaged during treatment and the heat primarily catchesthe tumor cells
- treatment is possible mainly due to different blood supply, which makes tumor cells more sensitive to heating
- uses the secondary thermal effect of microwave radiation, ultrasonic waves, laser
- other, less used heating methods: infrared radiation, local perfusion, immersion (tissue temperature increases in a limited volume)

According to the temperature is divided into

- **low-temperature** – heating of tissues to temperatures of 39 °C
- **high temperature** – interval 41-45 °C
- higher temperatures – **thermal destruction of tissues (thermoablation)**

Mechanism of action

- The exact mechanism is not known, but it is said to be the so-called **primary thermosensitivity of the tumor cell**
- An important role is played by bloodsupply to tissue - the highest effect is in the place where the blood flow through the area is minimal - >different cooling oftumor and normal tissue
- The amount of thermal energy that is removed by the blood from the tissue over a certain period of time can be calculated by the following formula:
  - **Q= c.m.Δt**; c... specific heat capacity of blood, m... the mass of blood flowing through the area, $\Delta t = t_2 - t_1$... temperature change (final - initial temperature).
  - the more blood flows through, the cooler the area is and the less the effect of hyperthermia.

The result of the action of thermal energy on the cell

- change in pH of the internal environment -> activationof lysosomal enzymes
- slowing down to stopping reparation processes
- sometimes also direct decomposition of cells

Usage

- **increasing the effects of radiotherapy orchemotherapy**
- tumour recurrence *(if radiotherapy options have been exhausted)*
- tumors with a diameter of more than 2 cm
- radioresistant tumors
- preoperative tumor reduction
- paediatric oncology

According to the volume of heated tissue, hyperthermia is divided

- **local** – heating of surface-mounted bearings to a depth of 3–4 cm
- **regional** – heating of deep-seated tissue and organs
- **interstitial** – acting directly into tumor-affected tissues (e.g. brain)
- **intracavital** – in which applicators are inserted into the cavities (e.g. bladder)
- **full-body** – warming of the whole body

Thermotolerance

- resistance of cells to higher temperatures (above 41 °C)
- transient, non-hereditary type of temperature resistance of cells
- It fully develops after the initial heating and lasts for 2-3 days, after whichthe cellregains thermoresistivity

Treatment

Thermoradiotherapy

- uses the opposite effects of hyperthermia and radiation treatment

	hyperthermia	**radioterapy**
hypoxic tissue	highest effect	resistance
anaerobic metabolism	highest effect	minimal effect
high mitotic activity	ůow effect	high effect
sufficient blood flow	low effect	high effect
S–G_0 Phases of the cell cycle	high effect	resistance

- By combining both methods, we can achieve synergy of action - > the same therapeutic effect even at a lower dose of radiation, or a higher effect at the same dose of radiation
- low-temperature hyperthermia - increase blood flow to the tissue
- ionizing radiation destroysthe DNAof a cancer cell, heating prevents its renewal
- The essence of increasing the effect of radiotherapy is changes in the conformation of proteins (mainly repairenzymes)
  - reduced ability of cells to repair DNA damage caused by radiotherapy -> a higher chance of triggeringapoptosis, or preventing cell growth and division.
  - decrease in the synthesis of DNA and cellular proteins
- Hyperthermia is applied 1–4 hours after radiotherapy
- The application of hyperthermia lasts 45–60 minutes and is carried out 1–2× / week during the course of radiotherapy

Thermochemotherapy

- The essence of enhancing the effect of chemotherapy is also inhibition of DNA repair*(see thermoradiotherapy)*
  - influencing drug pharmacokinetics, drug concentration in the tumor, penetration of drugs through cell membranes and their metabolism -> increasing the concentration of the drug in the heated area
  - restoration of tumor sensitivity to somecytostatics (cisplatin)
  - Substances administered in special capsules (liposomes) are released due to hyperthermia in the tumor – reduction of negative effects
- Chemotherapy is applied simultaneously with hyperthermia, or just before hyperthermia
- toxicity increases significantly

Microwave hyperthermia

- high-frequency (>106 MHz) electromagnetic field propagates through the tissue as an electromagnetic wave – the tissue absorbs it (the tissue acts as a lossy dielectric) > the electromagnetic wave is converted into heat
- The electromagnetic field causes the movement of polar molecules and ions -> allows the formation of a

current, which then heats the biological tissue.

Ultrasound

- fittest
- mechanical wave penetration into the targeted tissue causes thickening and dilution of the environment, the tissue absorbs the ultrasonic wave, and mechanical energy is converted into thermal energy
- at frequencies around 10 MHz – layer up to 1 cm
- at frequencies of 0.5 MHz – up to a depth of 10 cm
- allow local, regional, intracavital or interstitial heating

Links

Related articles

- Thermoregulation
- Effects of extreme temperatures on living organismus
- Thermotherapy
- Effects of high temperatures on the body
- Heat loss of the organism
- Fever

External links

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