

This Lecture Aims To:

- Describe the physiological effects of heat and cold on the tissue
- Outline some different methods of heat and cold application
- Discuss the appropriate uses of heat and cold
- Make you more aware of what you can achieve and how to achieve it with heat and cold in your therapy

Physical principles of energy exchange

Use of thermal agents results in the transfer of heat TO or FROM a patient's body, and between tissues and fluids in the body.

Body heat lost or gained by the following mechanisms:

- CONDUCTION, CONVECTION, CONVERSION, RADIATION, EVAPORATION

Conduction

- Heat transfer by direct contact
 - Direct collision between molecules of different temps. results in energy exchange
 - Eg. Hot pack on skin = heat transferred from agent to pt
 - Eg. Cold pack on skin = heat transferred from pt. to agent
- Heat also transferred from one area of the body to another by conduction
- Tissues adjacent to a heated area will also rise in temperature

Rate of heat transfer by conduction

- Rate of energy transfer b/w two materials is dependent on
 - Temperature difference between two materials
 - Their thermal conductivity
 - The total contact area

$$\text{Rate of Heat transfer} = \frac{\text{Area of contact} \times \text{thermal conductivity} \times \text{temp difference}}{\text{Tissue thickness}}$$

How is this useful to know?

- Greater the temp diff – faster energy transfer – select fast but safe range
- Materials with high thermal conductivity transfer energy more rapidly – low conductors can be used as insulation – ice has higher conductivity than water at same temp.
- Larger area of contact – greater heat transfer
- Rate of transfer decreased in proportion to tissue thickness – skin temp increases the most – deeper tissue is less affected by conductive thermal agents

Convection

- Exchange of thermal energy as a result of direct contact between a circulating medium and object of different temperature
- Eg. Whirlpool bath – movement of water
- Eg. Blood circulating to warm area will move heat out of the area – reduces impact of superficial heating agents – protects the tissue from burning
- Warm air rising from skin – replaced by cooler air

Conversion

- Conversion from one type of energy to another
- Eg converting non-thermal energy such as mechanical ultrasound into heat due to micro-massage of tissue
- Rate of energy transfer depends on the power of the source I.e watts/cms²

Radiation

- Exchange of electromagnetic energy between skin and environment
- There is no intervening medium or contact
- Eg. Infrared lamp

Evaporation

- Absorption of energy as the result of conversion of a material from a liquid to a vapor state
- Eg. Vapocoolant sprays, sweating
- Material must absorb energy to evaporate and change from liquid to vapor

Energy transfer

- COOLING OF TISSUE WITH CRYOTHERAPY MAKES USE OF ENERGY TRANSFER USING CONDUCTION AND EVAPORATION
- HEATING OF TISSUE PRIMARILY USES CONDUCTION, CONVERSION, CONVECTION AND RADIATION.

Heat

- Many heating agents are available. Generally categorised as superficial or deep heating agents.
- Used clinically for pain control, increase tissue extensibility, increase circulation, accelerate healing
- Superficial heating: hot packs, wax baths, whirlpool etc

heating of superficial joints/skin/subcutaneous tissue may cause minor reflex heating of deeper tissue
heat collagen tissue = increased flexibility

Heat

- Deep heating:
 - heating of deeper joints and tissues
 - heating of large muscle belly
- Ultrasound is an example of a deep heating agent

Effects of heat

- Haemodynamic
 - Changes to blood flow in the form of vasodilation
- Metabolic effects
 - Increased metabolic rate
- Neuromuscular effects
 - Changes to nerve conduction velocity
 - Increased pain threshold
 - Changes in muscle strength
- Altered tissue extensibility
 - Increased collagen extensibility

Haemodynamic effects

- Vasodilation – increase in blood flow:
 - Effect occurs both locally where heat is applied and systemically in areas distant from where heat applied
 - Vasodilation occurs by variety of methods:
 - Direct action on smooth muscles of the blood vessels by cutaneous thermoreceptors
 - Indirect activation of spinal cord reflexes
 - Increasing the local release of chemical mediators of inflammation
 - This phenomenon can be used to inc blood flow to an area where heat is not able to be applied eg. Insensate limb or an ulcer on the leg

Haemodynamic effects

- Most pronounced change in local cutaneous blood vessels
- Less effect in deeper vessels
- Need to use deep heating agent for muscles and joints
- Vasodilation is a protective mechanism to prevent burning
- Inc. blood flow increases rate at which area is cooled
- Thus therapeutic and protective at same time

Neuromuscular effects

- Increases nerve conduction velocity
 - Not well understood but may contribute to reduced pain sensation
 - May work by gating method in the CNS and reduction of ischaemia and or muscle spasm
- Changes in muscle strength
 - Muscle strength and endurance found to decrease for initial 30 mins following heat application
 - Gradually recovers then increases for next 2 hours
 - Not really used therapeutically but should keep in mind if measuring muscle strength in therapy

Metabolic effects

- Increased metabolic rate
 - All cellular chemical reactions accelerated
 - Results in increased biochemical reactions
 - This can increase oxygen uptake and accelerate healing but may also increase destructive processes eg:
 - Can also increase activity of collagenase that may increase destruction of articular cartilage in patients with acute RA
 - Use heating agents with caution in inflammatory disorders
 - Hb releases twice as much oxygen when heated – thus more oxygen available in the blood – may contribute to accelerated tissue healing

Altered tissue extensibility

- Increased collagen extensibility
 - Better stretch and maintains increased length after stretch
 - Less force is require to achieve stretch
 - Tissue tearing risk is reduced
 - Increased and maintained stretch thought to be due to changes in organisation of collagen fibers
 - Superficial agents only good for small superficial joints, deep agents required for deeper large joints, capsules, muscles etc.

Uses of superficial heat

- Pain relief.
 - Not in acute inflammation
- Promotion of relaxation.
- Increase joint range of motion / dec stiffness
- Reduction of muscle spasm.
- Promotion of healing.
- Prelude to passive mobilization and exercise.

Contraindications for heat

- Acute inflammation or injury
 - Can increase oedema and bleeding in the area due to vasodilation
- Over area of recent or potential haemorrhage
- Impaired circulation or thrombophlebitis
- Chronic venous insufficiency / Lymphoedema.
- Over or near malignant tissue
- Impaired sensation or impaired mentation
- Dermatological anomalies.
- Extremes of age.

Contraindications for heat

- Over any open wound
 - Loss of epidermis reduces insulation of tissue
- To areas with metal implants
 - Metal has higher thermal conductivity
- Over area where topical counterirritants have recently been applied:
 - For instance methylsalicylate - vasodilator

Adverse affects of heat

Burns due to:

- poor technique
- patients' inability to dissipate or detect heat
- treatment over areas of implanted metal or open wounds

Bleeding

- In acute trauma or haemophilia

Fainting

- Due to potential superficial vasodilation

Heat

- Various forms of providing superficial heat are:
 - Whirlpool baths
 - Hot packs
 - Wax baths
 - Contrast baths

Whirlpool baths:

- Large bath of agitated water b/w 28 and 38 degrees C – provides superficial heat
- Massages and relaxes muscles
- Can produce mild analgesia and increase local circulation
- Useful for
 - Chronic inflammation
 - Adhesions
 - Pain
 - Joint stiffness
 - Prior to mobilisation of an area

Hot packs

- Heat transference by direct contact
- Variety of commercially available packs or can use hot water bottle for home treatment
- Produces increase in local temp, circulation and metabolic rate – mild sedative effect
- Useful for:
 - Local pain relief
 - Muscle relaxation
 - Prior to stretching program
 - Reduction of chronic inflammation

Hot packs

- Do not apply hot pack directly to skin – wrap in towel
- Apply for approx. 10-20 minutes with rest periods of 30 mins between applications
- Contraindications:
 - Acute sprains, strains and inflammation
 - Impaired peripheral circulation or sensation
 - Malignancies

Wax baths:

- Superficial heating mechanism – by conduction
- Large bath of wax that contains seven parts wax to one part paraffin oil – melting point approx 49C
- Paraffin wax conducts heat slowly so creates nice feeling of warmth in tissues
- Uses concept of 'latent heat' – the energy required for or by a change in state of matter – releases energy (heat) to the skin

Wax baths – apparatus & method

- Large steel tub with electric element to heat wax
- Contains about 20kg of wax
- Check patient for contraindications
- Check wax to ensure correct temp
- Explain procedure to patient
- Swab part to be treated to reduce contamination
- Ladle wax on to foot to completely cover dorsum and plantar surfaces
- Repeat 5 – 6 times to thicken layers
- Wrap foot in plastic and then a towel

Wax baths

- Elevate the leg for comfort and leave in place for 20-30 minutes
- Peel wax from the foot and leave in plastic bag

Wax bath effects:

- Reduces evaporation of sweat and acts as insulator
 - Marked increase in skin temperature
 - Some warming of underlying superficial structures
 - Stimulation of circulation due to vasodilation
 - Reduction of pain and muscle spasm
 - Skin becomes moist and pliable
 - Adhesions and scars are softened

Wax bath indications

- General heating of extremities
- Chilblains
- Arthritic conditions (when not inflamed)
- Stiff joints following immobilisation
- Scar tissue
- Chronic overuse injuries
- Chronic strains and sprains

Cold

- The use of cold to reduce tissue temperature is termed cryotherapy. The magnitude of temperature change is dependent upon a number of factors as listed below:
 - Temperature difference between cold object and tissue
 - Time of exposure
 - Thermal conductivity of the tissue
 - Type of cooling agent (ice packs better than gel packs)

Cold

- Greater difference b/w skin and cold object then greater tissue temp. change
 - 15min. Forearm in water of 1 degree – subcutaneous temp dropped by 24 degrees
 - Same duration and area exposed, water at 17 degrees – tissue temp dropped by only 6 degrees
- Important consideration when working with muscles and joints
- Time of exposure is important – deeper the tissue the longer time will be needed to lower the temperature

Cold

- Skin temp. changes quickly
- More time needed for subcutaneous and muscle tissue
- May take as long as 30 minutes to lower muscle at 4cms by 3.5 degrees using ice packs

Cold

- Thermal conductivity
 - Measure of the ability of a tissue to conduct heat....simply means that the amount of adipose tissue can act as thermal insulator
 - Slower to allow heat exchange
 - Slower to return to pre-cooled temperature
- Blood flow effects
 - Cooled area can take longer to return to pre-cooled state than a heated area
 - Cold causes vasoconstriction – less warm blood flowing to area – less heat exchange occurs
 - Area does not re-warm rapidly

Cold

- Type of cold agent is also important
 - Ice requires more internal energy to alter it's solid state
 - Will absorb more heat from the tissue
 - Internal energy will first change ice to water then raise it's temperature

Therapeutic use of cold

- Control of inflammation
- Control of pain
- Control of oedema
- Reduce muscle spasticity
- Facilitate movement
- Can do these things due to the effects on HAEMODYNAMIC, NEUROMUSCLAR AND METABOLIC processes

Effects of cold

- Haemodynamic
 - Initial dec in blood flow
 - Later inc in blood flow
- Metabolic
 - Decreased metabolic rate
- Neuromuscular
 - Dec nerve conduction velocity
 - Increased pain threshold
 - Altered muscle strength
 - Decreased spasticity
 - Facilitation of muscle contraction

Haemodynamic effects

- Initial decrease in blood flow
 - Immediate constriction of cutaneous vessels
 - Persists for as long as the cold is applied (if under 15 mins)
 - Can have local and distant effects due to CNS
 - Can increase blood viscosity – inc resistance to flow
 - Thought to be protective – prevent other areas from being cooled by cold blood
- Later increase in blood flow
 - Reflex vasodilation can occur following prolonged exposure or reduction of tissue temp < 10C
 - Known as 'cold induced vasodilation' (CIVD)

Haemodynamic effects

- Also known as 'Hunting response'
- Cyclic vasoconstriction and vasodilation
- Occurs due to axon reflex in response to the pain of prolonged cold
- Not useful therapeutically if you are aiming to cause vasoconstriction
- Need to consider length of time of cryotherapy application

Neuromuscular effects

- Dec nerve conduction velocity
 - Occurs in sensory and motor nerves
 - Effects small diameter pain fibres
 - Can also cause total nerve block over superficial nerves
- Increased pain threshold
 - Due to counterirritation via gate control mechanism
 - Reduction of spasm, nerve velocity and oedema
- Altered muscle strength
 - Can cause both inc and dec of strength depending on duration of treatment and time of measurement
 - Thought to interfere with facilitation of motor neurones

Metabolic effects

- Cold decreases all metabolic reactions
- Can be used to control acute inflammation but not recommended when healing is delayed – can impair recovery
- Cold can impair activity of cartilage degrading enzymes – useful in inflammatory joint diseases such as OA and RA

Cold

- Indications for the Use of Cold
- Reduction of pain
- Prevention/reduction of oedema, when combined with compression.
- Prevention/reduction of haemorrhage when combined with compression.
- Reduction of muscle fatigue.
- Facilitation of muscle action.
- Reduction or control of inflammation (dec. in metabolism)
- Reduction of muscle spasm.
- Treatment of verrucae.

Cold

- Dangers and Contra-indications (see handout)
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- **Intolerance**
- face, hands and feet.
- very old and very young.
- individual sensitivity.

Cold

- **Exacerbation of disorders.**
- Vasospastic disorders
- Other vascular disorders
- Connective tissue disorders

Cold

- **Miscellaneous others.**
- Precipitation of angina pectoris.
- Retardation of wound healing.
- Unexpected effects on some nervous system disorders.
- Toxicity from chemicals in commercial spray packs.
- Irritation of the eyes from cold sprays.

Cold

- **COLD PACKS:**
- • inexpensive
- • can be made at home with ice
- • commercial packs contain silica gel or sand slurry
- • chemical packs for one off emergency use
- • variety of sizes and shapes
- • store at -5°C for 2 hours before use
- • place towel between skin and pack
- • moist towel is better than dry
- stay cold for 15 to 20 minutes

Cold

- **ICE MASSAGE:**
- • useful for small area
- • freeze water in paper or polystyrene cups
- • ice rubbed over skin in small overlapping circles
- • patient feels intense cold, burning, aching then analgesia

Cold

- COLD FOOT BATH:
 - • useful for lower extremity
 - • careful if elevation is needed to control oedema
 - • temp. may vary from 13°C to 18°C
 - • lower temp. the shorter duration of immersion needed
 - • can add crushed ice to make a slurry

Contrast baths

- Application of heat and then cold
- Meant to stimulate circulation by changes in temp
- Intermittent contraction and vasodilation
- Good for chronic inflammation or bruising
- Place affected part alternatively in hot then cold baths
- For chilling disorders or elderly – start with hot for 5 mins then cold for 2 mins – repeat 5-10 times
- Younger patients or athletes – start with cold for 2 mins then warm for 30 seconds. Repeat 10-15 mins

Cold

- VAPOCOOLANT SPRAY:
 - • two types used - Fluori-Methane and Ethyl Chloride
 - • Fluori-Methane banned due to fluocarbons
 - • Ethyl-Chloride volatile and flammable
 - • can freeze the skin on contact
 - • used mainly in treatment of trigger points
 - • long sweeping motion over muscle belly

Cold

- SELECTION OF AGENT:
 - • must consider body area to be cooled
 - • how much body surface to be cooled
 - • consider depth of tissue to be cooled

Review on ice therapy:

- D. C. MacAuley, Ice Therapy: How Good is the Evidence, *Int. J. Sports Med*, 2001: 22: 379-384.
 - Systematic review aimed at evidence based guidance on use of ice following acute soft tissue injury
 - Findings suggest that melting iced water applied through wet towel for repeated periods of 10 mins is most effective
 - Important points are repeated applications, resting of skin, prevention of further injury

Further reading:

- Michlovitz, S.L. "Thermal Agents in Rehabilitation" 3ed. F.A. Davis Company, Philadelphia, 1996.
- Lots of information here – very well written – easy to understand.